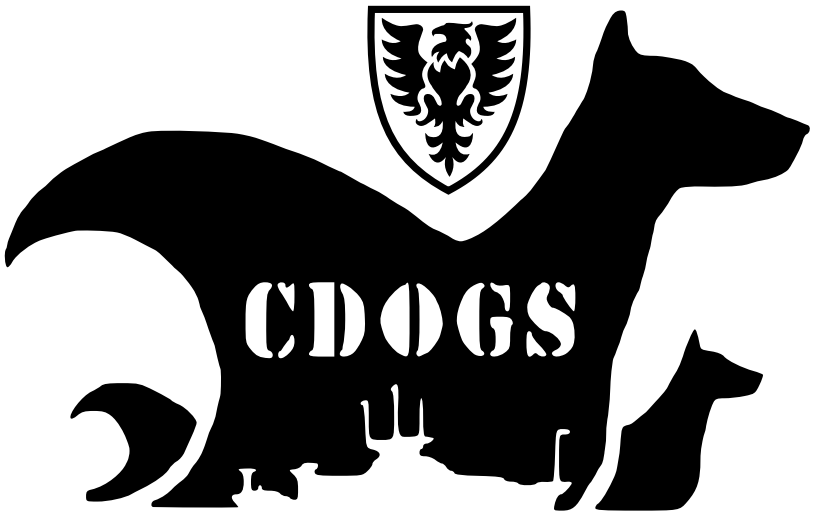

CDOGS 2021

Conference of Dalhousie Oceanography Graduate Students

Friday March 19, 2021
9:00 - 17:30, Virtual Event
Dalhousie University, Halifax, Nova Scotia

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The impact of wave breaking, Langmuir turbulence and conservative Stokes drift effects on the upper ocean dynamics under hurricane conditions

Colin Hughes[1, 2] Guoqiang Liu[1, 2] William Perrie[1, 2] Jinyu Sheng[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at Colin.Hughes@Dal.ca

Ocean surface gravity waves can modulate the ocean currents and vertical mixing in the upper ocean through air-sea interactions, wave breaking, Coriolis-Stokes forcing, Langmuir turbulence (LT) and the vortex force. However, the roles of these wave induced processes remain to be studied. This study examines the impact of these wave generated dynamics on the turbulent kinetic energy (TKE), thermal structure and currents in the upper ocean from numerical model results under idealized hurricane forcing. Six numerical experiments using a coupled circulation-wave model were conducted with hurricanes moving at three different translation speeds. The wave related simulations include two fully coupled experiments and three additional coupled experiments in which wave effects are selectively disabled (LT, wave breaking and conservative Stokes drift effects). Model results in coupled experiments are compared with a baseline circulation simulation. Our results indicate that wave breaking has the biggest impact on the ocean currents, temperature and TKE in the upper ocean during hurricanes. However, all three main effects of waves on currents contribute to vertical mixing and the two-way fully coupled experiment differs the most from the Base experiment. The combined wave effects reduce the surface currents by over 1 m/s in the front two quadrants of the hurricane and enhance the cold wake and near-surface cooling by as much as 0.6°C, predominantly to the right of the storm track. We found that wave contributions to the cooling are inversely proportional to the hurricane translation speed, although their contributions to currents and TKE are proportional to hurricane translation speed. SST differences can alter the latent heat flux driving the hurricanes, suggesting that wave dynamics should be included in hurricane forecast models. Future studies will examine real hurricane case studies.

Seasonal variations of ambient sound and ice draft in the Northwest Passage between 2018-2021

Emmanuelle Cook[1] David Barclay[1] Clark Richards[2] Shannon Nudds[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at emmanuellecook@dal.ca

The Barrow Straight Real-time Observatory is a cabled underwater monitoring station operated by Fisheries and Oceans Canada in the Tallurutiup Imanga National Marine Conservation Area. The observatory measures temperature, salinity, pressure, dissolved oxygen, currents, ambient noise and ice draft. Every 2 hours a hydrophone records a 1-minute pressure time series and generates a spectrogram with a frequency range of 10 - 6390 Hz and time resolution of one second. The IPS generates a histogram of ice draft measurements every 2 hours. Data are sent in near real-time to the Bedford Institute of Oceanography via satellite. The average monthly sound levels follow seasonal ice variations with higher frequencies varying more strongly with season than the lower frequencies and depend on the timing of ice melt and freeze-up. Ambient levels are higher in the summer during open water and quieter in the winter during periods of pack ice and shore fast ice. An autocorrelation of weekly noise levels over the ice freeze-up and complete cover periods reveal a 24hr periodic trend in noise at high frequencies (>1000 Hz) which is caused by tidally driven surface currents in combination with increased ice block collisions or increased stress in the shore fast sea ice.

Turbulence in the deep ocean: understanding the interaction of currents with underwater topography

Marie Babineau[1] Ruth Musgrave

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at marie.babineau@dal.ca

When steady stratified currents flow over rough topography, upward propagating internal waves, known as lee waves, are generated. Similar to waves at the beach, internal lee waves can steepen and break, leading to turbulence, energy dissipation, and mixing. However, the rates at which these waves are generated, and where they dissipate are still poorly understood. Theoretical models for lee wave generation and dissipation predict turbulent dissipation rates that are 2-3 times higher than what has been observed. These discrepancies could be attributed to an unrealistic simplification employed in the theoretical model where currents are constant in depth. To test this, we will use a numerical model, MITgcm, to run idealized 2D simulations with depth varying currents. In this talk, I will present preliminary work with simplified, bell-shaped bathymetry, and stratified depth-uniform currents to demonstrate agreement between linear theory and the model. Later work will include depth varying current and how they lead to different wave responses and energy dissipation above topography.

Sea Surface Temperature Trends and Variability in the Northwest Atlantic

Jonathan Coyne[1] Eric Oliver[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at jonathan.coyne@dal.ca

Increases in ocean temperature and the presence of large multidecadal sea surface temperature (SST) oscillation have the potential to cause severe impacts on Northwest Atlantic ecosystems and fisheries. Differences between historical SST datasets for the regions have also been noted making it difficult to determine the true SST record. It is therefore imperative that steps be taken to take into account cross-dataset variability when determining warming trends and patterns of variability of SST in the Northwest Atlantic. Here, we use a novel multi-dataset approach consisting of observation-based data products and climate models, to determine long-term SST trends and yearly-to-multidecadal variability in Northwest Atlantic SST. SST was spatially averaged over continental slope and shelf regions of interest from North Carolina to Labrador, to simplify the data and allow for a multi-dataset approach. A climate model was used to determine the role of anthropogenic forcing in Northwest Atlantic SST. An extended empirical orthogonal function (EEOF) analysis was then use to determine leading modes of variability. The EEOF analysis results were then correlated with potential ocean and atmosphere predictors. Unprecedented positive SST trends outside of the global climate models natural run variability were found in all regions of interest by the mid 21st century. The EEOF indicates that the two dominant modes of variability are associated with Atlantic Multidecadal Oscillation (AMO) and North Atlantic Oscillation (NAO) and that the SST signal may extend to the shelf and slope regions of the Northwest Atlantic. Comparisons between the leading EEOF modes with ocean and atmosphere predictors indicate support for positive NAO years forcing the Northwest Atlantic to a positive AMO regime.

