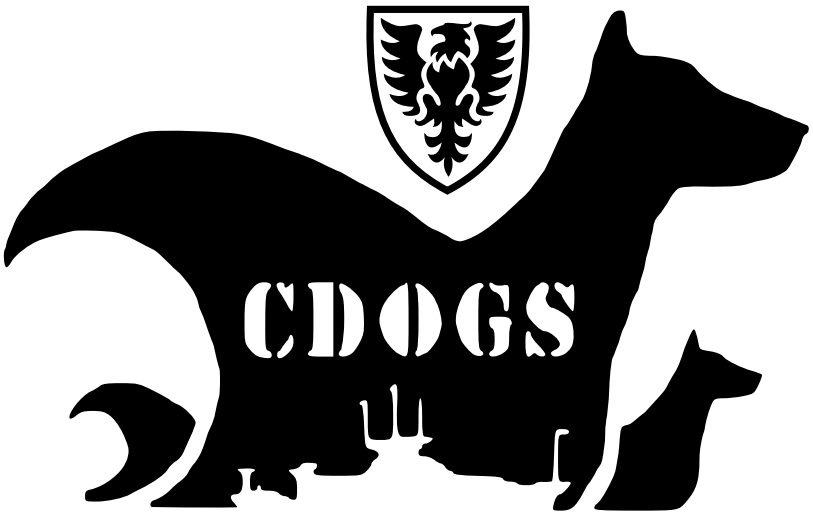

C-DOGS 2017

Conference of Dalhousie Oceanography Graduate Students

Friday March 24, 2017
9:00 - 17:30, University Hall
Dalhousie University, Halifax, Nova Scotia

Contents

10:30: ***Coffee Break***

12:35: ***Lunch and Undergraduate Poster Session***

Risky business: plankton movement and encounter rates

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Encounters represent the initial step in the process of zooplankton feeding, which influences growth of the predator and mortality of prey. Movement of zooplankton facilitates encounters. In a uniform environment, straight-lined swimming paths (i.e. ballistic movement) maximize the probability of encountering both food and predators. Convoluted paths (i.e. diffusive movement) are less "risky" from a predation perspective, but result in a lower probability of finding food. Ballistic and diffusive movement are extremes on a continuum of "directional persistence", defined as the tendency to travel in the same direction between successive points in time. I developed an individual-based model, in which a motionless predator "feeds" in a field of moving prey, to explore the consequences of violations to the assumptions of only ballistic or only diffusive movement used in classic encounter rate models. I defined an encounter as the occurrence of a prey item within a radial "detection distance" of the predator. I parameterized directional persistence of prey movement as a probability of maintaining direction of travel. I used this probability to calculate a "persistence length", defined as the mean distance travelled by prey between reorientations in random directions. Encounters were used to derive a "maximum clearance rate", which represents the rate the predator scans water for prey. I used data from my model to make methodological recommendations for future predictions of the maximum clearance rate (and encounter rates) over the transition from diffusive to ballistic movement of zooplankton. My study provides the only description of variability in the maximum clearance rate over a range of length scales of the directional persistence of prey and detection distance of predators that are relevant to zooplankton, and emphasizes the utility and limitations of classic encounter rate models.

How Salty Was It? Investigation of a Biomarker Proxy for Paleo-Salinity

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Reconstruction of past ocean dynamics has to rely on biological and geochemical proxies recorded in the sediments. Biomarkers, in particular, are principle components of a paleoceanographer's proxy 'toolkit'. The exact make-up of these organic molecules is a result of a systematic response to environmental conditions during their biosynthesis. Together with other proxies many key oceanographic variables can be reconstructed, which provide insight into past changes in ocean circulation and heat transport, or marine productivity and CO_2 sequestration. Sea surface salinity (SSS) is arguably the least constrained variable of the past ocean. This is unfortunate because salinity is a fundamental variable controlling the density of seawater, thus large-scale ocean circulation, and is also reflective of the global hydrological cycle.

The hydrogen isotopic signature (δD) of seawater is strongly correlated with SSS and there is evidence that the δD of seawater is recorded in non-exchangeable hydrogen of organic matter, in particular of alkenones. The record of δD in alkenones, which are molecules exclusively synthesized by marine haptophyte algae, has therefore been proposed as a proxy for paleo SSS. Indeed, lab culture studies have shown the δD of alkenones to reflect the δD of growth water and a number of paleo studies have already used this novel proxy to infer past changes in SSS. However, a large-scale field study exploring the proxy is lacking. Thus, the focus of this project will be to investigate the relationship between the δD of alkenones and the δD of seawater from surface water alkenone samples in the Atlantic and Western Equatorial Pacific.

Performance Assessment of Wave Breaking Parameterizations over Shallow Waters in Spectral Wave Models

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Depth-induced wave breaking is the most important dissipation mechanism for ocean surface waves in shallow waters. Different parametric schemes were developed for parameterizing depth-induced wave breaking process in ocean surface wave models. In this study, the performance of six commonly-used numerical schemes is assessed by comparing the simulated significant wave heights (SWHs) with observations. The main differences between these six schemes are representations of the breaker index and the fraction of breaking waves. Various types of laboratory and field observations are used in the assessment, including 849 cases from 14 sources of published observational data. We demonstrate that these six schemes have reasonable performances in parameterizing the depth-induced wave breaking in shallow waters, but with their own limitations and drawbacks. The widely-used scheme suggested by Battjes and Janssen (1978, BJ78) generates underpredictions of SWHs in the locally-generated wave conditions and overpredictions in the remotely-generated conditions over flat bottoms. The drawback of the BJ78 scheme was addressed by Salmon et al. (2015, SA15), but the SA15 scheme had relatively larger errors in SWHs than the BJ78 scheme over sloping bottoms. We follow SA15 and propose a new scheme with a similar dependence of the breaker index on the normalized water depth in deep waters as in the SA15 scheme. In shallow waters, the breaker index of the new scheme has a nonlinear dependence on the local bottom slope rather than the linear dependence used in the SA15 scheme. This new scheme shows a significant improvement over sloping bottoms, with the scatter index of 8.3% in comparison with 11.2% for the SA15 scheme. The new scheme also has a superior performance over flat bottoms, with an average scatter index of 6.5%, which is much smaller than the scatter index of 15.3% for the BJ78 scheme.

