Bigelow | Laboratory for Ocean Sciences

Research Experience for Undergraduates
The Gulf of Maine and the World Ocean

REU Symposium Program & Abstracts
Wednesday - Thursday, July 29-30, 2020

<u>Wednesday July 29</u>

Bigelow's REU Program 2020

1:00 Opening Comments

1:15 Benjamin Bromberg – Lewis and Clark College, Portland, OR

Building a framework to generate an iPSC line for *Crassostrea virginica*

Benjamin H. Bromberg[1,2], José Antonio Fernández Robledo[2] (1) Lewis & Clark College, Portland, OR, USA (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

1:30 Cameron Carlson – *University of Alaska Anchorage* AK

Simulating hydrocarbon gradients in the water column with mesocosms

Cameron Carlson1,2, Dr. Christoph Aeppli2, Dr. David Fields2
University of Alaska Anchorage1, Bigelow Laboratory for Ocean Sciences

1:45 Hannah Primiano – Drew University Madison NJ

Phytoplankton patterns at the Subantarctic Front in the Southern Indian Ocean

Hannah Primiano[1,2], Dr. William Balch[2] (1) Drew University Madison NJ, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

2:00 Sam McNeely– University of North Carolina Wilmington, Wilmington, NC

Tiny Travelers: Behavioral Response of Copepod (*Calanus finmarchicus*) to Crude Oil Spills

Sam McNeely[1,3], Cameron Carlson[2,3], Maura Niemisto[3], Erin Beirne[3], Abigail Tyrell[3], Christoph Aeppli[3], David Fields[3], (1)University of North Carolina Wilmington, Wilmington, NC, United States, (2) University of Alaska Anchorage, Anchorage, AK, United States, (3) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

2:15 Katherine Squires - Colby College, Waterville, ME

Calibrating Cr as a paleoproxy: The effects of Fe, Mn, and organic C on Cr deposition and accumulation in marine sediments

Squires KR[1,2], Rauschenberg S[1], McManus J[1] Bigelow Laboratory for Ocean Sciences[1], Colby College[2]

2:30 Estelle Baldwin - Colby College, Waterville, ME

Predicting Respiration in Coastal Waters is Complex

Estelle Baldwin[1,2], Dr. Patricia Matrai,1 (1) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States, (2) Colby College, USA

2:45 Turner Johnson– Haverford College, Ardmore, PA

Forecasting Whale Populations in the Northwest Atlantic with Machine Learning and Big Data

Turner Johnson 1,2 , Ben Tupper 2 , Nick Record 2 , (1) Haverford College, Ardmore, PA, United States (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA.

3:00 Molly Spencer – University of Southern Maine, Portland, ME

Day and Night Influences on the Zooplankton community in a Coastal Environment

Molly Spencer[1], Maura Niemisto[2], David M Fields[2], (1) University of Southern Maine, Biological Sciences, Portland, ME, United States, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA

3:15 Annabelle Adams-Beyea– The New School, NY, NY

What are they doing in the ocean crust? Investigating the DNA of candidate phylum OP8 collected from crustal fluid.

Adams-Beyea A[1,2] , Booker A[1] , Brown J[1] , Orcutt BN[1] Bigelow Laboratory for Ocean Sciences, East Boothbay, ME[1] , The New School[2]

Thursday July 30

Bigelow's REU Program 2020

1:00 Opening Comments

1:15 Dylan Halbeisen – Texas A&M University, College Station, TX

The Power of Three: Comparing Upper Ocean Dissolved, Particulate, & Phytoplankton Trace Metal Micronutrient Stoichiometries Within and Between the Atlantic and Pacific.

__Dylan J. Halbeisen__[1], Benjamin S. Twining[2], (1)Texas A&M University, College Station, TX, United States; (2)Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States.

1:30 Ajay Patel– University of Florida. FL

Historical Overview of Known Breeding Seabird Ecology in the Gulf of Maine

Ajay Patel [1] and Doug Rasher [2] [1]University of Florida, [2]Bigelow Laboratory for Ocean Sciences

1:45 Alexis Oetterer – Truman State University, Kirksville, MO

Predator-prey dynamics of *Dinophysis* spp. and *Mesodinium* spp. in Booth Bay region of the Gulf of Maine

Alexis Oetterer[1], Laura Lubelczyk[2], Nicole Poulton[2]
Truman State University, Kirksville, MO, United States[1], Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States[2]

2:00 Allegra Rocha – *University of the Pacific, Stockton, CA*

An Analysis of the Trends of Phytoplankton Fluorescence along the Maine Coast

Allegra Y Rocha[1], Abigail S Tyrell[2] and David M Fields[2], (1) University of the Pacific, Stockton, CA, United States (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States.

2:15 Jess Liu, Vassar College, Poughkeepsie, NY

The Hunt for Carnivorous Algae and Solar-Powered Sea Creatures:
Creating Gene-Based Predictive Trophic Models for Unicellular Mixotrophic Organisms

Jess Liu[1], Tre'Andice Williams[2], and John Burns[3], (1) Vassar College, United States, (2) Truman State University, United States, (3) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States

2:30 Emily Cunningham – *Colby College, Environmental Science, Waterville, ME.*

Global Trends in the Biogeography of Coral Recruitment

Emily Cunningham[1], Nichole Price[2], Pete Edmunds[3] (1) Colby College, Environmental Science, Waterville, ME, United States, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States, (3) California State University, Northridge, Los Angeles, CA, United States

2:45 Taylor Rouse – I*owa State University, Environmental Science, Ames, IA*

Evaluating the Performance of Standard Ocean Color Algorithms for Carbon in the Gulf of Maine

Taylor Rouse[1], Catherine Mitchell[2], (1) Iowa State University, Environmental Science, Ames, Iowa, United States, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States

3:00 Elizabeth Westbrook – University of Maryland MD

Predicting the Dissolved Organic Matter-Water Partitioning for Short-Chain Chlorinated Paraffins

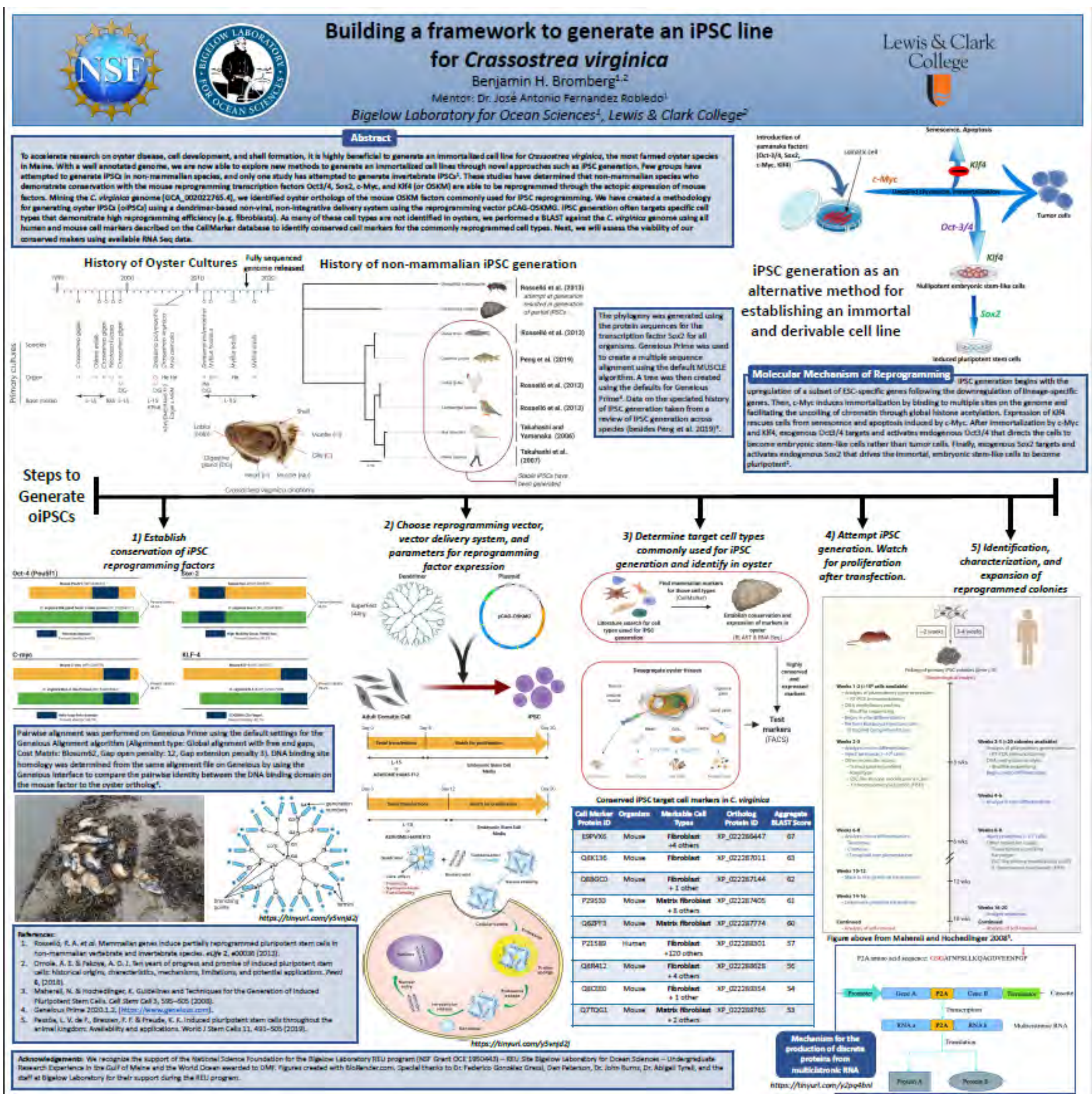
Elizabeth Westbrook[1], Christoph Aeppli[2], Brian DiMento[2]; (1) University of Maryland, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States

Abstracts and Posters

Building a framework to generate an iPSC line for *Crassostrea virginica*

Benjamin H. Bromberg[1,2], *José Antonio Fernández Robledo*[2]*; (1) Lewis & Clark College, Portland, OR, USA (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, USA*

To accelerate research on oyster disease, cell development, and shell formation, it is highly beneficial to generate an immortalized cell line for *Crassostrea virginica*, the most farmed oyster species in Maine. With a well annotated genome, we are now able to explore new methods to generate an immortalized cell lines through novel approaches such as iPSC generation. Few groups have attempted to generate iPSCs in non-mammalian species, and only one study has attempted to generate invertebrate iPSCs[1]. These studies have determined that non-mammalian species who demonstrate conservation with the mouse reprogramming transcription factors Oct3/4, Sox2, c-Myc, and Klf4 (or OSKM) are able to be reprogrammed through the ectopic expression of mouse factors. Mining the *C. virginica* genome (GCA_002022765.4), we identified oyster orthologs of the mouse OSKM factors commonly used for iPSC reprogramming. We have created a methodology for generating oyster iPSCs (oiPSCs) using a dendrimer-based non-viral, non-integrative delivery system using the reprogramming vector pCAG-OSKMG. iPSC generation often targets specific cell types that demonstrate high reprogramming efficiency (e.g. fibroblasts). As many of these cell types are not identified in oysters, we performed a BLAST against the *C. virginica* genome using all human and mouse cell markers described on the CellMarker database to identify conserved cell markers for the commonly reprogrammed cell types. Next, we will assess the viability of our conserved makers using available RNA Seq data.