High-resolution oceanographic and microbial diversity analyses within trophic groups reveal new provincialism across the Atlantic Ocean

Cora Hoerstmann[1] Pier Luigi Buttigieg[2] Uwe John[1] Eric Raes[3] Anya Waite[3] Dieter Wolf-Gladrow[1]

[1]Alfred-Wegener Institute Helmholtz Center for Polar and Marine Research, Am Handelshafen 12 27570, Bremerhaven, Germany; Department of Life Sciences and Chemistry, Jacobs University gGmbH, Bremen, Germany
[2]Helmholtz Metadata Collaboration, GEOMAR, Wischhofstraße 1-3 24148, Kiel, Germany
[3]Ocean Frontier Institute and Department of Oceanography, Dalhousie University, Halifax, NS, Canada, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at cora.hoerstmann@awi.de

Ocean currents, fronts, and eddies shape the distribution of phylogenetic and functional microbial biodiversity, thereby sustaining a mosaic of niche and ecosystem structures with high and low productivity. Major sampling campaigns have created a wealth of general knowledge about the Atlantic microbiome; however, we lack an in-depth understanding of how microbial diversity and primary productivity change at fine spatial scales (∼10-100 km). Here, we present results from a transect in the Atlantic Ocean (from ∼50°S to 50°N), sampled at high resolution (every ∼1/2° latitude). We applied a combination of in-situ rate measurements of primary productivity, with 16S and 18S rRNA gene sequencing, and physicochemical analyses to contextualize how the hydrographic environment impacts changes in the microbial diversity. We detected boundaries of ecological regions – partially coincident with Longhurst provinces – which we could divide into regions of high and low chl *a*, respectively. Eukaryotic autotrophs and prokaryotic heterotrophs showed higher beta diversity in high chl *a* provinces, while beta diversity of mixotrophs, cyanobacteria and eukaryotic heterotrophs was higher in low chl *a* provinces. Additionally, we calculated productivity-specific advection length-scales to assess the scale at which biological-physical coupling is maximized. The impact of advection by surface currents on microbial diversity can be related to patchiness in beta diversity patterns within provinces. We propose an integrative approach that evaluates trophically disaggregated diversity alongside productivity and advection thus improving our understanding of the mosaic nature of microbial provincialism.

The role of sea ice melt in the missing Arctic Ocean carbon uptake

Benjamin Richaud[1] Katja Fennel[1] Eric Oliver[1] Mike DeGrandpre[2] Timothe Bourgeois[3] Xianmin Hu[4] Youyu Lu[4]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Dept. of Chemistry and Biochemistry, University of Montana
[3]NORCE
[4]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at benjamin.richaud@dal.ca

The Arctic Ocean is undersaturated in CO_2, and currently acts as a carbon sink. This oceanic uptake is controlled by sea ice, which can prevent gas exchanges between the atmosphere and the ocean and has major impacts on stratification, primary production and carbon tracer concentrations. Given the rapidly changing ice-scape in an acidifying Arctic Ocean, a better quantification of carbon uptake is necessary. To this end, this study investigates the link between the seasonal cycle of sea ice and the oceanic uptake of CO_2. The storage of carbon in sea ice, with a high alkalinity to dissolved inorganic carbon (DIC) ratio, is suspected to increase oceanic carbon uptake in seasonally ice-covered areas by amplifying the pCO_2 seasonal cycle. This amplification should be dependent on the alkalinity-to-DIC ratio in ice. These two hypotheses were tested and confirmed using a simple parametrization of carbon storage in sea ice implemented in a 1D physical-biogeochemical ocean model. We found a linear relation between ice melt and the amplification of seasonal carbon uptake that is also supported by idealised theoretical arguments. We then applied this relationship to outputs from a CMIP6 model to accommodate for its lack of representation of carbon in sea ice, and in doing so, quantified the underestimation of carbon uptake in a future climate projection.

Impact of Poor Water Quality on the Physiological Stress Response in Farmed Atlatic Salmon (*Salmo salar*)

Jennie Korus[1, 2] Jonathan Grant[1]

[1]Department of Oceanography, Dalhousie University Halifax, NS, Canada, B3H 4R2
[2] Innovasea Halifax, NS, Canada B4B 1H3

Speaker may be reached at jennie.korus@dal.ca

Atlantic salmon (*Salmo salar*) are a commercially important species across the globe. There has been rapid expansion in production rates over the last few decades to meet an increasing demand for healthy, sustainable protein. The welfare of these animals has been of increasing interest to consumers, producers and regulating bodies. It is common practice to use the tertiary stress response as an indicator of fish welfare. This response includes reduced growth rate, compromised immune response and changes in swimming behavior. However, these represent a delayed response to a stressor and do not allow farmers to identify the initial cause of stress and this prevents the implementation of any mitigation strategies. As the welfare of fish in aquaculture continues to be scrutinized it is imperative to define a welfare standard using a variety of indicators that can be implemented as standard operating procedures. Advancements in technology have allowed for the increased ability to monitor animals in situ. Complex bio-loggers can be used to monitor heartrate, temperature, acceleration and depth of fish as they experience regular aquaculture practices and adverse water quality conditions. Environmental sensors that monitor dissolved oxygen, temperature and depth can be used to capture fine-scale changes in water quality within individual pens. The combination of these sensors can be used to help characterize an earlier stress response to adverse water quality and enable farmers to determine stressful environmental impacts sooner. This project aims to tag twenty Atlantic Salmon (Salmo salar) with heartrate, temperature, accelerometer and depth tags in a single cage on an aquaculture farm. The pen will be outfitted with twenty environmental sensors that will measure dissolved oxygen and temperature. Data will be collected with high frequency during three intervals to capture three common farm instances. The first in late summer when dissolved oxygen levels are low, in the winter, when superchill is a concern and finally during a lice treatment procedure. This study aims to correlate and grade the severity of the physiological and behavioral response to common farm occurrences and gain a better understanding of how these events impact livestock to maintain a high level of care.