Stage duration and survivorship as emergent properties: how variation in environmental conditions and mortality influence copepod demographic patterns

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Copepods are essential linkages in marine food webs, with spatiotemporal patterns in their population size and structure influencing their ecological connections. It is therefore highly valuable to understand and predict such patterns. This can be done using models that describe the complex interaction of copepod life history with transport through variable environments. In such biophysical models, copepod realized stage durations and survivorship are derived from characterizations of development and mortality rates. Model sensitivity to these parameterizations is of concern due to the inherent uncertainty associated with both environmental dependencies and the conditions experienced by individuals, as well as difficulties in reliably estimating mortality. Here, we couple an individual-based model (IBM) of copepod population dynamics to particle tracks from a 3D regional circulation model, to investigate the sensitivity of temperature variability on simulated copepod demography. The IBM is calibrated for *Calanus finmarchicus* on the Newfoundland-Labrador shelf, using field data for abundance and defining rates based on empirical relationships. We test the hypothesis that mortality causes realized stage durations to differ from those measured in the laboratory, such that corollary effects on survivorship greatly impact simulated dynamics. Different model scenarios for scales of variability in temperature are considered, and resultant patterns of realized stage durations, survivorships, as well as population size and structures, are examined. Our ongoing work to include variability in mortality and recommendations for future modeling efforts are discussed.

Investigating Photoacclimation of Phytoplankton in the Gulf of Mexico using Observational and Modelling Approaches

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Chlorophyll is a common oceanographic measurement and is often used as a proxy for phytoplankton concentration, and to infer primary production. Phytoplankton is the basis of the oceanic food web and, as such, understanding it's relation to chlorophyll variations is vital to understanding phytoplankton dynamics, and therefore overall biological processes occurring in the ocean. We specifically focus on observations recorded by autonomous profiling biogeochemical floats in the Gulf of Mexico that have shown evidence of a seasonal patterns of chlorophyll content in phytoplankton in the region. The seasonal trend observed here is an example of photoacclimation, which is the adaptive modulation of chlorophyll concentration within a photosynthetic organism based on the availability of sunlight. We employ a one-dimensional numerical model to understand which parameters and processes influence the modulation of the chlorophyll to biomass ratio. The model simulates the structure of phytoplankton, chlorophyll, and nutrient profiles in the water column, and reproduces observed patterns. With the combined in-situ observations and one-dimensional model, several controlling factors for magnitude (ex. maximum growth rate, nutrient half saturation) and structure of growth (light attenuation, diffusion coefficient) are presented, including evidence for seasonally varying drivers of photoacclimation.

Re-examination of the 1929 Grand Banks submarine landslide

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On November 18th, 1929 a large submarine landslide occurred along the St. Pierre Slope of the southwestern Grand Banks of Newfoundland, as a result of a Mw 7.2 earthquake. This submarine landslide led to the first recognition of naturally-occurring submarine turbidity currents and is one of the few landslides known to have generated a tsunami. The event caused 28 causalities in Newfoundland and severe infrastructural damage. Earlier investigations of the area identified widely distributed shallow mass failures (15 - 20 m high escarpments), but no evidence of a larger headscarp. It is difficult to conceive, therefore, how this distributed shallow failure that rapidly evolved into a turbidity current would have generated a tsunami. It is hypothesised in this study that a deeper rooted sediment failure (∼500 m), involving faulting and mass-rotation, was involved in the sediment failure and this displacement generated the tsunami. In order to test this hypothesis, the volume and kinematics of the 1929 slope failure are analysed by means of recently acquired high resolution seismic reflection and multibeam swath bathymetry data, in addition to a significant volume of legacy data. The data allow determination of: 1) the dimension of the failure area, 2) the thickness and volume of failed sediment on St. Pierre Slope, 3) fault patterns and displacements, and 4) styles of sediment failure involved. Shallow (20 m high) sinuous escarpments and a number of faults are observed along the upper St. Pierre Slope (500 - 2 500 m water depth). The uppermost and largest of these escarpments shows association with a fault system. Preliminary results, therefore, indicate a complex sediment failure pattern along the St. Pierre Slope, possibly involving a deep-seated decollement and mobilization of a large volume of surficial sediment through retrogressive failure. Causes for the tsunami are yet to be determined.

Population connectivity in the design of marine protected areas

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Population connectivity, which governs the exchange of individuals among spatially distributed habitats, is important for understanding overall population survival and persistence. Measuring this ecological process incorporates methods from a diverse array of fields, including molecular genetics, biophysical modelling and microchemistry. While these methods provide detailed information on the connectivity of individual species in specific regions, they do not provide general rules of thumb for its application in spatial management planning, of which marine protected areas (MPAs) provide the most widely accepted and utilized tool. Although connectivity is generally acknowledged as an element in MPA design, it is rarely included as an ecological criterion. By collating information on ecological criteria used in MPA designation, I will determine the current inclusion of population connectivity in MPA design. This study aims to bridge the gap between the science and conservation aspects of population connectivity research. Preliminary results from Canadian MPAs suggest that population connectivity is rarely considered. By completing a comparative study along the coast of Nova Scotia using different connectivity measurement methods, I will delineate the most suitable and practical application approach for MPA design practices.