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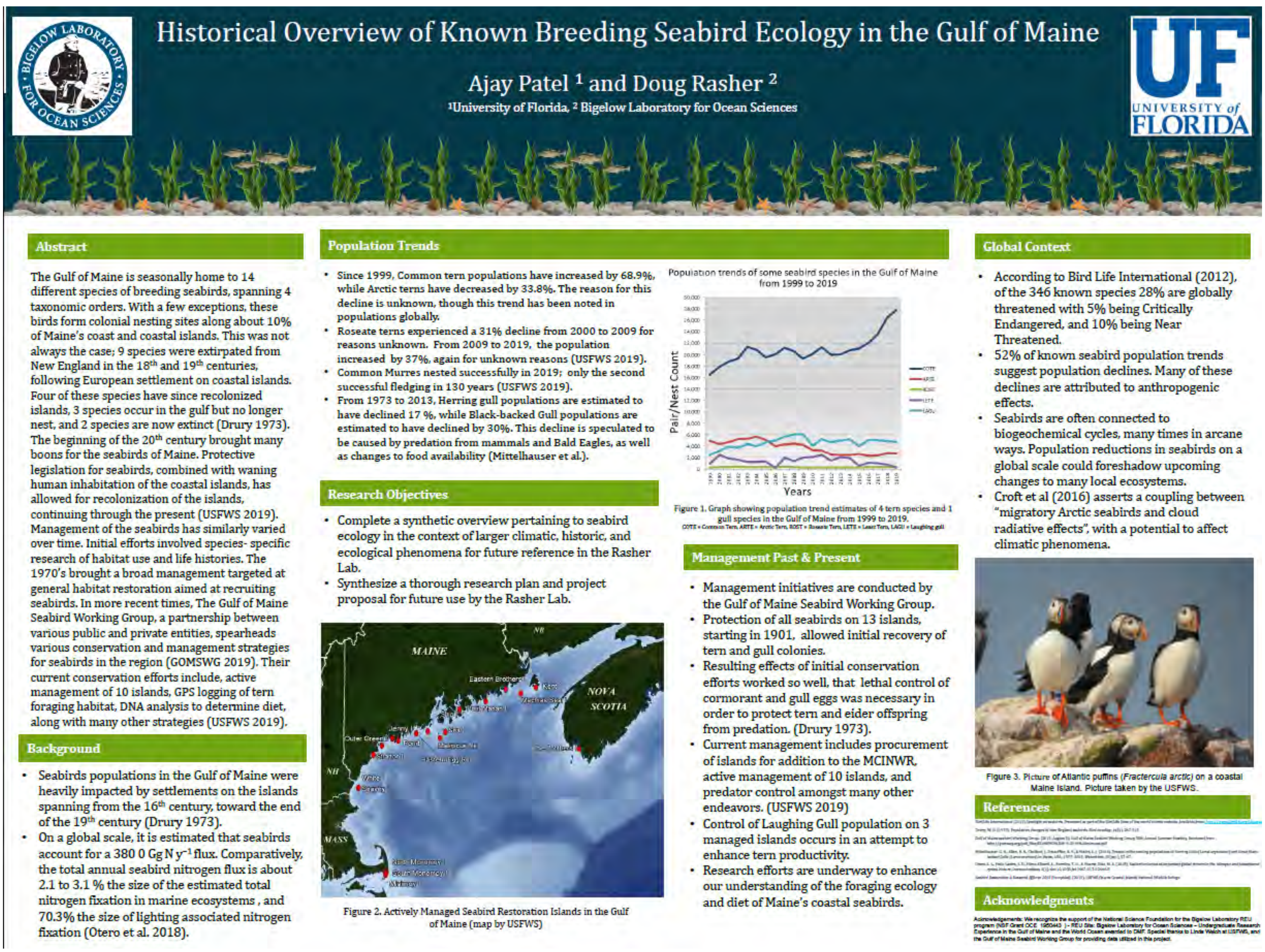
Historical Overview of Known Breeding Seabird Ecology in the Gulf of Maine

***Ajay Patel*[1]** *and Doug Rasher* [2]*;* [1]*University of Florida,* [2]*Bigelow Laboratory for Ocean Sciences*

The Gulf of Maine is seasonally home to 14 different species of breeding seabirds, spanning 4 taxonomic orders. With a few exceptions, these birds form colonial nesting sites along about 10% of Maine's coast and coastal islands. This was not always the case; 9 species were extirpated from New England in the 18th and 19th centuries, following European settlement on coastal islands. Four of these species have since recolonized islands, 3 species occur in the gulf but no longer nest, and 2 species are now extinct (Drury 1973). The beginning of the 20th century brought many boons for the seabirds of Maine. Protective legislation for seabirds, combined with waning human inhabitation of the coastal islands, has allowed for recolonization of the islands, continuing through the present (USFWS 2019). Management of the seabirds has similarly varied over time. Initial efforts involved species- specific research of habitat use and life histories. The 1970's brought a broad management targeted at general habitat restoration aimed at recruiting seabirds. In more recent times, The Gulf of Maine Seabird Working Group, a partnership between various public and private entities, spearheads various conservation and management strategies for seabirds in the region (GOMSWG 2019). Their current conservation efforts include, active management of 10 islands, GPS logging of tern foraging habitat, DNA analysis to determine diet, along with many other strategies (USFWS 2019).



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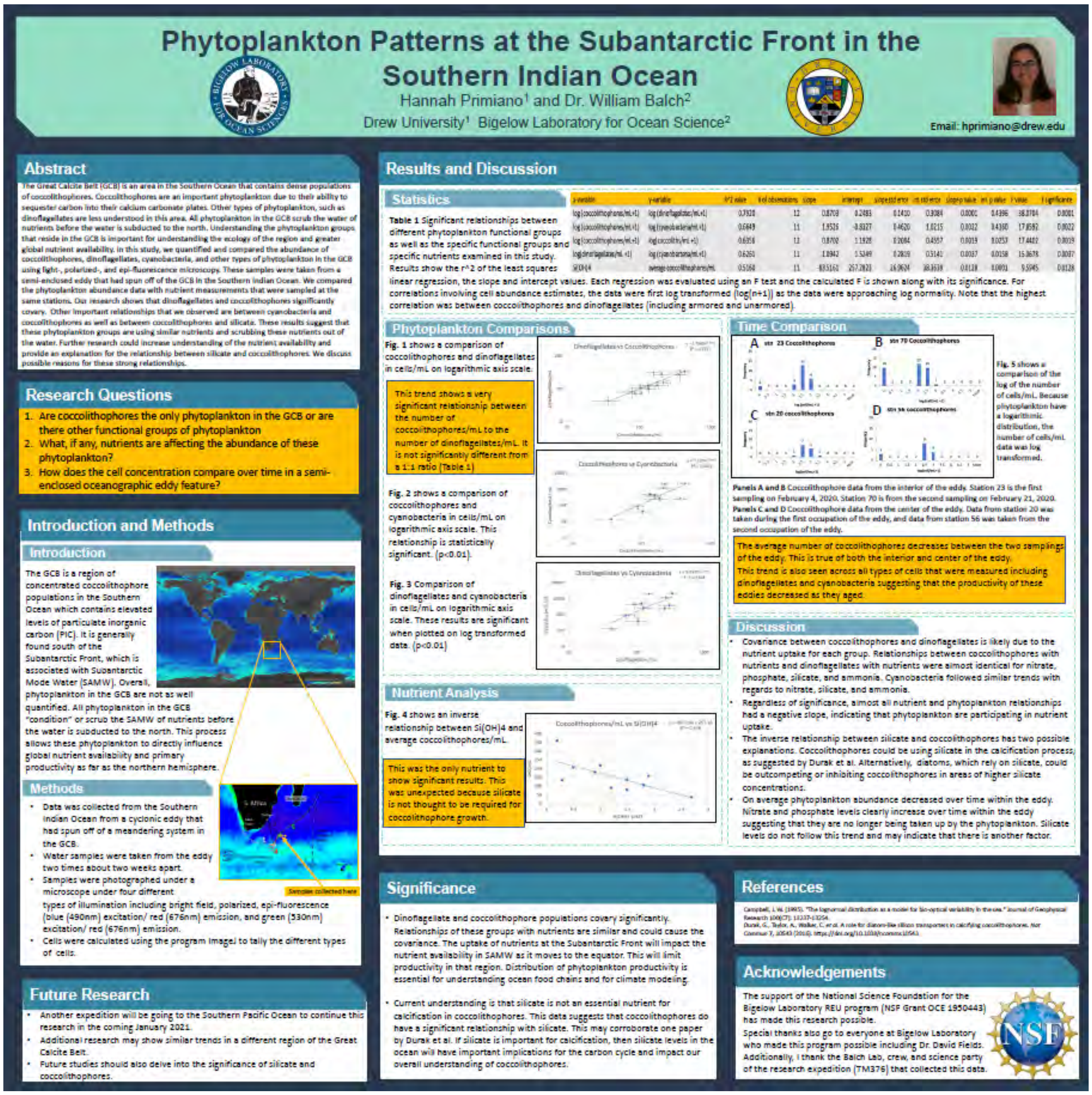
Phytoplankton patterns at the Subantarctic Front in the Southern Indian Ocean

Hannah Primiano,[1,2], *Dr. William Balch*[2]*; (1) Drew University, (2) Bigelow Laboratory for Ocean Sciences*

The Great Calcite Belt (GCB) is an area in the Southern Ocean that contains dense populations of coccolithophores. Coccolithophores are an important phytoplankton due to their ability to sequester carbon into their calcium carbonate plates. Other types of phytoplankton, such as dinoflagellates are less understood in this area. All phytoplankton in the GCB scrub the water of nutrients before the water is subducted to the north. Understanding the phytoplankton groups that reside in the GCB is important for understanding the ecology of the region and greater global nutrient availability. In this study, we quantified and compared the abundance of coccolithophores, dinoflagellates, cyanobacteria, and other types of phytoplankton in the GCB using light-, polarized-, and epi-fluorescence microscopy. These samples were taken from a semi-enclosed eddy that had spun off of the GCB in the Southern Indian Ocean. We compared the phytoplankton abundance data with nutrient measurements that were sampled at the same stations. Our research shows that dinoflagellates and coccolithophores significantly covary. Other important relationships that we observed are between cyanobacteria and coccolithophores as well as between coccolithophores and silicate. These results suggest that these phytoplankton groups are using similar nutrients and scrubbing these nutrients out of the water. Further research could increase understanding of the nutrient availability and provide an explanation for the relationship between silicate and coccolithophores.