Isolating Dissolved Inorganic Carbons Sources of Temporal Variability in the Northwest Atlantic Ocean

Claire Boteler[1] Michael Dowd[1] Eric C. J. Oliver[2] Elias T. Krainski[1] Douglas W. R. Wallace[2]

[1]Department of Statistics, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at claire.boteler@dal.ca

The NW Atlantic Ocean is an important global sink for atmospheric carbon produced by anthropogenic activities. However sparse and irregular sampling of ocean carbon make it difficult to capture a full picture of its spatio-temporal variations. Using observations of Dissolved Inorganic Carbon (DIC) from the GLOPAPv2 database (Olsen et al, 2016; Olsen et al, 2019) we used data-centric methods to disentangle DICs sources of variability: seasonal, natural carbon variability, and excess carbon due to anthropogenic sources. A monthly time series of excess carbon, with confidence intervals, was estimated from a state space statistical model. Our region was separated into 3-depth layers and analyzed independently. The long-term trends of excess carbon were found to be higher than the trends of total DIC estimated directly from the observations in each depth layer. The summer sampling bias of DIC sampled data contributes to this difference in trend, with the largest impact in the surface waters. Our findings show that to analyze DICs anthropogenic behaviour, it is recommended to first isolate its sources of variability, otherwise the long-term trend of anthropogenic carbon in the ocean would be underestimated.

Estimating Net Primary Production from daily in situ and remotely sensed bio-optical measurements in the central Labrador Sea

Kitty Kam[1] Douglas Wallace[1] Dariia Atamanchuk[1] Emmanuel Devred[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at kitty.kam@dal.ca

Net Primary Production (NPP) is a quantitative measure for the potential of carbon export to the deep ocean and directly linked to the biological carbon pump. In the Labrador Sea, the extent of winter vertical mixing could significantly alter the supply of nutrient and inorganic carbon for surface production in the spring. However, the constraints on NPP are still not well understood, notably mixed layer depth and seasonal cycle. Increasing amounts of ocean data from autonomous sensors and satellites allow us to observe temporal and spatial changes in NPP. Remotely sensed NPP relies on empirically derived bio-optical parameters from satellite measurement, such as daily averaged Photosynthetic Active Radiation (PAR) and surface chlorophyll-a concentration. Such estimation is often met with error with increasing depth as the satellite measurement is restricted to the surface ocean. A long-term, fixed-location and high-frequency moored profiler, SeaCycler, measured daily in situ bio-optical profiles up to 150 metres of depth in the Center Labrador Sea, allowing a validation of depth-resolved NPP and an opportunity for a rare comparison of high-resolution in situ observations with satellite measurements. NPPs will be estimated from a 1-dimentional primary production model using chlorophyll-a and irradiance measurements of SeaCycler and MODIS-aqua satellite. Preliminary comparison between mooring-measured and satellite-based parameters shows a stark contrast in temporal and spatial resolution, which poses a challenge to effectively comparing the NPP estimates. Extrapolation and conversion are adapted to carefully match in situ observations with satellite data on the same temporal and spatial scale.

Partitioning between water and sediment oxygen consumption in a seasonally hypoxic coastal basin

Subhadeep Rakshit[1] Christopher Algar[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at subhadeep.rakshit@dal.ca

Increasing hypoxia in the world oceans is a major environmental concern. The global ocean inventory of oxygen has decreased by 2% in the last five decades. The effect is more severe in the coastal ocean, due to eutrophication induced hypoxia resulting from anthropogenic nutrient input. The oxygen inventory below the mixed layer primarily depends on supply from the surface waters by downwelling or mixing and consumption due to respiration in deeper water and sediments. Although the contribution of sediments to oxygen consumption is negligible in the open ocean where the water is deeper, the sediment becomes increasingly important in shallower waters, such as in the coastal ocean and estuaries. In the current study, we aim to quantify the oxygen consumption in both the sediment and water column and identify the drivers controlling the development of hypoxia in Bedford Basin (BB), a semi-enclosed coastal fjord. Using a combination of oxygen microsensor profiling and whole-core flux incubations we quantified seasonal benthic oxygen uptake and sediment volumetric oxygen consumption in BB. The data was used to constrain a physical-biochemical 1D-model, which was able to predict the development of hypoxia in BB. We found that benthic oxygen consumption accounts for $\sim$ 25% of total oxygen consumption in the basin. We also identify the role of stratification and primary productivity of the surface layer in controlling hypoxia. This study highlights the importance of sediments in coastal ocean hypoxia and provides a plausible numerical tool for monitoring and predicting oxygen dynamics in BB.

Understanding the effects of ambient nutrient concentrations on the growth of the kelp, Saccharina latissima in 3 locations in Cape Breton

Katie Frame[1] Carly Buchwald[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at kframe@dal.ca

Seaweed aquaculture is an important industry because of its uses in fertilizers, beauty products, fish feeds and as a food source. The increased interest in growing seaweeds, such as Saccharina latissima, has sparked the need for finding areas which can naturally support their growth in the water column. In 2019 monthly water samples were collected to create a baseline to understand the nutrient regime in Arichat Harbour, Lennox Passage and St. Anns Bay in Cape Breton, NS, which were selected as test locations for seaweed aquaculture farms. In November 2019, seed lines of Saccharina latissima were installed at 2- and 4-meter water depths and the following June the seaweed was harvested and characterized for blade length, width and thickness. At all locations, we have found that nitrate, ammonium and phosphate concentrations were all very low throughout the summer and began increasing between October and November and were depleted again by harvest time in June. We found there was little difference between locations and that Arichat Harbour and Lennox Passage, produced larger yields of kelp close to 1 meter in length while in St. Anns Bay the seaweed grew to approximately 0.3 meters and had a small yield. Analysis so far shows that kelp size had no relationship with nitrate or phosphate but had an inverse relationship with ammonium (r^2 >0.8), indicating another factor may be affecting its growth. When we compared our kelp growth in Cape Breton to 3 other farms in the Northeastern US, we saw that there was also an inverse relationship with temperature (r^2 >0.7), which agrees with previous studies that have shown that Saccharina latissima prefers colder waters.