Beam attenuation spectra and flocculation dynamics in an estuary

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Size is a fundamental property of sediments that affects particulate light scattering and vertical flux. The power-law fit exponent (γ) of the spectral particulate beam attenuation is an indicator of the average suspended particle size. In this work we examine the relationship between γ and Sauter mean diameter (D_s) along an estuarine salinity gradient in the Columbia River Estuary. Overall, the γ derived from WET Labs ac-9 is inversely related to D_s calculated from the combined data from a LISST-100 and a floc camera. Focusing on the transition from fresh to medium salinity waters, however, larger D_s are observed in the medium salinity water with higher γ, which is opposite to the expected trend of smaller D_s and higher γ that are caused by disaggregation or sinking. Additionally, from low- to medium-salinity water *bbr* (particulate backscattering ratio) values increase, which indicates that the mineral content increases. Together, we infer that these trends in optical proxies are caused by flocculation. At low-to-medium salinities flocculation transfers mass preferentially from medium size particles to large size particles that are out of the range of the ac-9. Some of the newly flocculated mass is deposited at the same time. This process allows both D_s and γ to increase due to the mass transfer. The *bbr* values rise because the large aggregates formed by combining more organic-rich material are depositing to the seabed. Improved understanding of the relationship between D_s and γ is important to explore particle dynamics in stratified waters.

Simulating deep-water hydrocarbon plumes with a data-assimilative model of the Gulf of Mexico

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The Deepwater Horizon oil spill caused by a drilling rig explosion in 2010 is one of the worst environmental disasters that occurred in the Gulf of Mexico. During the event, an unprecedented quantity of crude oil (4.9 million barrels) was released into the Gulf at an approximate water depth of 1,500 m. The neutrally buoyant fraction of the oil formed deep-water hydrocarbon-enriched plumes at depths between 1,000 and 1,200 m. These deep plumes are estimated to make up 36% of the leaking mixture by mass, and comprise both water-soluble hydrocarbons and suspended trapped oil droplets. While much of the water-soluble hydrocarbons were observed to undergo rapid biodegradation, the fate of the suspended hydrocarbons and their impacts on the deep sea ecology remain uncertain.

The objective of this study is to simulate and understand the distribution, transport and decay of deep-water hydrocarbon plumes using a data-assimilative physical-hydrocarbon model of the Gulf of Mexico. The simple hydrocarbon model includes tracers for hydrocarbon (hydroC) and dissolved oxygen, and prescribes the net effects of hydroC respiration in the water column by an exponential decay process that consumes oxygen. A multivariate sequential data assimilation method, the Deterministic Ensemble Kalman Filter (DEnKF), is utilized to assimilate satellite data (SSH and SST) and profile data (temperature, salinity and oxygen) into the model in order to improve the model state estimation and constrain the decay rate. In the presentation I will show initial results of model simulations and data assimilation twin experiments demonstrating the impact of assimilating surface information alone versus assimilating surface and profiling data on model's fields.

Spatial Distribution of Nitrate Isotopes in the Western Equatorial Pacific: Sources and N Transformations of Subsurface Nitrate

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The western equatorial Pacific (WEP) is a "water mass crossroad", where subsurface/intermediate waters from both hemispheres impinge on the margins. For instance, Subantarctic Mode and Antarctic Intermediate Waters and Subtropical Mode Water are advected to the WEP, not only providing a conduit of southern hemisphere-derived subsurface waters to the equatorial Pacific but the latter also feeding into the eastward flowing EUC. North of the equator, the westward flowing North Equatorial Current advects nutrients to the WEP and contributes substantially to the Indonesian Throughflow. Here we will present water column profiles collected during the RV SONNE 228 expedition of $\delta^{15}N$ and $\delta^{18}O$ of nitrate from the SE tip of the Philippines, off Mindanao, and north of Papua New Guinea (PNG). Differences in the nitrate isotopic composition off PNG and off Mindanao imply different sub-thermocline water masses in the northern and southern WEP, respectively, consistent with the general circulation patterns described above. Subsurface values show isotopically light nitrate associated with North Pacific Tropical Water east of the Philippines. South of the equator off of PNG, however, we find nitrate enriched in 15N and 18O within the same depth range. Water column data presented here will be discussed in terms of N transformation processes and isotope variability of the WEP.

Diagnosing the dynamics of the barotropic transport in the North Atlantic Ocean with a high-resolution circulation model

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The main objective of this study is to examine the main physical processes affecting the Gulf Stream and its extensions over the North Atlantic Ocean, based on the model results produced by the VIKING20, which is a high-resolution coupled ocean-ice model covering the North Atlantic with a horizontal resolution of 1/20°. The VIKING20 captures reasonably well the Gulf Stream, North Atlantic Current (NAC) and their associated recirculation gyres without data assimilation. To obtain the barotropic transport associated with different dynamics, we calculate annual means in period 1960-2009 of the three vertically integrated forcing terms in the horizontal momentum equations: eddy momentum fluxes, mean-flow advections, and the potential energy (as known as the Joint Effect of Baroclinicity And Relief in the vorticity equation). We then run a linear shallow water equation model with a horizontal resolution of 1/20°driven by only one of four forcing terms (three vertically integrated terms and sea surface wind stresses) in each run until the model reaches an equilibrium state. The results indicate that the potential energy term is the primary forcing in driving the barotropic transport in the North Atlantic Ocean. The eddy momentum fluxes and mean-flow advections also play important roles in the Gulf Stream and NAC regions. Wind stresses play a minor role in general, but are the primary forcing in driving the barotropic transport in the region of the Mid-Atlantic Ridge south of the Gibbs Fracture Zone.