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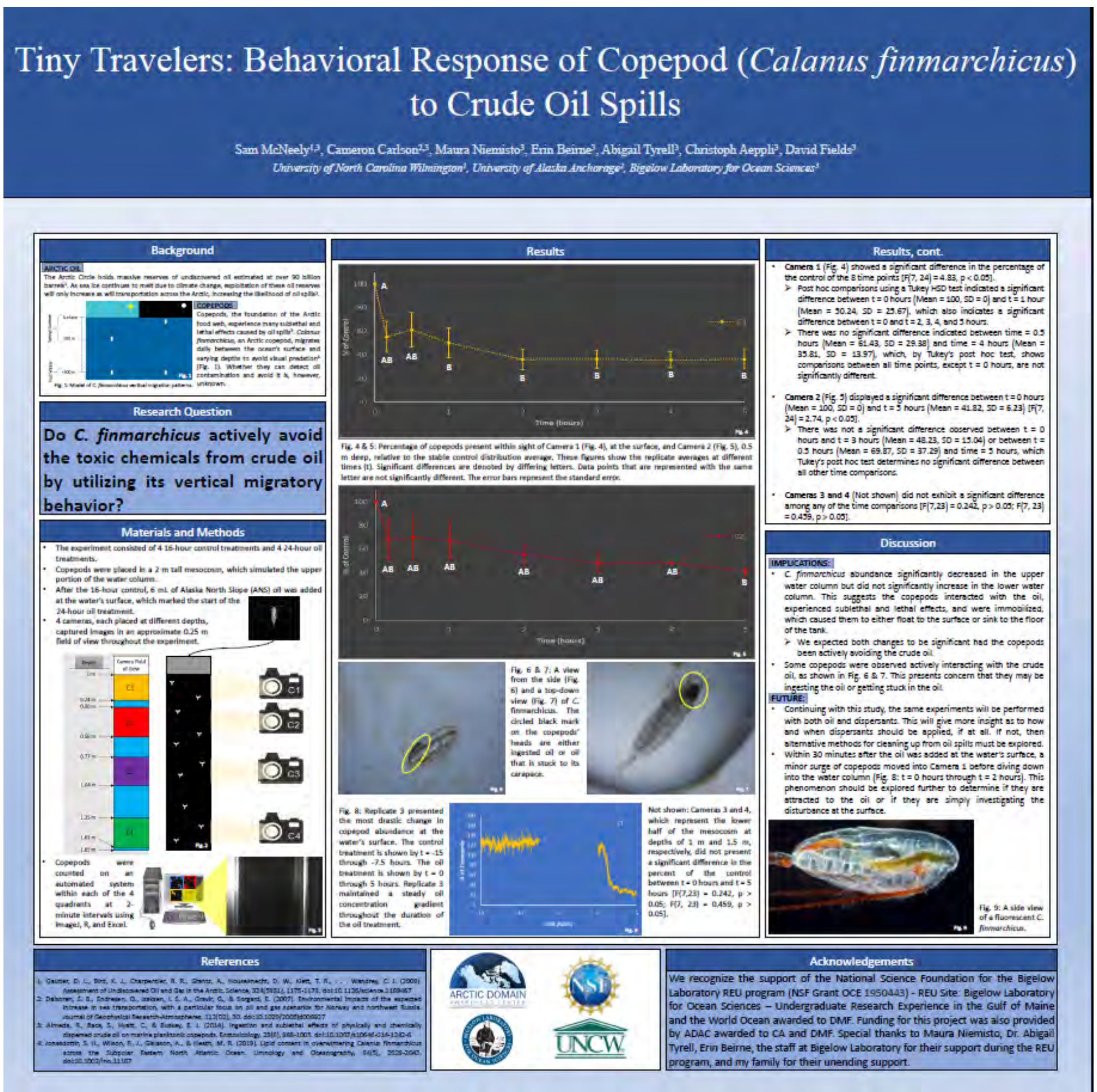
Tiny Travelers: Behavioral Response of Copepod (*Calanus finmarchicus*) to Crude Oil Spills

Sam McNeely[1,3], *Cameron Carlson*[2,3], *Maura Niemisto*[3], *Erin Beirne*[3], *Abigail Tyrell*[3], *Christoph Aeppli*[3], *David Fields*[3]; *(1)University of North Carolina Wilmington, Wilmington, NC, United States, (2) University of Alaska Anchorage, Anchorage, AK, United States, (3)Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States*

The Arctic Circle holds massive reserves of undiscovered oil estimated at over 90 billion barrels, and, as sea ice continues to melt due to climate change, exploitation of these oil reserves will only increase as will transportation across the Arctic, increasing the likelihood of oil spills. Copepods, the foundation of the Arctic food web, experience many sublethal and lethal effects from crude oil. An Arctic copepod (Calanus finmarchicus), makes daily vertical migrations between the ocean's surface and a depth of 100 m. Our hypothesis is that C. finmarchicus can use its vertical migratory behavior to actively avoid the toxic chemicals that come from crude oil. C. finmarchicus are placed into a 2 m tall mesocosm, simulating the upper water column, with 4 cameras positioned at different depths. The cameras capture images throughout the 16-hour controls and the 24-hour oil treatments. The videos from the experiment are analyzed in ImageJ, R, and Excel. Our results show that copepod abundance in the upper mesocosm experienced significant decreases in proportion of the control ($p < 0.05$). The two cameras at depth displayed slight changes, however, they were insignificant ($p > 0.05$). This indicates that C. finmarchicus interacted with the oil, experienced sublethal and lethal effects, and were immobilized. This provides insight into the behavior of C. finmarchicus following the introduction of crude oil indicating the foundation of the Arctic food web are vulnerable to oil spills, highlighting the necessity of proper cleanup methods to minimize the environmental impact.



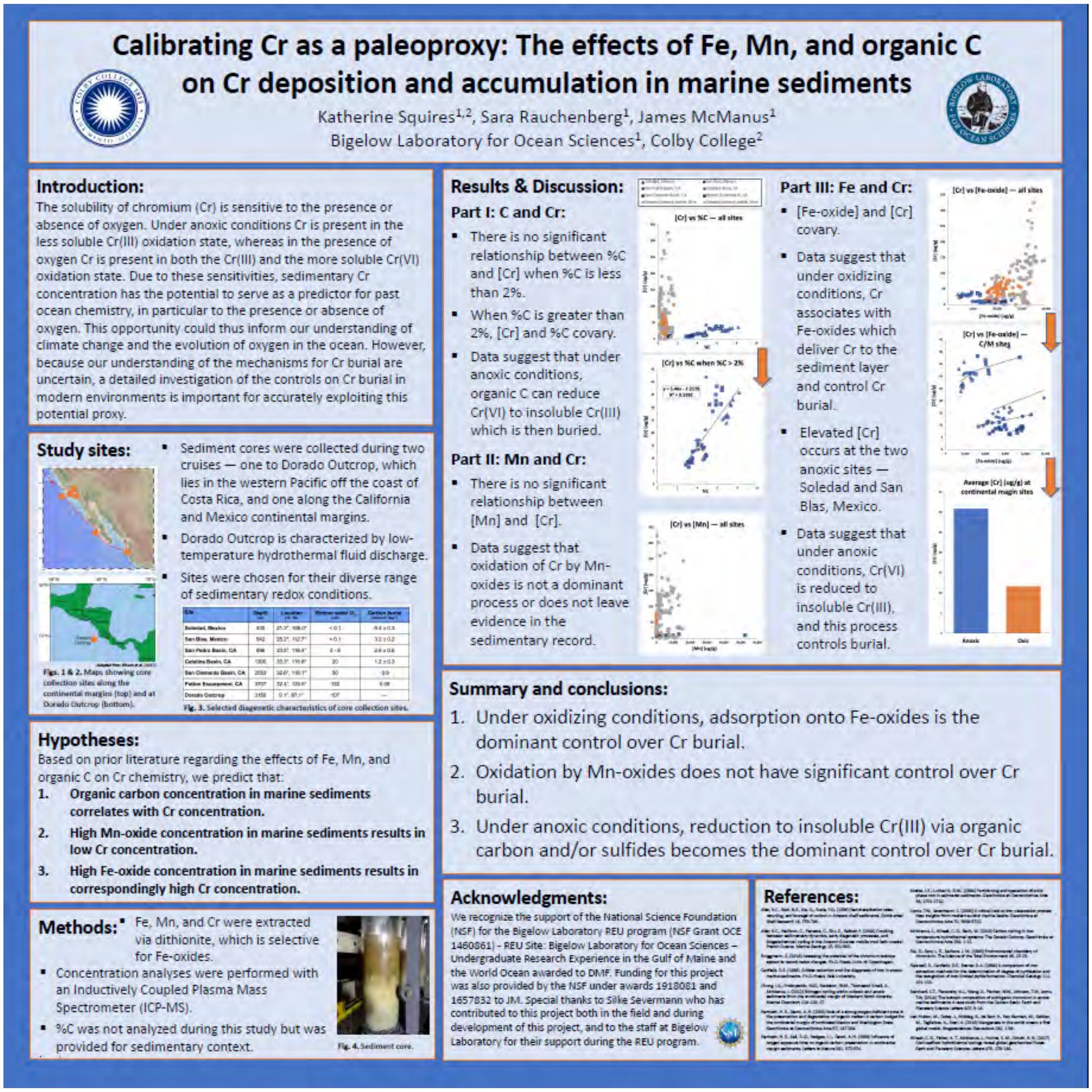
Bigelow's REU Program 2020

Calibrating Cr as a paleoproxy: The effects of Fe, Mn, and organic C on Cr deposition and accumulation in marine sediments

Squires KR[1,2], *Rauschenberg S*[1], *McManus J*[1]; *Bigelow Laboratory for Ocean Sciences*[1], *Colby College*[2]

Chromium's concentration in marine sediments has the potential to serve as a predictor for past ocean chemistry. This potential arises because the solubility of Cr is sensitive to the presence or absence of oxygen. This sensitivity could allow for reconstruction of the evolution of dissolved oxygen in ancient oceans. However, because understanding of the mechanisms for Cr uptake is uncertain, a detailed investigation of Cr's depositional controls is essential for exploiting this potential tool. The central hypothesis of this research is that Cr will exhibit predictable behavior tied to Fe-oxide, Mn-oxide, and organic C cycling.