Carbon export via different mechanisms in the subpolar North Atlantic

Bin Wang[1] Katja Fennel[1]

[1]Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada

Speaker may be reached at Bin.Wang@dal.ca

The biological carbon pump (BCP) is an important pathway for export of organic carbon from the surface to the deep ocean. However, current estimates of this carbon flux and subsequent respiration are uncertain due to lack of observations. In addition, the long-term standing paradigm that the BCP is mainly fueled by the gravitational sinking of large, fast sinking POC has been challenged recently. The imbalance between carbon export and heterotrophic demand in the mesopelagic zone suggests that there may exist some alternative mechanisms, e.g., the mixed layer pump and the eddy subduction pump. Recent advances of the BGC-Argo floats have greatly expanded the availability of observations, which can be used to infer export flux. In this study, estimates of the BCP via different mechanisms and their subsequent respiration are conducted based on the BGC-Argo floats in the subpolar North Atlantic. Our results show the dominance of gravitational sinking flux but also highlight the importance of other export mechanisms.

Comparing visual and acoustic surveys for the dynamic management of North Atlantic right whales (Eubalaena glacialis) in Canada

Valentina Ceballos[1] Hansen Johnson[2] Christopher Taggart[2]

[1]Department of Biology, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `Valentina.Ceballos@dal.ca`

Until recently, dynamic management of critically endangered North Atlantic right whales in Canadian waters was solely based on visual observations, mainly from aircrafts. This changed in early 2020, as the Government of Canada began using near real-time acoustic detections of right whale calls interchangeably with visual observations to trigger risk-mitigation measures. Comparing visual and acoustic survey methods has become critical for the correct interpretation and combination of survey data, as well as for the development of optimal monitoring strategies. This comparison is impossible to measure empirically due to our inability to observe the true number of whale surfacings and calls that are available for detection. The goals of this study were to develop a simulation-based method to quantitatively compare acoustic and visual surveys, and to use the simulation to inform future right whale management. We first expanded upon an established whale movement model by adding calling and diving behaviors based on previous observations. We then applied this model to generate a realistic distribution of surfacings and calls available for visual or acoustic detection, respectively, for various numbers of whales constrained within dynamic management zones established by Fisheries and Oceans Canada and Transport Canada in the Gulf of Saint Lawrence. The next step was to model acoustic surveys from ocean gliders and visual surveys from planes and vessels of the simulated whales using realistic survey designs, platform movement characteristics, and detection functions. A Monte Carlo approach was used to estimate the probability of detecting a single call or surfacing from each platform as a function of the number of whales within and transits through each management area. Preliminary results suggest that there are substantial differences between acoustic and visual survey performance, as a single ocean glider transit always correctly identified right whale presence, while the visual surveys required multiple transits and large numbers of whales to detect whale presence. Our results can potentially inform the optimal use of acoustic and visual surveys for right whale monitoring and risk mitigation efforts, and also show that certain limitations must be considered by decision-makers when reviewing survey data.

Assessment of Rapidly Developing, Accessible Technology for the Engagement of Coastal Communities in Ocean Observations

Teala Chambers[1] Doug Wallace[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at tchambers@dal.ca

The advancement of ocean technology could provide greater opportunity for coastal community members to become involved in research that involves their environment. Coastal communities, Indigenous governments, and local industries increasingly require the ability to assess and monitor the underwater environment to inform management, operations, planning, and regulation. For example, remotely operated vehicles (ROVs) are becoming smaller, less expensive, and easier to use, and may help to fulfill these needs. In this study, we assess the ability of an ROV to address the needs and interests of the community living around the Bras dOr Lake ecosystem in Cape Breton. Around the shoreline of the Bras dOr are several hundred barachois ponds, small ponds of saline to brackish water found behind a barrier beach that separates them from the lake. These barachois offer important ecosystem services and are uniquely threatened by human disturbances. In our assessment, we ran ROV transects in Irish Vale barachois pond, as chosen by community leaders, once in August and once again in September 2021. This was completed along with representatives from the Collaborative Environmental Planning Initiative (CEPI) and the Unamaki Insititute of Natural Resources (UINR), as well as with researchers from Cape Breton University. The ROV was equipped to record video footage, conductivity, salinity, and depth data, as well being able to take water samples during the September expedition. The poster will present preliminary temperature and salinity data collected by the ROV during the sampling expeditions. Our analysis draws on the comparison of ROV values between historical data on the pond and current data that we have collected. Salinity and temperature profiles made from collected ROV data will be compared to CTD measurements taken on the same day in a boat. Profiles in August and September will also be compared, and different aspects of the data will be examined to evaluate if the ROV is a useful and reliable tool to study barachois ponds. We anticipate that the development of accessible technology will result in more community-led research initiatives, which will have numerous effects on the future of oceanographic research and the health of coastal communities

Volume, Heat and Freshwater Transport in the Labrador Current off Nunatsiavut, Northern Labrador

Taylor Davies[1] Eric Oliver[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at ty993945@dal.ca

The Labrador Current is a cold boundary current that flows south from the Davis Strait along the Labrador Sea's western edge, passing Newfoundland and Labrador and eastern coastal Nova Scotia. This current is a key component of Labrador Sea dynamics, being the western boundary current of the subpolar gyre, and plays an important role in meridional heat and freshwater transport at high latitudes. The Labrador Current forms part of the main outflow of water from the Arctic to the Atlantic ocean, transporting sea ice, and cold, fresh water of polar origin as far south as coastal Nova Scotia. The Labrador Current has two branches; a strong offshore branch that lies over the continental slope and a relatively weaker inshore branch, that lies over the shelf, closer to the coast. We use measurements of temperature and salinity from CTD casts for the three northernmost lines of the Atlantic Zone Monitoring Program (AZMP), along with surface drifting buoys to calculate volume, heat, and freshwater transports in the two branches of the Labrador Current. We then analyze how different physical variables contribute to the variability of heat and freshwater transport, and look at the coherency of transport between the three lines. Our results indicate that variations in velocity dominate variations in heat transport in both branches of the current, and that variations in salinity and velocity both play an important role on variations in freshwater transport.