AUV Localization in an Underwater Acoustic Positioning System

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This presentation develops a linearized Bayesian inversion algorithm for localizing an autonomous underwater vehicle (AUV) on a test range using time difference of arrival (TDOA) acoustic data. The Bayesian approach allows the uncertainty of several factors, including precise receiver locations and bias and lateral variability of the water-column sound-speed profile, to be included in the inversion as unknown parameters with varying levels of prior information. This provides better estimates of these parameters (and hence AUV locations), and includes the effect of their uncertainties in the uncertainty estimates for AUV locations. A modeling study comparing AUV localization uncertainties from the linearized inversion to results from non-linear Monte Carlo analysis shows that linearization errors are small, and hence linearized analysis is used to efficiently map AUV localization uncertainty as a function of position over the test range. These approaches are applied to model localization uncertainty for an AUV test range associated with the Victoria Experimental Network Under the Sea (VENUS) cabled observatory system, examining the factors mentioned above as well as the effects of water-column refraction and receiver geometry.

POSTER: Performance of a low-frequency high-flow acoustic sensing array for turbulent ocean conditions

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Baseline ambient sound level assessment is important in quantifying additional noise contributions from tidal energy infrastructure. Static acoustic sensing in high-flow conditions is complicated by pseudo-sound, or flow noise, generated by pressure fluctuations due to turbulent flow on the surface of a hydrophone. Signal processing methods are used to identify and suppress flow noise at low frequencies on a four-element horizontal hydrophone array with data collected in the Minas Passage in October, 2016. Observations of spectral slope and spatial coherence are used to track the masking effect of turbulence across frequency and flow speed, and identify the critical frequency threshold where flow noise exceeds the ambient noise. The array's performance in the Minas passage is quantified by an empirical relationship between current speed and the critical frequency. Beamforming, and coherent and incoherent averages are proposed as possible flow noise suppression methods and evaluated.

POSTER: Particulate carbon fluxes in the Gulf of Eilat/Aqaba

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Transfer of particulate organic carbon from surface to deep waters, also known as export production, is an integral part of the biological pump, which sequesters carbon in the deep sea. Despite the importance of export production, the precise nature of the relationships among dust input, primary production, and export production in the Gulf of Eilat/Aqaba remains elusive. The Gulf is a silled basin in the northern Red Sea, and it has deep waters located close enough to shore for frequent data collection over long time periods. Because of the Gulf's low latitude and shallow sill, water at depth is relatively warm, so mild cooling of surface water during winter induces vertical mixing. This research project investigates seasonal trends in the Gulf's export production by collecting settling particles in sediment traps at high temporal resolution (36 hours) and several depths and analyzing sample composition in laboratories. Results show that both total inorganic carbon (TIC) and total organic carbon (TOC) fluxes, along with bulk flux and surface chlorophyll a concentrations, expand to much greater ranges in the winter than in the summer. TIC flux is closely correlated to bulk flux, implying that the export of particles to depth may depend on carbonate as ballast. TOC flux reveals a weaker correlation with TIC and bulk fluxes, indicating the potential relevance of variables such as mixed-layer depth, solar radiation, or nitrogen fixation. In addition, bulk and TIC fluxes increase with depth, especially in winter, whereas TOC fluxes are highest near the surface. This trend suggests that winter convection may induce some resuspension of sea-floor sediments from which most of the organic matter has already been remineralized.

POSTER: Modelling shifts in sediment nitrogen cycling under Atlantic salmon, *Salmo salar*, aquaculture cages: impacts on benthic nutrient release and recovery

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High ratios of organic matter to nitrate have been suggested to favor dissimilatory nitrate reduction to ammonium (DNRA) over denitrification as the dominant nitrate reducing pathway in coastal marine sediments. Unlike denitrification, which is a major nitrogen sink and competes with DNRA for nitrate, DNRA can support eutrophication by contributing ammonium to sediments and the overlying water column, thus supporting primary production and potentially ensuing anoxia. Finfish and shellfish aquaculture deposit high amounts of organic matter to sediments in the form of feces or uneaten feed, increasing the ratio of organic matter to nitrate and facilitating DNRA dominance.

In this study, we examine the potential effects of aquaculture on sediment biogeochemistry by (1) assessing changes in nutrient transport and organic matter remineralization as DNRA dominates nitrate reduction pathways and (2) predicting the impact of aquaculture organic matter load on sediment recovery after aquaculture cessation. To achieve this, we used a depth-resolved sediment reaction-transport model that was parameterized and forced using data from an Atlantic salmon, *Salmo salar*, cage culture operation in Loch Creran, Scotland.

As DNRA becomes dominant, dissolved inorganic nitrogen effluxes from sediments can be nearly 4 times that of when denitrification is dominant. Organic matter deposition from aquaculture greatly stimulated anaerobic respiration and depleted oxygen from the overlying water. Dissolved inorganic nitrogen and rODU (inclusive of reduced metal oxides and sulfides) effluxes increased by nearly 100 and 23000 times, respectively, shortly before harvest. DNRA-dominant sediments did not recover as quickly as denitrification-dominant sediments. After sediments were fallowed for ten years, nutrient fluxes were comparable to what was observed prior to aquaculture impact. However, based on sediment chemical profiles, neither DNRA- nor denitrification-dominated sediments were fully recovered. Results from this study can inform policy decisions surrounding aquaculture site fallowing time. This study also supports the use of reaction-transport models to evaluate changes in sedimentary processes resulting from anthropogenic impacts and the importance of incorporating sediment biogeochemistry in aquaculture models.