Marine sediments were analyzed for their Cr, Fe, and Mn concentrations in cores that were collected from a diverse range of oceanographic chemical conditions. An Inductively Coupled Plasma Mass Spectrometer was used to quantify metal abundances. Depth profiles highlighted relationships between [Fe-oxide] and [Cr], and between %C and [Cr], but not between [Mn-oxide] and [Cr]. These data indicate that under oxidizing conditions, Cr adsorbs onto Fe-oxides within marine sediments. These data also indicate that %C and [Cr] covary when %C > 2%, but not when %C < 2%. These observations suggest that under reducing conditions, organic C and sulfides likely reduce Cr to insoluble Cr(III), which is then sequestered within the sediment package. Additional synthesis of our data suggest that there is no significant relationship between Mn-oxide phases and Cr, thus indicating that oxidation of Cr by Mn-oxides does not have significant control over Cr burial.

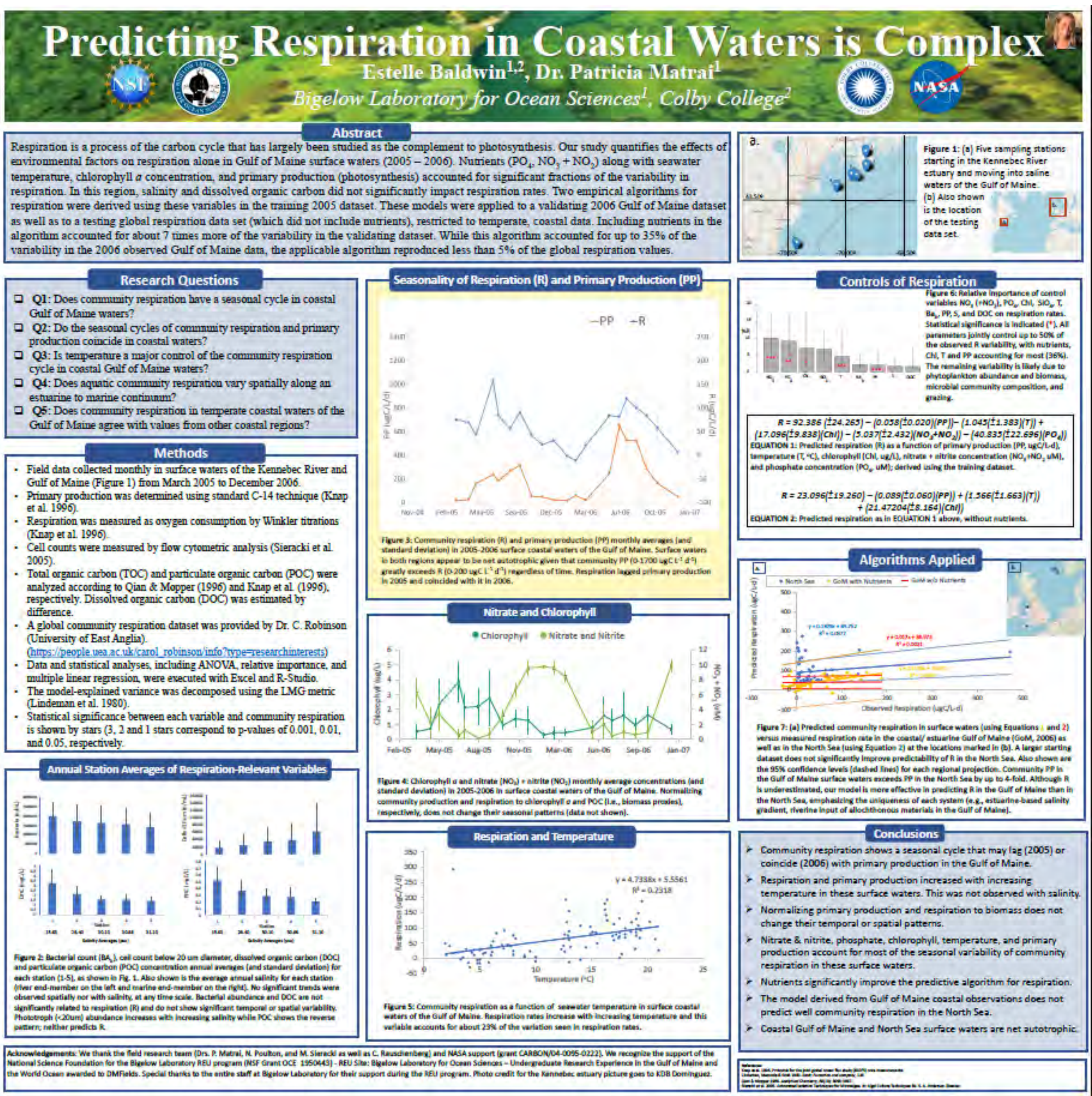


Bigelow's REU Program 2020

Predicting Respiration in Coastal Waters is Complex

***Estelle Baldwin**[1,2]*, *Dr. Patricia Matrai,1; (1) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States, (2) Colby College, United States*

Respiration is a process of the carbon cycle that has largely been studied as the complement to photosynthesis. Our study quantifies the effects of environmental factors on respiration alone in Gulf of Maine surface waters (2005 – 2006). Nutrients (PO4, NO3 + NO2) along with seawater temperature, chlorophyll *a* concentration, and primary production (photosynthesis) accounted for significant fractions of the variability in respiration. In this region, salinity, bacterial abundance, and dissolved organic carbon did not significantly impact respiration rates. Two empirical algorithms for respiration were derived using these variables in the training 2005 dataset. These models were applied to a validating 2006 Gulf of Maine dataset as well as to a testing global respiration data set (which did not include nutrients), restricted to temperate, coastal data. Including nutrients in the algorithm accounted for about 7 times more of the variability in the validating dataset. While this algorithm accounted for up to 35% of the variability in the 2006 observed Gulf of Maine data, the applicable algorithm reproduced less than 5% of the global respiration values.



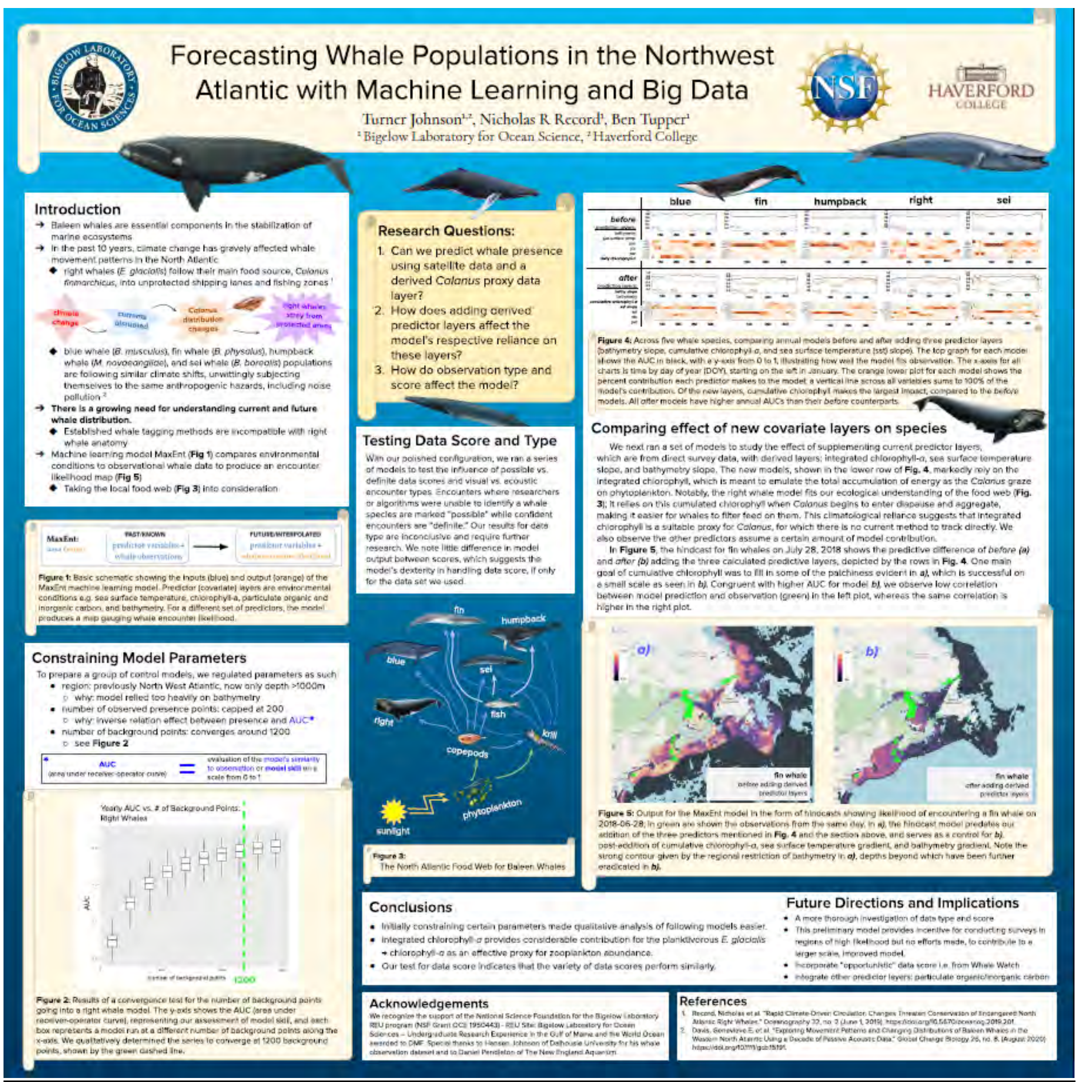
Bigelow's REU Program 2020

Forecasting Whale Populations in the Northwest Atlantic with Machine Learning and Big Data

***Turner Johnson** 1,2 , Ben Tupper 2 , Nick Record 2 , (2) Haverford College, Ardmore, PA, United States (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States.*

Within the past decade, large swaths of the North Atlantic trophic web have been geographically uprooted due to the effects of climate change. Notably, the right whale (*E. glacialis*) is following its main food source, *C. finmarchicus*, out of historically protected waters and into ship routes and fishing grounds. Similar effects are observed in blue (*B. musculus*), fin (*B. physalus*), humpback (*M. novaeangliae*), and sei whale (*B. borealis*) populations. To gain detailed insight into future whale distribution, we use the machine learning model, MaxEnt, to produce daily encounter-likelihood maps using whale observations, and covariate data layers gathered by the Aqua MODIS satellite. Using data from January 2014 to June 2020, we produced a series of

daily predictive models, varying predictor, observational, and model parameters to test the ability of this model to anticipate distributions across two or more trophic levels in the whale food chain. The favorable effect of adding calculated covariate layers (integrated chlorophyll-a, bathymetry gradient, and sea surface temperature gradient) is noted in the strong contribution of integrated chlorophyll to the planktivorous *E. glacialis* model, but not the piscivorous whales, suggesting that chlorophyll-a could be an effective proxy for zooplankton abundance. In a comparison of definite sightings to possible sightings, we find little difference in model output and infer the usability of a range of data scores. A whale distribution forecast on a massive scale is a critical tool in ecosystem conservation, as each whale's actions have resounding effects on both their local food web and the global carbon and oxygen cycles.