Identifying the critical nitrogen to phosphorous ratio in food-grade wastewater for the growth of the diatom Thalassiosira pseudonana

Olivia Melville[1] Hugh MacIntyre[2]

[1]Department of Marine Biology, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at oliviamelville@dal.ca

The untreated release of high-nutrient wastewater can disrupt ecosystems by causing harmful algal blooms, hypoxia, and habitat change. The efficient and cost-effective removal of nutrients from wastewater is therefore of high interest and can be done through cultivation of microalgae. The microalgal biomass produced during remediation can be valorized for foods, fuels, or fertilizers. Optimization of growth requires adjusting the stoichiometry of nutrients in the waste to meet the requirements of the microalgae. In this study, the diatom Thalassiosira pseudonana was grown in cultures containing distillate tails, the wastewater from alcohol production. This waste-stream contains very high dissolved inorganic phosphate (5.3 mM) and nitrate (4.8 mM). The average required molar ratio of N:P is 16:1, therefore the waste-stream is at least an order of magnitude lower than the requirements for growth. In this experiment, I tested the growth of T. pseudonana in seawater amended with 0.2% distillate (final concentration of 10.5 μM dissolved phosphorous and 8.8 μM dissolved nitrogen). I set up 15 culture tubes with nitrate different additions (0340 μM), and a common mixture of trace metals and vitamins (f/2-media concentrations) in order to identify how much nitrogen was missing from the waste-stream to support the growth of T. pseudonana. Cultures were monitored daily via chlorophyll A fluorescence spectroscopy and harvested once they reached stationary phase (no biomass increase). Elemental analysis (carbon, nitrogen, phosphorous) was performed on both biomass (particulate material) and the media (filtered water/filtrate). The results indicated that residual phosphorous was entirely removed from the cultures by the time of harvest. Residual dissolved organic nitrogen, however, remained present. This suggests a form of nitrogen that is not available to the diatom. Complete remediation of the waste will require further research to form a strategy for mobilizing and removing this form of nitrogen. The results also indicated the cultures were in nitrogen limitation below a concentration of 170 μM nitrate, above this concentration the cultures exhibited phosphorous limitation. This suggests that the ideal ratio of N:P for Thalassiosira pseudonana, for remediation is 17:1. For maximal biomass, when cultures had highest particulate nitrogen and phosphorous concentrations, the suggested ratio is 18N:1P.

The effect of discharge on productivity in a shallow-water subtropical estuary

Deklan Mengering[1] Hugh MacIntyre[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at d.mengering@dal.ca

Repeated algal blooms in the shallow-water systems of the north-eastern Gulf of Mexico have been linked to discharge from the aquifer headwaters. Weeks Bay is a National Estuarine Research Reserve (NEER) on the Gulf of Mexico and the focus of our study. We assess the utility of a conceptual 1-D model proposed by Lucas et al. (2009) to determine if it has predictive power in this complex 3-D system. Their model predicts biomass accumulation from the ratios of transport, productivity, and intrinsic loss. Here, productivity was estimated using the simplified BZI bio-optical model (Cole Cloern 1987). If the approach suggested by Lucas and co-workers has predictive power, it will be a useful tool in predicting the effect of climate change on the ecosystem. In the future, we are likely to see an increase in discharge from the aquifer resulting in a higher frequency of more extreme discharge events. Gaining insight into the ecosystem response as a result of these events is the goal of our analysis.

A time series of nitrogen in the Northwest Arm of Halifax Harbour

Mandi Newhook[1] Carolyn Buchwald[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at mandi.newhook@dal.ca

Human activity is greatly increasing the amount of bioavailable nitrogen in coastal ecosystems, impacting microbial structure and dynamics, oxygen availability, and the overall functioning of the marine nitrogen cycle. We hypothesized we would see the largest concentration of nitrogen in the late fall and during the winter during periods of low biological activity, and that nitrogen species concentrations would increase between sample sites as they become further away from the outer Halifax Harbour. We also expected to see the highest ammonium concentrations at Horseshoe Island Park due the presence of combined sewer overflows, which would also increase during times of increased precipitation. A year of bi-monthly samples in the Northwest Arm of Halifax Harbour show two peaks of total nitrogen concentration occur in the year, in June and December. Between the three sampling sites, Horseshoe Island Park, Oakland Dock, and Point Pleasant Park, for the three months of data available, Horseshoe Island had the highest concentration of nitrate and ammonium, while Point Pleasant had the lowest total nitrogen concentrations. The increased distance from the outer Halifax Harbour at Horseshoe Island Park increases the flushing time, and therefore could provide more time for nitrogen species to build up in the water and explain, at least in part, the high concentration of nitrogen species seen compared to the other sites. There is the possibility that increased flushing at Point Pleasant compared to Oakland Dock and Horseshoe Island is responsible for the build up of nitrate as reduced interactions with the anoxic sediments prevents nitrate removal. The data suggests there is a significant relationship between surface water temperature and total nitrogen concentration while there is no correlation between total nitrogen concentration and air temperature, max wind gust, or precipitation. The lack of correlation of nitrogen nutrients and precipitation could suggest that the combined sewer overflows are not a large source of nitrogen to the Arm, although more research is needed to confirm this.

The effect of seasonal and short-term destratification events on the detection of phytoplankton on the Scotian Shelf

Adam Stoer[1] Hugh MacIntyre[1] Ruth Musgrave[1] Adam Comeau[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Coastal Environmental, Observation, Technology and Research group, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at adam.stoer@dal.ca

Phytoplankton blooms seen in satellite remote sensing are commonly attributed to autumnal and hurricane-driven destratification of the water column injecting nutrients into the surface from deeper waters. We present a time series of glider-based bio-optical observations from the Scotian Shelf that does not indicate increased net growth in the fall and after the passing of two hurricanes. The gliders measured two annual peaks in depth-integrated chlorophyll-a fluorescence (ΣF_{Chla}; a proxy for chlorophyll-a inventory) and particulate backscattering (Σb_{bp}; a proxy for particulate organic carbon). The first peak (ΣF_{Chla} = ∼90 mg m^{-2}; Σb_{bp} = ∼0.14) occurred in April, an observation consistent with the spring bloom, while the second peak (ΣF_{Chla} = ∼60 mg m^{-2}; Σb_{bp} =∼0.13) occurred in the middle of the summer when the water column was highly stratified. The summer peak was followed by a small but consistent decrease in ΣF_{Chla} and Σb_{bp} up until early winter. In contrast, during the same period, satellite-based estimates of chlorophyll-a and particulate organic carbon increased by ∼100% and ∼42%, respectively. Weak increases in ΣF_{Chla} (∼10%) and Σb_{bp} (∼12%) were observed after the passage of Hurricane Arthur in July 2014, while weak decreases in ΣF_{Chla} (∼-8%) and Σb_{bp} (∼-13%) were measured after Hurricane Dorian in September 2019. Changes in ΣF_{Chla} and Σb_{bp} after the storms were comparable to the seasonal changes detected in years without hurricanes. In both storms, satellite imagery measured increases that were consistently 20–80% larger than in the integrated values. We attribute the apparent blooms observed by satellite imagery to the redistribution of a deep chlorophyll maximum, causing it to become entrained into surface waters during destratification. The results suggest that 1) there is a distinct summertime peak in the in-situ proxy measurements for chlorophyll-a and particulate organic carbon (a feature not seen in concurrent satellite imagery), 2) hurricanes may only prompt a limited biological response on the Scotian Shelf, and 3) the apparent blooms seen at the surface in the fall and after the passing of hurricanes are simply due to an observation bias. The study underscores the importance of having a multi-year time series of in-situ measurements for interpreting satellite imagery, especially for episodic events like storms.