POSTER: Grazers regulate early succession on coral reefs in the Gulf of Aqaba, Red Sea

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Reef-associated fishes and macroinvertebrates can directly (as predators) or indirectly (as grazers that dislodge or incidentally consume non-algal prey) regulate settlement and recruitment of sessile benthic invertebrates on coral reefs. I examined the effect of large mobile consumers on recruitment and succession of invertebrates using exclusion cages on a suspended artificial reef and an adjacent natural reef in the Gulf of Aqaba, Red Sea. The topsides and undersides of ceramic tiles, which were used as collectors, were photographed *in situ* and relative cover of colonizing taxa was measured using image analysis. I compared rates of colonization between collectors (controls) at monthly intervals over 7 months when the tiles were recovered and biomass measured. The topsides and undersides of collectors facilitated different assemblages, with the former consisting mostly of filamentous algae, detritus and inorganic matter in an algal matrix and the latter providing a sheltered microhabitat for a diversity of benthic invertebrates. Greater algal cover on the topsides of collectors in caged treatments than open controls at IUI suggest that herbivorous fish are important grazers on exposed surfaces of natural reefs. In contrast, algal cover on topsides of collectors did not differ significantly between caged and open treatments at the artificial reef, likely because demersal herbivorous fish (e.g. parrotfish) were rare or absent at the artificial reef, which was suspended 20 m above bottom. Predator exclusion altered species composition (mainly ascidians, bivalves, bryozoans and sponges) on the undersides of the collectors at both sites, indicating that large mobile consumers strongly affect recruitment and early succession of benthic invertebrates in sheltered microhabitats. After 7 months, caged treatments accumulated more biomass than controls at both sites, but the orientation of the tile also influenced biomass with the undersides accumulating more biomass than the topsides. Differences in benthic assemblages between the reef types indicate that the artificial reef community did not converge with that of the natural reef within 30 weeks of colonization. This study underlines the importance of long-term monitoring of benthic community succession, which may differ between reef types, particularly on suspended artificial reefs, which offer unique refuges due to isolation from the sea floor.

POSTER: Exploring the Effect of Salinity on Prymnesiophyte Lipid Composition

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Alkenones are 37-, 38-, and 39-carbon ketones, with two, three, or four double bonds. They are produced exclusively by coccolith-bearing Prymnesiophyte phytoplankton, principally *Emiliania huxleyi* and *Gephyrocapsa oceanica* in the open ocean. The proportion of 37-carbon alkenones with two and three double bonds (di- and tri-unsaturation) is refered to as the UK37' index, and is correlated to the growth temperature of the Prymnesiophyte. Alkenones are conserved in sediments, and as such, UK37' from sediment cores is used to reconstruct past sea surface temperatures (SST).

There currently does not exist a reliable proxy measure for past ocean salinity, however it has been suggested that the percent of 37-carbon alkenones with four double bonds (C37:4%) is affected by salinity. The proportion of 37-carbon and 38-carbon alkenones (K37/K38) is affected by salinity though its potential as a salinity index has not been determined.

This study examines the effect of salinity on the alkenone composition of *Emiliania huxleyi* strains CCMP 1742 (formerly 55a) and CCMP 1516, as well as *Gephyrocapsa oceanica* strain CCMP 2054. CCMP 1742, 1516, and 2054 were cultured at 22C at 28, 32, and 36 psu. CCMP 1742 was also cultured at 16C and 10C, both at 28, 32, and 36 psu. No relationship was found between salinity and UK37', or between salinity and C37:4%. There was however a significant relationship between salinity and K37/K38, though the smallest salinity change detected by K37/K38 was between 28 and 36 psu. This inability to detect small-scale salinity changes limits the usefulness of K37/K38 as a salinity index.

POSTER: Evidence that Roseway Basin may be a unique right whale feeding habitat on the Scotian Shelf

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Sightings of endangered North Atlantic right whales (pop. ∼540) have since 2010 declined in federally protected critical feeding habitats of the Scotian Shelf, such as Roseway Basin. This is likely due to a decline in regional food availability. Where the whales have relocated to is unknown, but their food (*Calanus* spp. copepods) are also present in several deep basins on the Scotian Shelf that lack right whale survey data. Ultra-dense copepod aggregations that right whales seek in Roseway Basin are thought to occur through 4 biophysical mechanisms: high copepod productivity in continental slope water, frontal accumulation, tidal aggregation across sloped bathymetry, and copepod avoidance of the bottom mixed layer (BML). The objective of this study was to determine whether another Shelf basin, Emerald Basin, contains undiscovered right whale habitat. To do this, we compared both right whale presence and the presence of the 4 copepod aggregating mechanisms between Roseway and Emerald Basins. During summer and fall 2015, two ocean gliders equipped with a Conductivity, Temperature, Depth (CTD) sensor and a passive acoustic monitoring (PAM) sensor made 6 transits across both basins to record whale-habitat associations, while fixed PAM platforms persistently measured temporal variation in whale presence. These data revealed key differences between basins that suggest Emerald Basin is not a right whale feeding habitat. First, although right whales were acoustically present in both basins, presence was far lower in Emerald than in Roseway Basin. Second, although slope water was present in Emerald Basin, it occurs at a depth that may make it less effective at aggregating copepods than in Roseway. Third, water masses showed strong tidal variation in Roseway Basin, not evident in Emerald Basin. Finally, Roseway Basin displayed a shallower bottom mixed layer depth than Emerald Basin, which effectively forces copepods to aggregate shallower in the water column, allowing for efficient foraging by diving right whales. These findings imply that other deep Shelf basins, with deeper mixed layers and minimal tidal activity may not contain profitable aggregations of copepods for right whale feeding. Searching for prospective feeding habitats using the prey aggregating mechanisms represented in Roseway Basin may lead to greater success in understanding right whale movement and distribution.

POSTER: Guidelines Governing Size and Spacing in Marine Protected Area (MPA) Network Design

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A marine protected area (MPA) is an area of the ocean designated for the conservation and protection of the natural or cultural resources from human use. If properly designed and effectively managed, MPAs can preserve the ecological integrity and biodiversity of an area, protecting ecosystem functions, species and habitats for future generations. Recently, the Canadian government committed to a goal of protecting 5% of its coastal and marine areas by 2017 and 10% by 2020. To reach these goals, the Department of Fisheries and Oceans is currently in the process of designing and implementing a network of MPAs in the Maritimes Region. To achieve the ecological objectives of the network, the design process needs to consider basic principles, such as population connectivity, which requires an understanding of species life-histories (i.e. the movement of adults and the dispersal of larval life-stages). General guidelines in the literature suggest a minimum and maximum size of each MPA and spacing between MPAs to apply broadly to allow for connectivity. However, these guidelines have not been ground-truthed in many areas and the decision process is lacking biological information. A literature review was conducted to collect information on the distribution, movement patterns and oceanographic processes for a subset of the species targeted for protection by DFO-Maritimes. The objective was to identify the population parameters that are pertinent for sizing and spacing individual MPAs. The population parameters that factor into sizing and spacing rules of individual MPAs will differ depending on the species to protect. The result of this process was a decision tree that considers processes such as larval dispersal, juvenile and adult movement to assist with the definition of size and spacing of individual MPAs in a network. Decision makers can follow the tree to help determine the general size and spacing between areas that will help ensure population connectivity is incorporated in the network design.