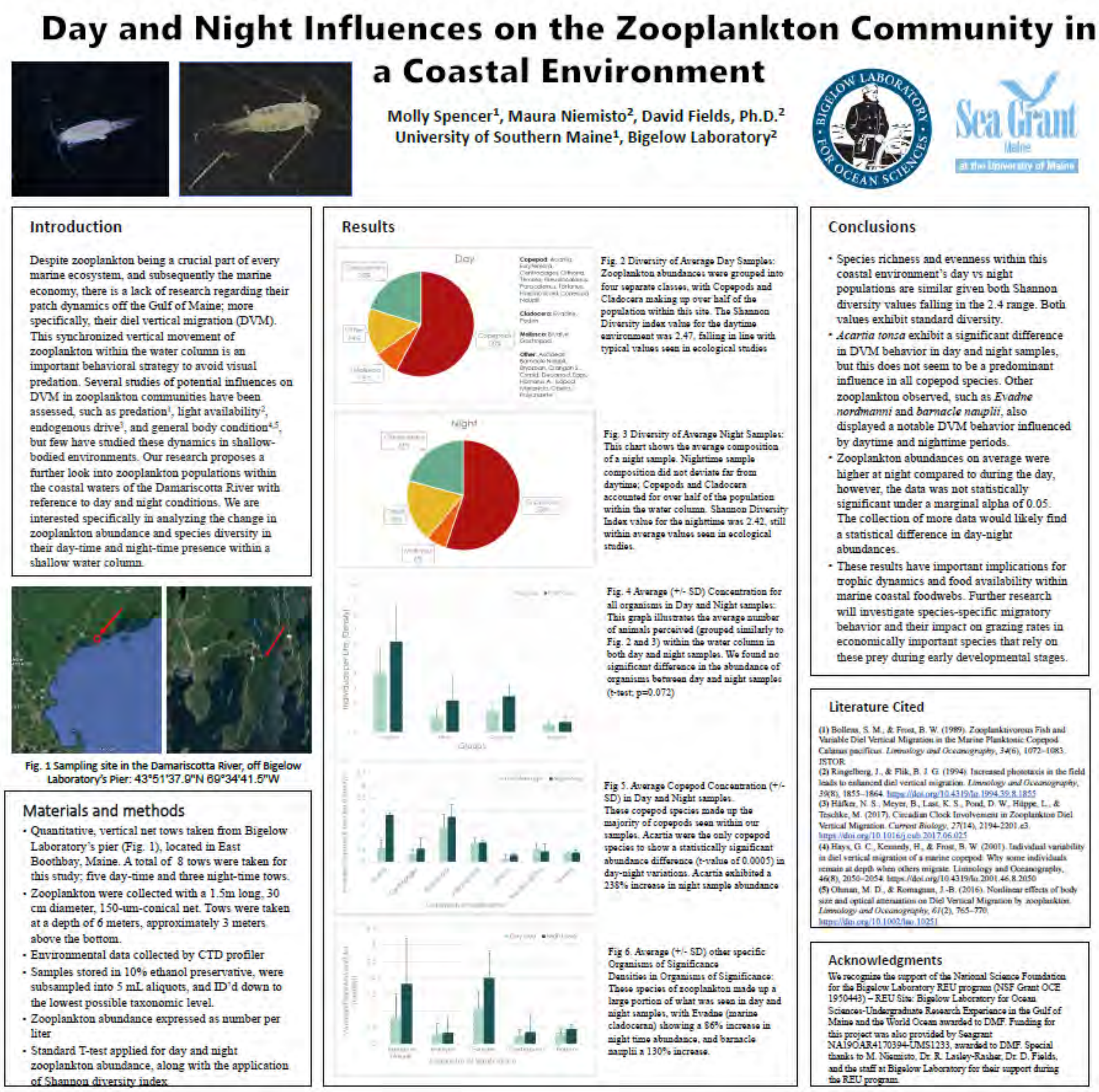


Bigelow's REU Program 2020

Day and Night Influences on the Zooplankton community in a Coastal Environment

Molly Spencer[1] *, Maura Niemisto*[2]*, David M Fields*[2]*; (1) University of Southern Maine, Biological Sciences, Portland, ME, United States, (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States*

Despite zooplankton being a crucial part of every marine ecosystem, there is a lack of data describing day-night changes in their vertical distribution in the Gulf of Maine; more specifically, the population's diurnal vertical migration(DVM). This synchronized vertical movement of zooplankton within the water column is an important behavioral strategy to avoid visual predation. In this study, we analyzed the diversity and abundance of zooplankton species over the course of a diel cycle within the coastal waters of the
Damariscotta River. Our data revealed that diversity between day and night samples did not differ, however, certain abundances of specific zooplankton species were significantly higher at night compared to the day. For example, *Acartia tonsa* and *Evadne nordmanni* abundances increased by 238% and 86% during the nighttime. Similarly, barnacle nauplii showed a more than 2 fold increase in abundance at night, a 129% change in size. Diverging from this pattern is the considerably smaller copepod species *Oithona* , which displayed a 20% decrease in abundance during the nighttime. These results suggest that zooplankton predators such as larval fish and other planktivores may benefit from the higher abundances of zooplankton in the upper water column at night. Further research will investigate species-specific migratory behavior and the impact these migrations have on the grazing rates of economically important species that rely on these prey during early developmental stages.



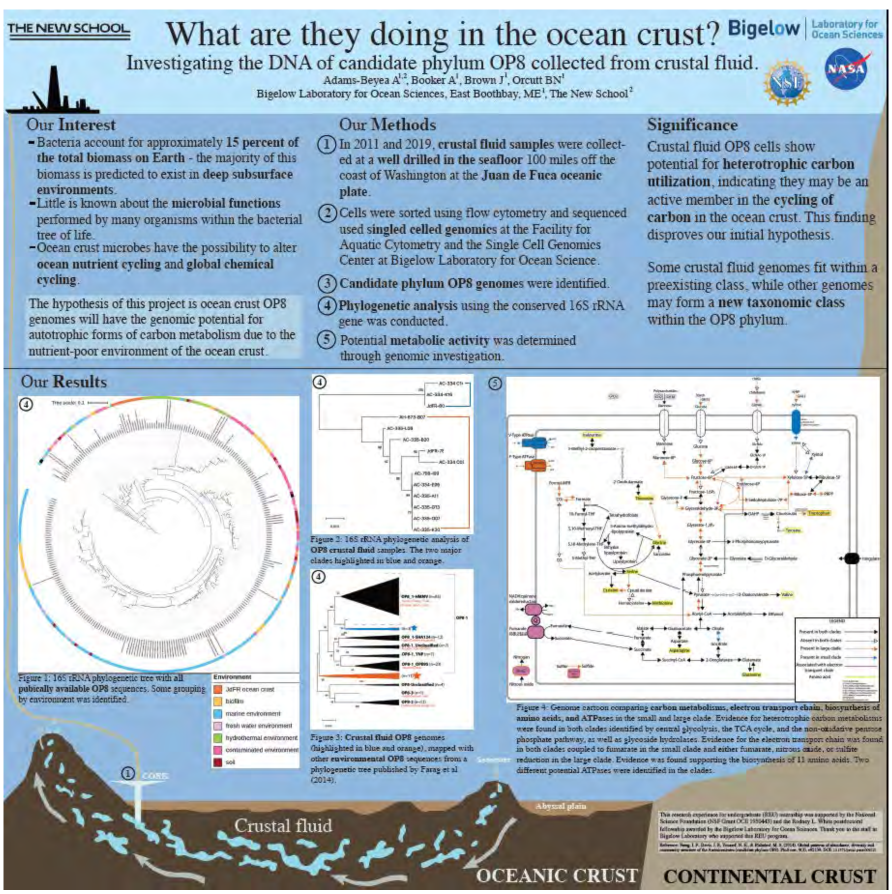
Bigelow's REU Program 2020

What are they doing in the ocean crust? Investigating the DNA of candidate phylum OP8 collected from crustal fluid.

Adams-Beyea A[1,2], *Booker A[1], Brown J[1], Orcutt BN[1]*
Bigelow Laboratory for Ocean Sciences, East Boothbay, ME[1], The New School NYC NY[2]

Little is known about the microbial life that terrestrial and oceanic subsurface environments support. The subsurface of the ocean, the ocean crust, is composed of porous rock through which seawater circulates. As fluid circulates through the crust, water-rock interactions provide nutrients for the microorganisms that live in this extreme environment. This project aims to study a largely unresearched group of bacteria found in the ocean crust that could contribute to a wealth of undiscovered information including new life strategies, additions to the genomic tree of life, and a deeper understanding of ocean nutrient cycling and global chemical cycling.

Two research cruises in 2011 and 2019 traveled 100 miles off the coast of Washington State in the Pacific Ocean to the Juan de Fuca oceanic plate. There, crustal fluid was accessed through a well drilled into the crust. Cells were isolated from crustal fluid samples using flow cytometry at the Facility for Aquatic Cytometry and genomic DNA was sequenced using single-cell genomic techniques at the Single Cell Genomics Center at Bigelow Laboratory for Ocean Science. Candidate phylum OP8 cells were identified in samples from both research cruises indicating that this bacteria is an active and consistent member of the ocean crust microbial community. This project investigates 16 crustal fluid origin OP8 genomes aiming to learn what types of carbon this organism is utilizing in the ocean crust. The hypothesis of this project was ocean crust OP8 genomes will have the genomic potential for autotrophic forms of carbon metabolism due to the nutrient-poor environment of the ocean crust. However, our searches found compelling evidence that ocean crust OP8 use heterotrophic forms of carbon metabolism, indicating that this bacterial phylum may be an active member in the carbon cycling occurring in the ocean crust. Additionally, this project used 16S rRNA phylogenetic analyses to review all publically available OP8 sequences to determine where the crustal fluid OP8 cells fit within this phylum. Based on this comparison, two of our crustal fluid OP8 genomes fit within a preexisting class, while the other group may form a new class. This research adds to the limited knowledge about the carbon cycling role crustal fluid OP8 may play in the ocean crust environment.