Localization of North Atlantic Right Whales using a Deformable Array of Passive Acoustic Monitors

Zachary Wallot-Beale[1] David Barclay[2] Carolyn Binder[3]

[1]Department of Biology, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[3]Defense Research and Development Canada - Atlantic, Dartmouth, NS, Canada, B3A 3C5

Speaker may be reached at zachwallotbeale@gmail.com

Rising global temperatures have shifted the habitat range of many marine species towards the poles. The endangered North Atlantic Right Whale is among these species. With the expansion of their range has come an increased mortality rate largely attributed to ship strikes and entanglements in fishing gear. If the positions of whales were known, large vessels could actively avoid them, reducing ship strikes and noise emission impacts without widely imposing remarkably strict regulations on industry. In July 2018, a two-day data-blitz effort was put together in the Gulf of Saint Lawrence with members of the Royal Canadian Airforce and Dalhousie University. 32 DIFAR sonobuoys, two acoustic gliders, two planes, and a vessel were deployed to collect visual and acoustic data of North Atlantic Right Whales. The aim of this research is to describe the performance of large deformable arrays for passive acoustic monitoring and to quantify the arrays effective detection range, localization accuracy and uncertainty as a function of size and number of elements. Bearing information was extracted and cross-referenced between characteristically similar acoustic detections, with the help of a parabolic equation model for calculating the probabilistic range of detection and the visual detections for ground-truthing, in order to produce estimates of North Atlantic Right Whales positions through time. Preliminary results will be presented focusing on extracting and visualizing the bearing information and generalizing the probabilities of detection inside and outside of the deformable array through time.

Inuit knowledge of ocean conditions, trends and changes in coastal Nunatsiavut

Breanna Bishop[1] Eric Oliver[2] Claudio Aporta[3]

[1]Interdisciplinary Studies, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[3]Marine Affairs Program, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at breanna.bishop@dal.ca

The effects of climate change are increasingly impacting Arctic and sub-Arctic communities, and there is an evident drive for research that can inform future adaptation and planning at regional and local scales. This is true for Nunatsiavut an Inuit self-governing region in northern Labrador where an increased understanding of oceanographic variables can support ongoing policy development and planning for future change. Currently in Nunatsiavut there is limited recorded oceanographic data derived from Inuit knowledge. Through participatory mapping and semi-structured interviews in the communities of Rigolet and Hopedale, this research identified oceanographic features of relevance to each community, and related conditions, trends or changes. One prominent observation is the changes to sea ice that occurred after construction of the Churchill Falls hydroelectric dam. Long term changes to ice conditions and weather were also identified, which have implications for livelihoods and cultural wellbeing, in addition to influencing the way that knowledge can be generated and transmitted within communities. Documenting Labrador Inuit knowledge of oceanographic features supports an area deficient in data, while identifying features of relevance to community members. with the potential to guide future oceanographic research in the region. When documenting Inuit knowledge in such a way, it is also important to account for the worldview that has shaped that knowledge, which is distinct from that guiding western scientific approaches. In doing so, this research suggests that characteristics such as seasonality, mobility, relationality and narratives should be documented alongside the features themselves to help contextualize the data. Such an approach will allow research to be situated at a relevant scale for communities, respecting the tangible and intangible ways in which Labrador Inuit are connected to the marine space.

Temporal and Spatial Variations of Sea Ice Along the Labrador Coast and Shelf

May Wang[1] Eric C.J. Oliver[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at may.wang@dal.ca

The spatial extent and thickness of the sea ice in the Northern Hemisphere have noticeably changed over the past 50 years. The effects of these changes threaten the health of regional ecosystems, and the livelihood of coastal communities, who rely on the sea ice for travel and hunting. In general, responses of sea ice to anthropogenic climate warming include ice thinning, reductions of landfast ice, shorter ice seasons, and a decline in sea ice extent. However, a better understanding of sea ice changes and their physical drivers along the Labrador coast is still needed. Here we analyze 21 years of weekly sea ice data between 1997 and 2020 provided by the Canadian Ice Services. We calculate the seasonal climatology, linear trend, and anomalies of various sea ice metrics including concentration, thickness, edge of landfast ice, first and last date of the ice season, length of the ice season, and polynya occurrence. We propose to extend this work by examining the physical processes governing sea ice variability and long-term change in the region using a dynamical numerical ocean-sea ice model (ROMS-CICE). Preliminary results suggest later freeze-up time, earlier breakup time, and increased proximity of the landfast ice edge to some coastal communities.

Estimating turbulence in the Arctic Ocean at the Canada Basin shelf-break

Ruby Yee[1] Ruth Musgrave[1] Jonathan Nash[2] Robert Pickart[3] Louis St. Laurent[4]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Burt Hall 402, 2651 SW Orchard Avenue, Corvallis, OR, USA, 97331
[3]Department of Physical Oceanography, Woods Hole Oceanographic Institution, 266 Woods Hole Road, MS #21, Woods Hole, MA, USA, 02543
[4]Applied Physics Laboratory, University of Washington, 1013 NE 40th St, Box 355640, Seattle, WA, USA, 98105-6698

Speaker may be reached at `r.yee@dal.ca`

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151 full-depth profiles of temperature microstructure were obtained over the shelf, break, and slope of the Canada Basin during a November 2018 research cruise using a MicroRider-1000 (Rockland Scientific) mounted on a conductivity-temperature-depth (CTD) rosette. From these profiles we estimate two main turbulent parameters: the dissipation rate of temperature variance and turbulent kinetic energy, from which turbulent diffusivities can be derived. Estimates are made by fitting theoretical Kraichnan spectra to observed temperature gradient spectra over the inertial-convective subrange where data is well-resolved, and by assuming the turbulent diffusivities of temperature and density (κ_T and κ_ρ) are equal. We outline a set of criteria for rejecting profiles based on 1) resemblance to the Kraichnan spectral form and 2) wake contamination in regions of decreased CTD rosette fall speed. We will discuss some fundamental assumptions associated with the use of temperature microstructure for turbulence estimation in the Arctic Ocean, including whether $\kappa_T = \kappa_\rho$ in the presence of double diffusion. Finally, we present general observations on the patterns of turbulent mixing in 15 sections crossing the shelfbreak between Barrow and Mackenzie Canyons.