POSTER: Sillikers: A New Standard for Grain Size Measurements?

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"In a core of fine sediment, the last thing that happened to it of dynamical significance was that it was deposited." (Dyer 1986).

The grain size distribution of sediments has long been used to learn about the environmental conditions under which sediment particles are deposited. In the ocean, grain size distributions of marine sediments are used, for example, to track changes in the intensity of western boundary currents or focusing processes. Despite the long use of grain size measurements, a universal sediment standard for grain size measurements does not exist. This project investigates >200 individual analyses of a glacial mud that has been used as an "internal" grain-size standard at Dalhousie over the past 11 years. The material is referred to as Sillikers, and has been analysed on a Beckman-Coulter Multisizer (models II and III) by multiple operators (n=9). The immediate goal of this study is to 1) search for trends, if any, between operators and sample pre-treatment methods. The long-term goal is to explore the feasibility of Sillikers as a universal standard that can be shared with other laboratories. The collection of existing data shows relatively low standard deviations between different operators at Dalhousie ($\sim$0.79 μm) and between samples that have undergone the same pre-treatment ($\sim$1.01 μm). New Sillikers samples were also analyzed in this study to specifically test the effects of centrifugation, evaporation on hot plates, and evaporation in a convection oven . Thus far, no significant differences can be seen between untreated and centrifuged samples and the same appears to be true for the few samples treated on hot-plate evaporated so far.

Going with the flow: Space-time variation of euphausiid biomass in relation to water masses and bathymetry in Roseway Basin

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Dense patches of euphausiid krill are an important food source for several species of baleen whale that occur over the Scotian Shelf, yet little is known about how euphausiid distributions form feeding habitat for whales in this region. In this talk, I will present results from a two-month ocean glider survey in Roseway Basin that allowed me to investigate whether space-time variation in euphausiid biomass can be explained by changes in water mass properties and bathymetry. Between the two survey months, water masses in the basin became markedly cooler and fresher, while average euphausiid biomass concentrations decreased by nearly half. Patches of elevated euphausiid biomass also experienced changes in spatial distribution between months, shifting from the center of the basin to the southeast basin margin. Pairwise comparisons revealed associations between descriptive metrics of euphausiid biomass and both bathymetry and salinity, with these associations varying between survey months. To further investigate these associations, I will use Generalized Linear Models (GLMs) to examine relationships between variation in euphausiid biomass and the combined effects of oceanographic variation that were observed during the survey. The initial results suggest that advection from dominant currents and interactions of advected water masses with the seafloor both play a role in structuring euphausiid biomass concentrations and spatial distributions at subseasonal time-scales in Roseway Basin. By studying the interactions between euphausiids and their physical environment at the scale of a foraging whale, this work aims to support ongoing conservation efforts to identify where baleen whale feeding habitat forms over the Scotian Shelf.

Treacherous journey from river to sea: Elucidating the decline of North American Atlantic salmon with a time-dependent matrix model

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North American Atlantic salmon populations have experienced a significant decline since the 1990s, especially the elder life stages. Emerging evidence attributes the decline largely to poor marine survival. Since the marine phase of salmon's life cycle lasts several years and spans a large geographical range, it remains unclear at which specific life stage the most significant decline occurs. In order to address this question, we developed a new method to assess the status and fluctuation of North American Atlantic salmon population. By applying an optimization algorithm to fit an age- and stage-structured matrix model to available observations for the period of 1972 to 2011 we estimate stage-specific mortality rates over time. The model is able to closely replicate the observations and provides insights into the temporal variation of one-sea-winter (1SW) and two-sea-winter (2SW) salmon returns. Results suggest that changes in the relative proportion of the 1SW and 2SW returns resulted from a decrease of survival during the second year at sea. By combining model outputs, and homewater and distant fishery catch data, we quantified the relative influence of bottom-up (i.e. environmental changes) and top-down effects (i.e. fishing pressure). In addition to the importance of external environmental change impacting North American Atlantic salmon population dynamics, we show that the moratorium on commercial fishing is likely insufficient for Atlantic salmon recovery to previous abundance levels unless mitigation of environmental impacts occurs as well. However, the moratorium is crucial, at least in the short term, to maintain the relatively low yet stable abundance of Atlantic salmon.

New house, new rules: variation in life-history strategies can enhance invasion success of introduced species

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Incidences of marine invasions are increasing world-wide with significant ecological and economic consequences. *Membranipora membranacea* is an ecologically significant invasive bryozoan in the northwest Atlantic, where it is responsible for a dramatic decline in regional kelp bed ecosystems. There is evidence from native populations that larvae of *M. membranacea* settle preferentially within kelp beds, and may selectively settle on specific kelp species. In its invaded habitat in Nova Scotia, settlers of *M. membranacea* are most abundant on some but not all species of kelp. Preference for settling on kelp substrates may have consequences for the persistence of *M. membranacea* in the northwest Atlantic, given its propensity to negatively impact its host kelp. However, whether the increased abundance of *M. membranacea* on select kelp species is the result of larval settlement preference remains unknown. In this talk, I describe the use of field sampling and manipulative field and laboratory experiments to examine selective settlement by larvae of *M. membranacea* in response to different kelp species in its introduced range. Settlement behaviour of invasive populations differed from those of native populations, likely contributing to the initial invasion success and persistence of *M. membranacea* in the northwest Atlantic. These results emphasize the importance of early life-history stages in contributing to invasion success, and provide an example of how critical life-history strategies can vary for non-indigenous species outside of their native environments.