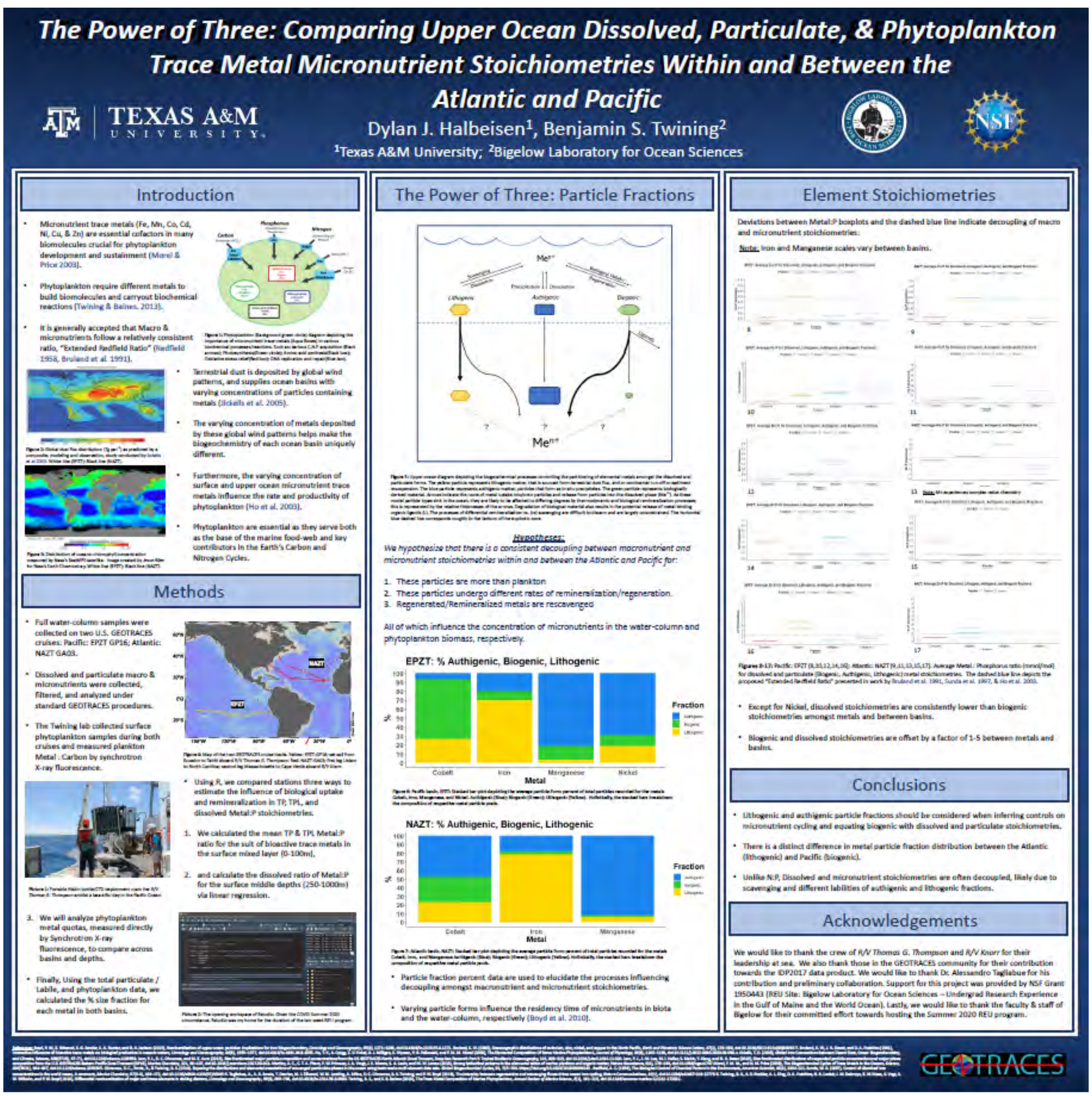
Thursday, July 30

Bigelow's REU Program 2020

The Power of Three: Comparing Upper Ocean Dissolved, Particulate, & Phytoplankton Trace Metal Micronutrient Stoichiometries Within and Between the Atlantic and Pacific.

***Dylan J. Halbeisen*[1]**, *Benjamin S. Twining*[2], *(1)Texas A&M University, College Station, TX, United States; (2)Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States.*

Macro & micronutrient stoichiometries are considered to occur in a relatively consistent ratio, the "Extended Redfield ratio", throughout the dissolved, particulate, and cellular nutrient pools of the ocean [Bruland et al 1991; Sunda 1997]. The presumed Extended Redfield Ratio is important because it is used to approximate cellular metal quotas. In this study we investigated the presumed consistent ratio between macro & micronutrient stoichiometries to evaluate the extent of presumed consistency. We used data collected on two U.S. GEOTRACES cruises (Pacific: EPZT; Atlantic: NAZT) and the programing language R, to compare dissolved, particulate, and phytoplankton stoichiometries, and calculate basin-scale particle fraction percentages to provide biogeochemical context to departures in the Extended Redfield Ratio. We found that dissolved stoichiometries are consistently lower than biogenic stoichiometries and are offset by a factor of 1-5 both amongst metals and between basins. There is a distinct difference in metal particle fraction distribution between the Atlantic (lithogenic) and Pacific (biogenic). Stoichiometric decoupling likely occurs due to scavenging and varying labilities of authigenic and lithogenic fractions. The Extended Redfield Ratio was found to decouple in the Atlantic and Pacific. For these reasons, the lithogenic and authigenic particle fractions should be considered when inferring controls on micronutrient cycling and equating biogenic with dissolved and particulate stoichiometries.

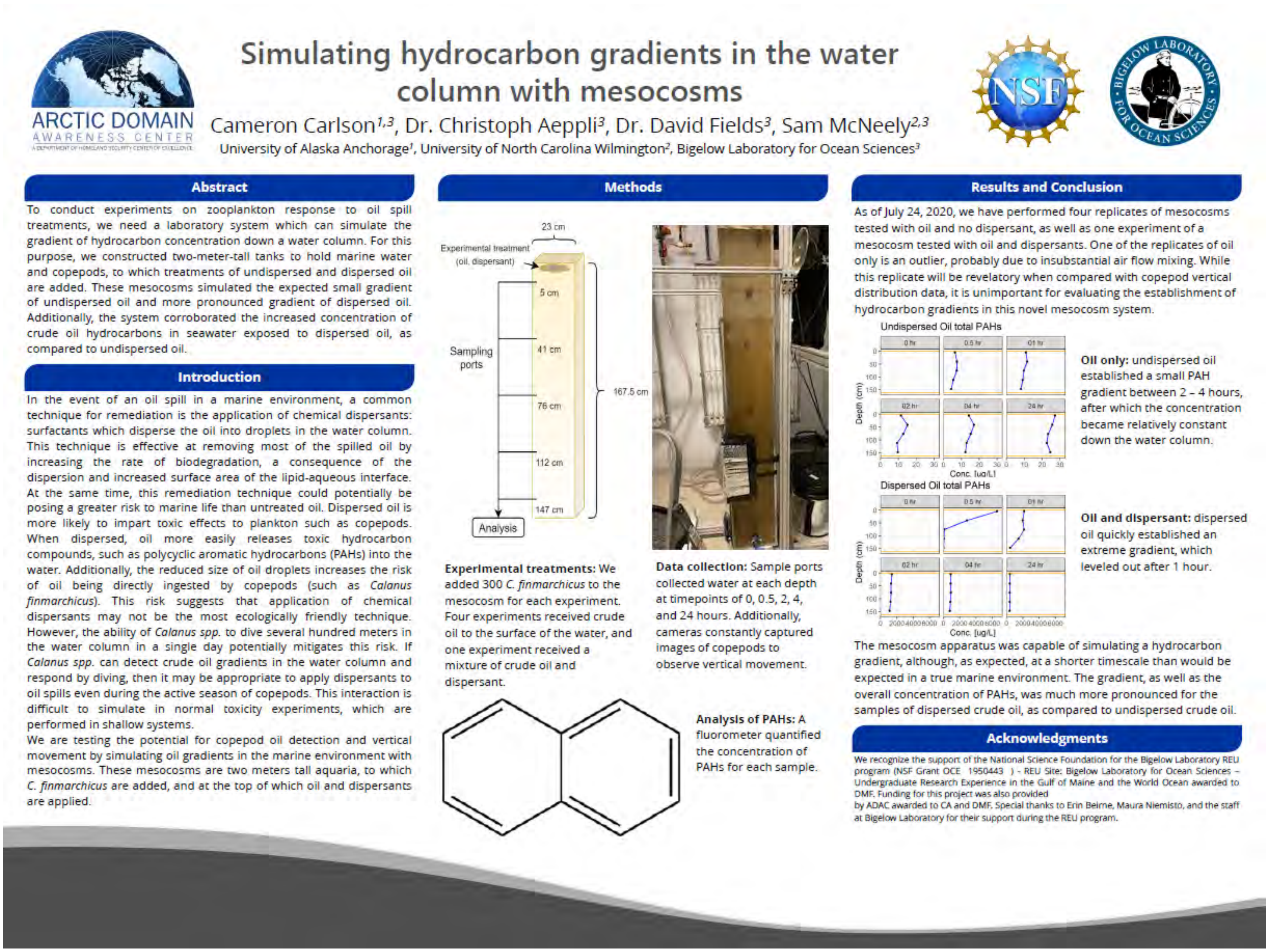


Bigelow's REU Program 2020

Simulating hydrocarbon gradients in the water column with mesocosms

***Cameron Carlson*[1,2]**, *Dr. Christoph Aeppli*[2], *David Fields*[2]
University of Alaska Anchorage[1], *Bigelow Laboratory for Ocean Sciences*[2]

To conduct experiments on zooplankton response to oil spill treatments, we need a laboratory system which can simulate the gradient of hydrocarbon concentration down a water column. For this purpose, we constructed two-meter-tall tanks to hold marine water and copepods, to which treatments of undispersed and dispersed oil are added. These mesocosms simulated the expected small gradient of undispersed oil and more pronounced gradient of dispersed oil. Additionally, the system corroborated the increased concentration of crude oil hydrocarbons in seawater exposed to dispersed oil, as compared to undispersed oil.