Mapping Eelgrass in Cole Harbour, Nova Scotia Using a Remotely Operated Hovercraft

Meghan Troup[1] David Barclay[1] David Burns[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at meghan.troup@dal.ca

Eelgrass (*Zostera marina*) is the dominant species of seagrass in the Northern Hemisphere. Historically, eelgrass in Atlantic Canada has been in decline due to disease, depletion by invasive species, and ocean pollution and eutrophication. Though eelgrass is an important foundation species, detailed habitat maps are uncommon, and beds are not surveyed often enough to track annual or seasonal population dynamics. The Shallow Water Autonomous Surveying Hovercraft (SWASH) system is applied to surveying eelgrass beds as a case study for a novel and effective method of creating detailed habitat maps that can be repeated easily and frequently.

Modelling seasonal nitrogen transformation rates using coupled nitrogen and oxygen isotope measurements on Browns Bank

Britton Dempsey[1] Carolyn Buchwald[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at britton.dempsey@dal.ca

Nitrogen limitation significantly regulates primary production in the Northwest Atlantic (NWA), and consequently the regions potential to export atmospheric carbon from surface to ocean depth. A component in understanding how climate warming will affect coastal nutrient regimes in the NWA is the characterization of the rates of biological processes that link marine nitrogen and carbon cycling. In particular, climate-induced changes to circulation and stratification patterns in the region may disrupt planktonic-nutrient dynamics concerning nutrient uptake and remineralization of organic matter at depth. Depth profiles of nutrients can qualitatively imply the presence of nitrate assimilation and nitrification throughout the water column. However, further interpretation of the microbial processes and associated rates that define these nutrient profiles require additional scrutiny using stable isotope analyses. In this work, stable isotopic composition measurements of nitrate (NO_3^-) will be used to compare seasonal microbial transformation processes within the nitrogen cycle of productive shelf waters. To examine the vertical rate distributions associated with ammonium oxidation and nitrate assimilation, an inverse 1-D reaction-diffusion model will be constructed based on vertical profiles of nitrate and corresponding $\delta^{15}N$ and $\delta^{18}O$ values. In addition, the extent of nitrogen assimilation and nitrification coexistence in the euphotic zone will be examined using $\Delta(15, 18)$ values. This work will compare seasonal isotope data sets collected on Browns Bank during fall and springtime months. The results from this work will serve to enhance our understanding of the internal supply of nutrients to surface waters, whether it be sourced from depth or at the surface to support new and recycled primary production, respectively. The modelling component of this work also serves as a precursor to future studies on interactions between nitrogen cycling and biological carbon pump processes in the deeper waters of the Labrador Sea.

Stratification and timing of maxima in remotely sensed surface reflectance in tidal seas, South Korea

Catherine Evans[1] Paul Hill[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at `catherineevans@dal.ca`

Satellite imagery has been used to investigate the spatial and temporal dynamics of suspended sediment in shallow marine environments, including the Heuksan Mud Belt (HMB) located off the southwest coast of Korea. The region is characterized by strong tides and an abundant supply of suspended sediment, which can lead to the development of sediment-induced stratification in the water column.

Our study area focuses on a region of tidal ridges and channels in the HMB. Previous fieldwork demonstrated that there is stratification in the tidal channels during peak flow. Stratification reduces the concentration of suspended sediment that reaches the surface in a tidal flow, and it increases the time required for suspended sediment to diffuse to the surface. Because stratification should be localized in channels, we hypothesized that peak surface reflectance observed by satellites should be lower over channels than over ridges and that the timing of peak reflectance over channels should lag peak reflectance over ridges. Analysis of Landsat 8 images of the study site showed that channels have lower maximum surface reflectances than ridges. This finding is consistent with the hypothesis of localized suspended sediment stratification in channels.

My research uses the Geostationary Ocean Colour Imager (GOCI) to investigate whether maximum reflectance over the channels lags maximum reflectance over the ridges. GOCI is stationed over the Korean peninsula and takes 8 images daily over the region. The use of these images taken on an hourly interval allows for observation of how reflectance changes throughout a tidal cycle. Preliminary analysis indicates that maximum reflectance over channels occurs near the time of high water, while maximum reflectance over ridges occurs after mid-tide, which is broadly consistent with the hypothesis that suspended sediment stratification causes a lag in the arrival of peak reflectance at the surface over channels.

Recruitment of deep-water coral on the continental slope off Nova Scotia: Implications for habitat distribution and population connectivity

Graeme Guy[1] Anna Metaxas[1]

[1]Dalhousie University, 6299 South St, Halifax, Nova Scotia, B3H 4R2

Speaker may be reached at G.Guy@dal.ca

Deep-water corals provide habitat complexity and shelter for many fauna, contributing to the health of deep-sea ecosystems. These corals are vulnerable to anthropogenic disturbances such as fishing and climate change because they grow slowly and have long life spans. This vulnerability has led to the protection of several deep-water coral aggregations in submarine canyons in Atlantic Canada, specifically focused on *Paragorgia arborea* and *Primnoa resedaeformis*. Populations of these two species are discontinuous and spatially fragmented, making self-recruitment and population connectivity important factors in regulating their distribution, and potential for recovery from perturbations. However, population connectivity is poorly understood, and measures of recruitment are rare. I present evidence of high coral recruitment in two locations on the continental slope off Nova Scotia. Size frequency distributions show variation with depth and provide insight into the recruitment dynamics at each location. These data can be incorporated into high resolution species distribution models, and in combination with hydrodynamic modelling, used to assess population connectivity between populations of *P. arborea* and *P. resedaeformis* on the Scotian continental margin.