Assessing the Performance of Formulations for Nonlinear Feedback of Surface Gravity Waves on Ocean Currents over Coastal Waters

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This study presents applications of a two-way coupled wave-circulation modelling system over coastal waters, with a special emphasis of performance assessments of two commonly-used methods for nonlinear feedback of ocean surface gravity waves on three-dimensional (3D) ocean currents. These two methods are a vortex force (VF) formulation suggested by Bennis et al. (2011) and a latest version of radiation stress (RS) formulation suggested by Mellor (2015). The coupled modelling system is first applied to two idealized test cases of surf-zone scales. Model results in the two test cases demonstrate that the VF-based coupled system produces a more reasonable vertical structure for the cross-shore currents with strong offshore-directed flow near the bottom than the RS-based model. The coupled system is then applied to Lunenburg Bay (LB) of Nova Scotia during Hurricane Juan (2003). The coupled system using both the VF and RS formulations generates much stronger and more realistic 3D circulation in the Bay during Hurricane Juan than the circulation-only model, demonstrating the importance of surface wave forces to the 3D ocean circulation over coastal waters. Furthermore, in comparison with the RS formulation, the VF formulation performs better in simulating currents at two observation sites in LB, and produces a more coherent spatial structure of coastal currents with complex topography. Our results also demonstrate that the VF formulation is a relatively better approach for applications over the surf zone or complex topography where wave nonlinear effects are important.

Protecting marine life from pile driving sound using linear and additive mixed models to better describe the noise footprint

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In the summer and fall of 2015 five offshore wind turbines were installed at the Block Island Wind Farm. Regulatory permits required in-situ verification of the pre-construction estimates of the range at which the sound levels fell below the thresholds believed to cause harm to marine life. Short term and long term monitoring of the sound levels were performed. The long-term program measured the sound levels at four distances from a total of 24 piles at four different wind turbine foundations. Previous analysis applied linear models to the measurements from the each of the 24 piling events individually and found a high degree of variability in the predicted sound levels. This analysis extended the previous work by applying linear and additive mixed models to the complete data set. We found that the sound levels have a directional component due to the inclination of the piles and that the sound levels depend on the strike energy.

An Indirect Estimate of Anthropogenic Carbon in the Labrador Sea

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Since the industrial revolution concentrations of greenhouse gases, in particular CO_2, have been dramatically increasing in atmosphere. Nevertheless only about 30% of the carbon emitted by anthropogenic activities (C_{ant}) is currently in the atmosphere due to the uptake by both oceans and lands. Because of the central role that oceans play in the carbon budget, it is fundamental to quantify this storage and understand how this excess of CO_2 is affecting the carbonate system. In this regard high latitude regions of the ocean represent a fast connection between air-sea interface and ocean interia due to deep convection of water. This vertical displacement of water acts as the main process through which gases like CO_2, both natural and anthropogenic, are sequestered and stored in deep waters. Among these areas the Labrador Sea has been identified as one of the major sink of anthropogenic carbon making of critical importance the monitoring of this basin over time. The aim of this study is to indirectly estimate the column inventory of C_{ant} by applying the Transit Time Ditributions (TTDs) method with several transient tracers, like CFC-113, CFC-12 and SF_6. In order to understand how the strength of winter wind-driven convection affects the inventory of C_{ant} we will compare the column inventory with the maximum mixed layer depth from each year (from 1992 to 2016) and we will investigate the decadal variability of this process.

Autotrophic and heterotrophic N_2 fixation in the Gulf of Aqaba, Israel: a modeling approach

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N_2 fixation is thought to be an important contributor to primary production and a source of new nitrogen in the oligotrophic Gulf of Aqaba (Red Sea), but direct measurements of this process are scarce. By combining multi-year time series observations with a biogeochemical model and recent direct measurements of N_2 fixation, we aim to quantify the importance of N_2 fixation in this system. We implemented a 1-dimensional physical model coupled with 4 biogeochemical model versions that treat N_2 fixation differently. The models are optimized using a genetic algorithm to replicate monthly profiles of NO_3, NH_4, PO_4, O_2, and chlorophyll concentrations at a 700 m deep-water monitoring station. We show that a model without diazotrophs can replicate well surface chlorophyll and the vertical distribution of O_2, but fails to simulate the inorganic nutrient ratios. Inclusion of autotrophic diazotrophs, either as a generic group or as separated unicellular and colonial cyanobacterial groups, improves the simulated surface nutrient ratios; however, the vertical structure of O_2 and nutrient ratios is better replicated when an additional heterotrophic diazotroph group is included. The heterotrophic diazotrophs fix N_2 in photic and aphotic waters, consuming an excess intermediate and deep PO_4. Our results agree with recent genetic and rate studies and are consistent with the correlation between bacterial productivity and N_2 fixation rates reported in the region. This suggests that heterotrophic N_2 fixation contributes to the surface-water excess PO_4 and deep-water excess NO_3 observed at this location.

Habitat Mapping of the American Lobster (*Homarus americanus*)

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Bay-scale habitat maps for benthic organisms, especially those of economically important species, are important for the comprehensive development of Marine Spatial Planning (MSP) initiatives. However, few such maps of that scale exist for the American lobster (*Homarus americanus*) in Canada's Maritime provinces. Salmon aquaculture, like several other coastal activities considered by MSP, occurs at scales of less than 1 km but has limited informed spatial placement options due to the potential conflicts with the broadly binned or patchy lobster habitat data available. Therefore, the objective of my research is to develop a standard method of bay-scale lobster habitat mapping specifically for the purposes of adding scientific GIS layers to the MSP process of finfish aquaculture lease placement. Two bays in Nova Scotia and New Brunswick have been surveyed and mapped using acoustic data (backscatter from a single-beam echosounding system), ground-truth video, and various forms of lobster presence data. The acoustic data have been split into substrate category bins and interpolated between tracks, then compared to the ground-truth video to create error matrices and provide estimates of accuracy. The accuracy of the maps created through these differing procedures has been evaluated and the early results of this work will discussed.