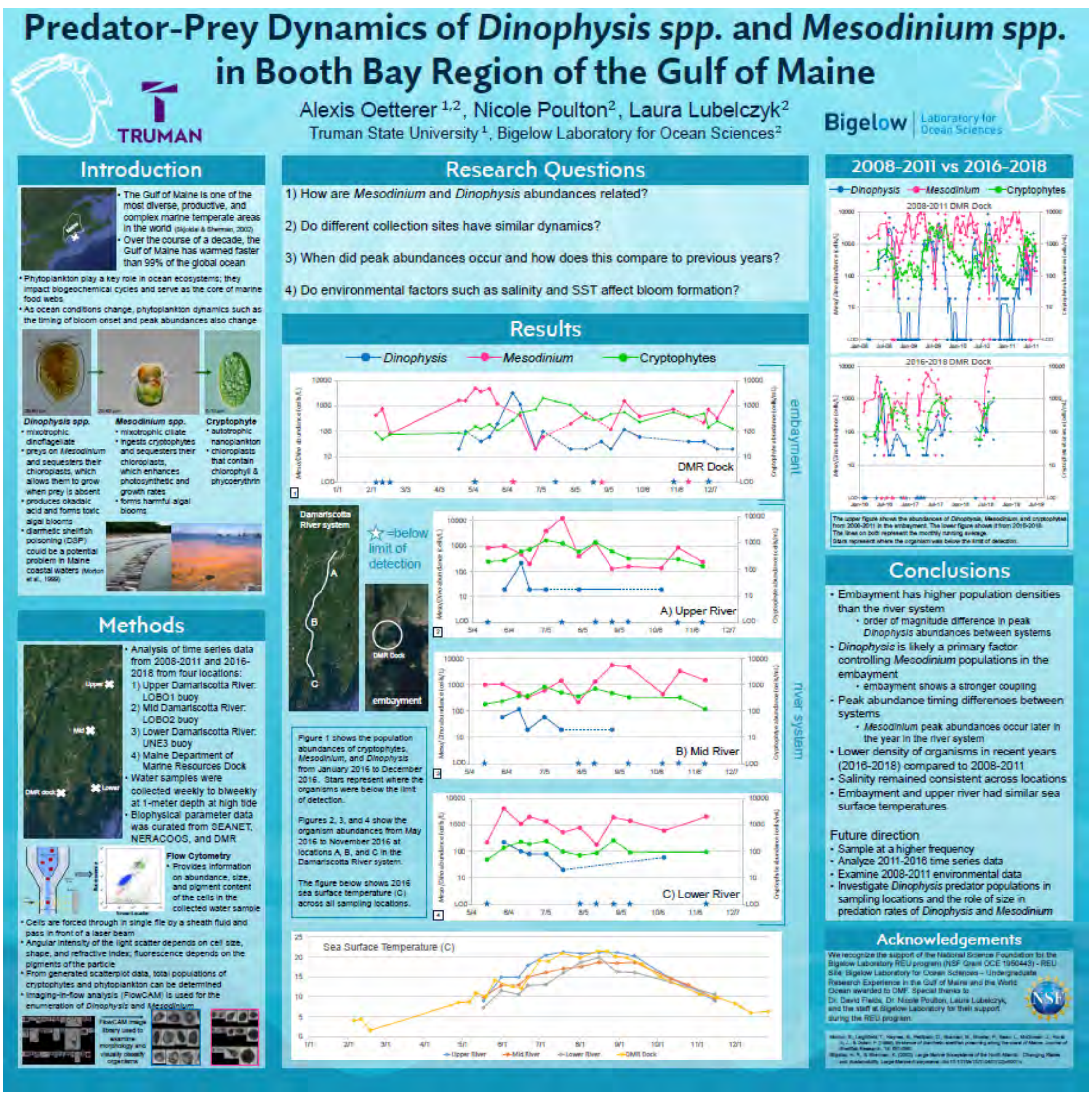


Bigelow's REU Program 2020

Predator-prey dynamics of *Dinophysis* spp. and *Mesodinium* spp. in Booth Bay region of the Gulf of Maine

***Alexis Oetterer*[1]**, *Laura Lubelczyk*[2], *Nicole Poulton*[2]
Truman State University, Kirksville, MO, United States[1], *Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States*[2]

Many dinoflagellates and ciliates are known for their ability to use chloroplasts from ingested prey. The toxic dinoflagellate *Dinophysis* and the ciliate *Mesodinium* are two genera of mixotrophic phytoplankton known to form harmful algal blooms and can acquire phototrophy. These harmful blooms can negatively impact other organisms and the aquaculture industry through the production of toxins. Over the course of a decade, the Gulf of Maine has warmed faster than 99% of the global ocean. As ocean conditions change, phytoplankton dynamics such as the timing of bloom onset and peak abundances also change. In this study we investigated the predator-prey dynamics of *Dinophysis* and *Mesodinium* spp. Both are known to possess plastids of cryptophyte origin. *Dinophysis* preys on *Mesodinium* and sequesters its chloroplasts. *Mesodinium* preys on cryptophytes and retains its chloroplasts. Water samples were collected weekly to biweekly at three sites in the Damariscotta River and one site in Booth Bay Harbor. Traditional flow and imaging cytometry were used to enumerate these organisms. Time series population data from 2008-2011 and 2016-2018 was analyzed in conjunction with physical data. Our results show that the embayment had higher population densities than the river system, up to an order of magnitude difference for *Dinophysis* peak abundances. The embayment has a more coupled system and *Dinophysis* is likely a primary factor controlling *Mesodinium* populations. Analysis of 2016-2018 populations compared to 2008-2011 populations revealed lower densities of these organisms in recent years.

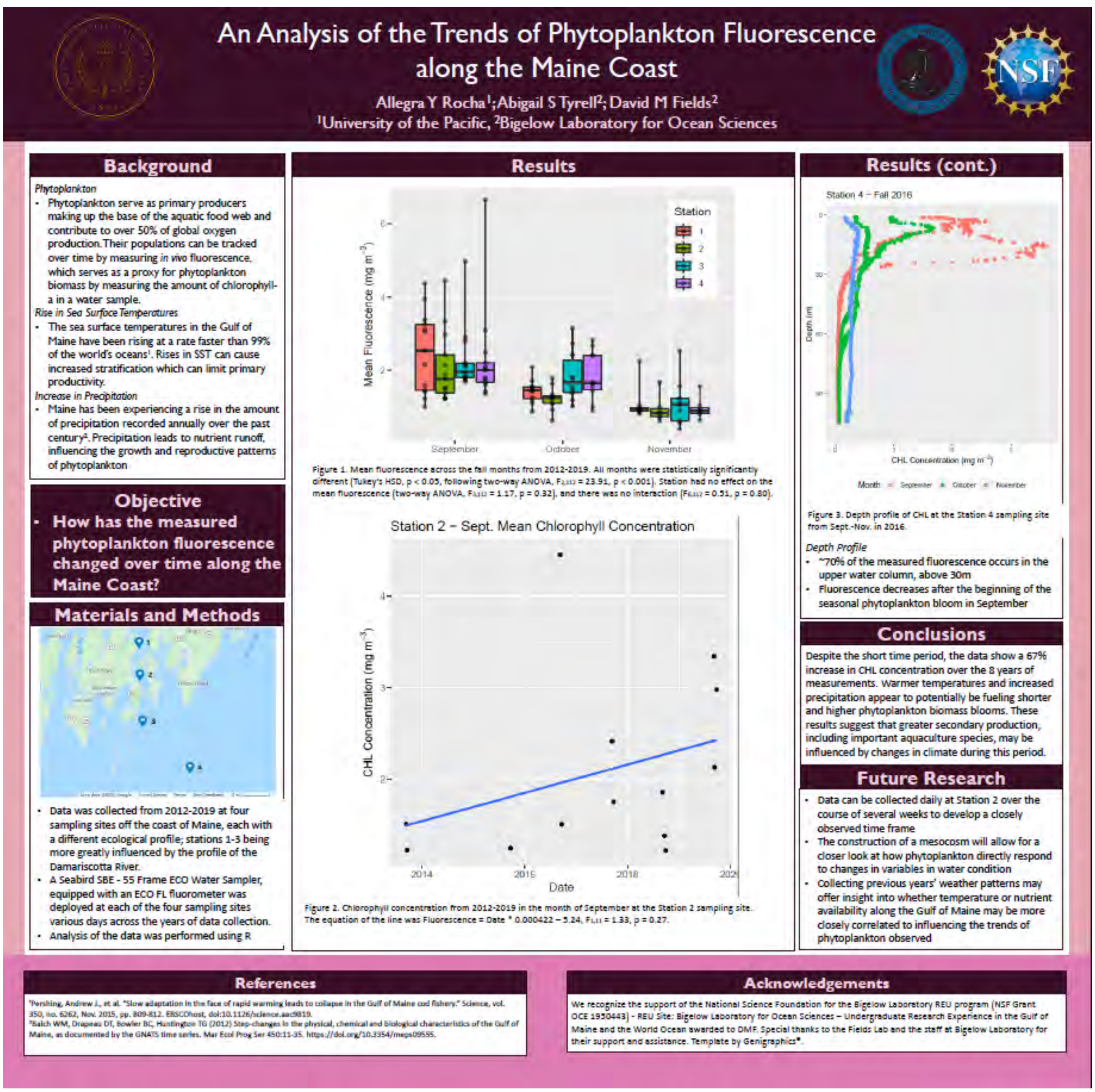


Bigelow's REU Program 2020

An Analysis of the Trends of Phytoplankton Fluorescence along the Maine Coast

Allegra Y Rocha[1], *Abigail S Tyrell*[2] *and David M Fields*[2], *(1) University of the Pacific, Stockton, CA, United States (2) Bigelow Laboratory for Ocean Sciences, East Boothbay, ME, United States.*

Over the past century, both sea surface temperatures and precipitation have increased in the Gulf of Maine, which could potentially disrupt the growth and reproduction of phytoplankton over time. In this study, we analyzed data from the Damariscotta River Estuary and Gulf of Maine to determine whether there were any changes in the amount of phytoplankton in this region. Trends of phytoplankton were quantified using *in vivo* fluorescence as a proxy for plankton biomass. Fluorescence was measured at four sampling sites during Sept.-Nov. from 2012 through 2019. Although there were no statistically significant trends in fluorescence over time, there was an increasing trend in chlorophyll concentration at one location during this sampling period. Warming temperatures and increased precipitation appear to be potentially fueling shorter and higher biomass blooms in the phytoplankton population. These results suggest that greater secondary production, including important aquaculture species, may be influenced by changes in climate during this period. Further research is necessary to determine how these important Maine ecosystems may be influenced by climate change.