North Atlantic right whale (Eubalaena glacialis) habitat in the southern Gulf of St Lawrence

Hansen Johnson[1, 2] Mark Baumgartner[2] Kim Davies[3] Delphine Durette-Morin[1, 4] Meg Carr[1] Moira Brown[4, 5] Philip Hamilton[5] Amy Knowlton[5] Christopher Taggart[1]

[1]Oceanography Department, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Biology Department, Woods Hole Oceanographic Institution, 266 Woods Hole Road, MS #33, Woods Hole 02543, Massachusetts, USA
[3]Department of Biological Sciences, University of New Brunswick, Saint John, NB, E2L 4L5, Canada
[4]Canadian Whale Institute, 20 Morning Star Lane, Wilsons Beach, New Brunswick E5E 1S9, Canada
[5]Anderson Cabot Center for Ocean Life, New England Aquarium, Central Wharf, Boston, MA 02110, USA

Speaker may be reached at `hansen.johnson@dal.ca`

North Atlantic right whales are critically endangered baleen whales that meet their energetic demands by filter feeding primarily on dense patches of energy rich *Calanus* zooplankton. The distribution of right whales has shifted in the last decade, perhaps best exemplified by the decreased use of several well-characterized habitats in the Gulf of Maine and Scotian Shelf and an increased occupancy of a relatively unknown habitat in the southern Gulf of St Lawrence (GSL). The goal of this project was to characterize right whale feeding habitat in the GSL region. We conducted opportunistic oceanographic sampling from visual survey vessels in the presence and absence of right whales in July and August over three years (2017 – 2019). Oceanographic stations (n = 115) were typically comprised of a depth-integrated oblique ring net tow that was preceded and followed by a vertical profile of a CTD and optical plankton counter (OPC; 2018/2019 only). The net data were used to identify and enumerate the major zooplankton taxa, while the CTD and OPC data were used to quantify the vertical structure of the water column and the size-frequency distribution of suspended particles, respectively. Several physical and biological variables were derived at each station and logistic regressions were used to quantify right whale habitat associations. Preliminary results suggest an association between right whale presence and aggregations of late-stage *C. finmarchicus* and *C. hyperboreus* near the bottom. The *Calanus* abundances derived from both net and OPC data are substantially lower than those observed in other feeding habitats. Additional analyses are underway to determine if variability in energy content or alternative feeding mechanisms could help compensate for this reduced *Calanus* abundance. The results will offer insights into the quality of the GSL as a right whale foraging habitat and the associated implications for right whale recovery.

Validation and Variability: Modelling the Diverse Aquaculture Environment

Hart Koepke[1] Jon Grant[1] Ramon Filgueira[1]

[1]Oceanography Department, Dalhousie University, Halifax, NS, Canada, B3H 4R2

Speaker may be reached at hart.koepke@dal.ca

Predictive modelling of aquaculture-origin biodeposit fluxes into the benthic environment, and subsequent changes to sediment and porewater biogeochemistry, is instrumental in defining ecosystem assimilative capacity. By characterizing system renewal, assimilative capacity can be used to achieve greater sustainability by helping determine suitable location, stocking density, and fallowing periods. During operational monitoring in Nova Scotia, porewater sulfide concentrations are measured as a proxy for benthic health, however existing organic matter depositional models have yet to incorporate sulfide concentration outputs. Furthermore, while the Canadian government does require site modelling prior to new site development and expansion, active lease sites can go years without any further modelling occurring, potentially compounding errors as time progresses. Since 2004, active lease sites in Nova Scotia have been subjected to a consistent benthic monitoring program, providing extensive data for predictive model validation. However, spatiotemporal variability of geochemistry between sites of the same bay and within individual sites can be quite vast, raising questions on the requirements necessary to constrain the model to new sites. Once these questions are addressed, this research aims to aid in development of an aquaculture modelling software through production of a sulfide-focused benthic biogeochemical module, utilized as part of an ongoing farm management routine.

Fishing-vessel risk to North Atlantic right whales in the Gulf of St. Lawrence

Meg Carr[1] Angelia Vanderlaan[2] Chris Taggart[1]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]Bedford Institute of Oceanography, Dartmouth, NS, Canada, B2Y 4A2

Speaker may be reached at m.k.carr28@gmail.com

Vessel strikes are one of the leading identified sources of mortality for North Atlantic right whales (*Eubalaena glacialis*; right whales) throughout their range. Since 2017, twenty-nine right whales have been observed dead in the Gulf of St. Lawrence (GSL), an area with active shipping and fishing industries. Many necropsied individuals presented with trauma consistent with vessel strike.

Vessel-strike risk derived from large (>20 m) vessels in the GSL has been quantified (Carr et al., in prep.) however, no studies have investigated vessel-strike risk derived from smaller platforms in the GSL, such as fishing vessels. A recent study found that smaller vessels such as 45-foot long, 45 tonne Cape Islander lobstering vessels are capable of causing lethal injury to right whales using a biophysical model (Kelley et. al 2020). This study aims to fill the small-vessel risk knowledge gap by quantifying vessel-strike risk from the 2017 snow crab fishing fleet using Vessel Monitoring System (VMS) data in concert with visual right whale detections. Lethality will be estimated for standard-dimension GSL snow crab vessels using the Kelley 4-layer model and *whalestrike* R package. Risk will be mapped to identify hotspots that may be the focus of future management schemes. Risk under normal operating conditions will be compared to risk during right-whale-triggered fishery closures.

Drivers of regional-scale variability in the abundance of an invasive bryozoan in the kelp beds of the northwest Atlantic Ocean

Conrad Pratt[1] Anna Metaxas[1] Danielle Denley[2]

[1]Department of Oceanography, Dalhousie University, Halifax, NS, Canada, B3H 4R2
[2]School of Resource and Environmental Management, Simon Fraser University, Burnaby, B.C. Canada V5A 1S6

Speaker may be reached at c.pratt@dal.ca

Non-indigenous species are one of the main threats to biodiversity in the worlds oceans, and their impacts are intensifying due to climate change. Membranipora membranacea, an invasive epiphytic bryozoan, has been causing damage to ecologically important kelp beds in the northwest Atlantic since its introduction in the 1980s. Although past studies have found temperature to be the main determinant of the abundance of M. membranacea, wave exposure and kelp substrate characteristics (species, abundance and community composition) may also play significant roles. Most previous research has been conducted at a small number of sites within a limited geographic range, and no study has investigated the relative impacts of these variables on bryozoan abundance. With a large compiled dataset, we used a multi-model inference framework based on generalized linear mixed models to investigate the relative impacts of temperature, wave exposure and kelp bed characteristics on regional patterns in the abundance of M. membranacea in the northwest Atlantic. Temperature was found to be the most important variable controlling the abundance of the bryozoan, but wave exposure and kelp substrate species also have an effect. This knowledge will facilitate the construction of species distribution models which can inform marine spatial planning for kelp conservation.