Simultaneous DIC and δ13C-DIC measurements by coupling Apollo Scitech AS-D1 DIC analyzer and Picarro G2201-i system

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The concentration of dissolved inorganic carbon (DIC) and its carbon isotope composition (δ13C-DIC) are important parameters for investigating the origin, movements, and flux of carbon in the coastal regions and open ocean. Whilst high-frequency measurements of DIC concentration have been achieved through various methods, the conventional methods for determining of δ13C-DIC are based on Isotope Ratio Mass Spectrometry (IRMS). IRMS system provides high precision, however, it requires time-consuming and labor-intensive collection, storage and pre-processing of discrete water samples and make the paired high-frequency DIC and δ13C-DIC measurements impossible. The objective of this project is to develop a high frequency, simultaneous DIC and δ13C-DIC measurement system by coupling a Cavity Ring Down Spectroscopy (CRDS) and an Apollo Scitech AS-D1 DIC analyzer. The precision and accuracy of this new measurement system are expected to be comparable to the conventional methods, and its small size and short measuring time will allow onboard high-frequency measurement. I will present the principle of the system, process of developing and optimizing the system and discuss intentions for further

Underwater Glider Measurements and Simulations of Storm-Induced Abrupt Upper Ocean Mixing

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As part of the Ocean Tracking Network (OTN), a glider captured the ocean temperature and salinity responses to fast-moving hurricane Arthur (2014), as the storm moved across the Northwest Atlantic and made landfall in New Brunswick. The high-resolution glider data provides a unique opportunity to investigate the ocean processes, for example current shear and wave-induced turbulence, under hurricane forcing. We used the General Ocean Turbulence Model (GOTM) to make one-dimensional analyses of these physical processes. Based on the GOTM k-epsilon equations, which incorporate the effects of wave breaking, the Coriolis-Stokes force (CSF) and Langmuir turbulence, represented as Stokes shear in the Turbulent Kinetic Energy (TKE). Simulations of temperature and salinity with GOTM are compared with glider observations. We found that wave breaking and Langmuir turbulence play an essential role in GOTM simulations. In particular, Langmuir turbulence dominates the surface wave impacts in the upper ocean cooling and the upper thermocline water warming in the developing-stage of the storm. Without inclusion of the Langmuir turbulence, the sea surface temperature (SST) cooling is underestimated by 0.7°C; temperature is overestimated by an average of 0.5°C in the upper 25 meters; whereas it is underestimated by an average of 0.7°C in depths from 25 to 40 meters. The surface wave breaking is parameterized as a source of TKE flux at the surface and a body force. It is shown that the body force scheme is more effective than the TKE flux, which has limited effect in the upper ocean. The simulation results also indicate that the CSF effect might be relatively negligible in severe hurricanes, since it takes more time to affect the underwater currents. This study provides a rare opportunity to investigate the processes occurring in the ocean response to fast-moving storms, particularly the role of surface waves.

A 'Nitrification Cascade' in Bedford Basin revealed by Speciation and Isotopic Composition of Inorganic Nitrogen

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Factors influencing the distribution and isotopic composition of nitrogen (N) compounds in aquatic environments are highly variable in both space and time. Yet, few studies have been able to resolve temporal variations beyond seasonal changes. High-frequency time series measurements can be used to observe N concentrations and isotope ratios in "natural experiments" influenced by changing physico-chemical parameters. Here we present a weekly-resolved three-year time series of inorganic N species ($NO3^-, NO2^-, NH4^+$) and their isotopic composition in the bottom water of the highly eutrophic, poorly ventilated Bedford Basin (Halifax, Nova Scotia, Canada). N isotope ratios and concentrations revealed pronounced nitrification in the bottom water of Bedford Basin: ammonium and nitrite oxidation resulted in the accumulation of nitrate and transient nitrite peaks. Significant inter-annual variations in N cycling were observed. The bottom water N pool was renewed periodically, by either vertical mixing or shelf-water intrusions. During long lags between these irregular renewal events the bottom water reached hypoxia, allowing us to study ammonium and nitrite oxidation along a temporal oxygen gradient. Using 16S rRNA analysis and qPCR assays for archaeal ammonium oxidizers, we were able to link microbial community composition and N transformations. Supporting oceanographic data collected in the framework of the Bedford Basin time series provided clues on factors regulating nitrifying activity in a coastal basin underlying strong anthropogenic impact.

Tilt, Tides, and Turbulence: Real-Life Struggles of an Ocean Modeller

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The alongshore tilt of mean dynamic topography (MDT) along the coast can be used to make inferences about both nearshore and regional circulation. The present generation of high-resolution ocean models is providing more accurate predictions of the tilt of MDT along coastal boundaries. This will be demonstrated using a regional-scale configuration of the NEMO ocean model with a grid spacing of 1/36° applied to the Gulf of Maine and Scotian Shelf. The accuracy of the model predictions of tilt will be assessed through comparison with coastal tide gauge observations referenced to the most recent version of the Canadian Gravimetric Geoid model (CGG2013).

There are however regions where the model predictions exhibit a surprisingly strong sensitivity to certain aspects of the numerics. In this presentation we focus on the sensitivity of the mean tilt in shallow, tidally-dominated regions to the model's formulation of the free surface and choice of turbulence parameterization. Reasons for the discrepancies in tilt based on the different formulations will be given and implications for modelling the circulation in this dynamic environment will be discussed.