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The Hunt for Carnivorous Algae and Solar-Powered Sea Creatures:
Creating Gene-Based Predictive Trophic Models for Unicellular Mixotrophic Organisms

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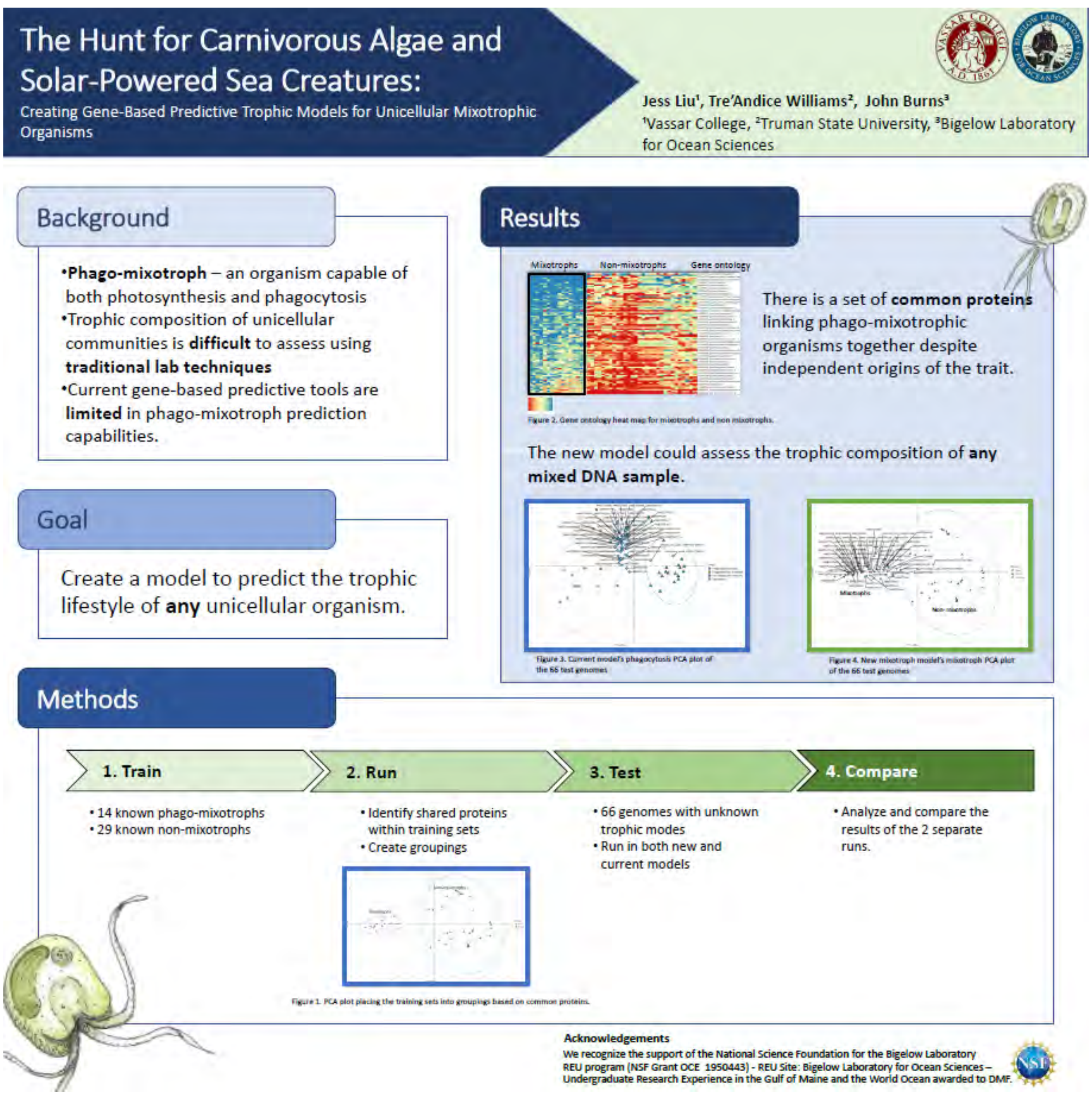
The term "phago-mixotroph", in the context of unicellular life, describes an organism that is capable of both photosynthesis and phagocytosis. Historically viewed as biological anomalies, mixotrophs (specifically mixotrophic plankton) are now understood to be extraordinarily common in the upper water column, with an estimated 50% of proto-zooplankton having the potential to photosynthesize [Flynn, 2019]. In order to gain a greater understanding of the trophic composition of aquatic communities, we created a new gene-based predictive trophic model using the Burns 2017 Trophic Mode Prediction Tool. Phago-mixotrophic organisms were represented by genome and transcriptome data from 14 phylogenetically diverse organisms observed to have a phago-mixotrophic lifestyle. Our outgroup of organisms lacking phago-mixotrophy was composed of 29 eukaryotes from groups as diverse as animals, plants, fungi, and photo-autotrophic green and red algae. After training the predictive model on those two groups, our results suggest there may be a common set of proteins linking phago-mixotrophic organisms, despite independent origins of the trait in different lineages. Further analysis of the molecular functions identified by the model may provide clues to genes relevant for maintaining a phago-mixotrophic lifestyle. This new predictive gene set may also help us assess the trophic composition of any mixed DNA sample.



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Global Trends in the Biogeography of Coral Recruitment

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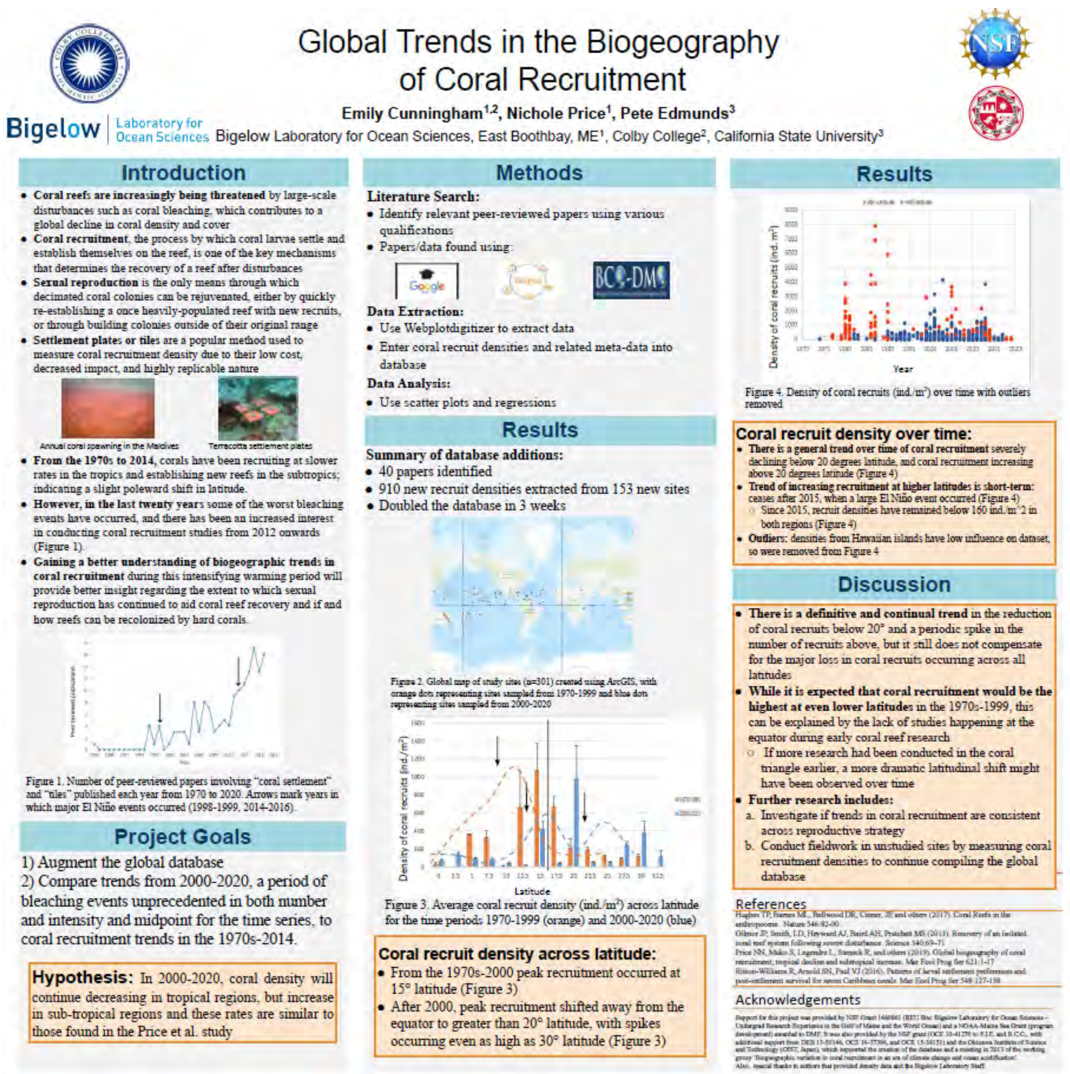
Coral reefs are increasingly threatened by large scale disturbances such as prolonged and severe heat waves which induce bleaching, especially in the last two decades. A recent meta-analysis revealed that, from 1970 to 2014, coral recruitment on standardized settlement tiles has shifted poleward. This study aims to augment the database and compare global trends in the biogeography in coral recruitment from the temporal periods 1970-1999 and 2000-2019. Coral recruit densities on tiles and associated metadata were extracted from 40 peer-reviewed journal articles using Webplotdigitizer, adding 910 unique data points and 153 new sites to the database. From 1970 to 2000, peak recruit densities occurred at 15° latitude. However, the lack of deployments of settlement tiles in equatorial regions before 1990 may influence this value. After 2000, the geographic extent of tile deployments was distributed more evenly across latitudes. Peak recruit densities shifted poleward to greater than 20° latitude, with unusually high recruit densities occurring even as high as 30° latitude. Using a 20° latitude inflection point, we also explored temporal trends in recruitment in the tropics and subtropics: in both regions, recruit densities have remained below 160 ind./m^2 since the last major El Niño in 2015, and the original trend of increasing recruitment at higher latitudes has ceased. Further study of larval supply and coral recruitment rates at high latitudes during this intensifying warming period will clarify to what extent reefs can escape the heat and recolonize in subtropical refugia.



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Evaluating the Performance of Standard Ocean Color Algorithms for Carbon in the Gulf of Maine

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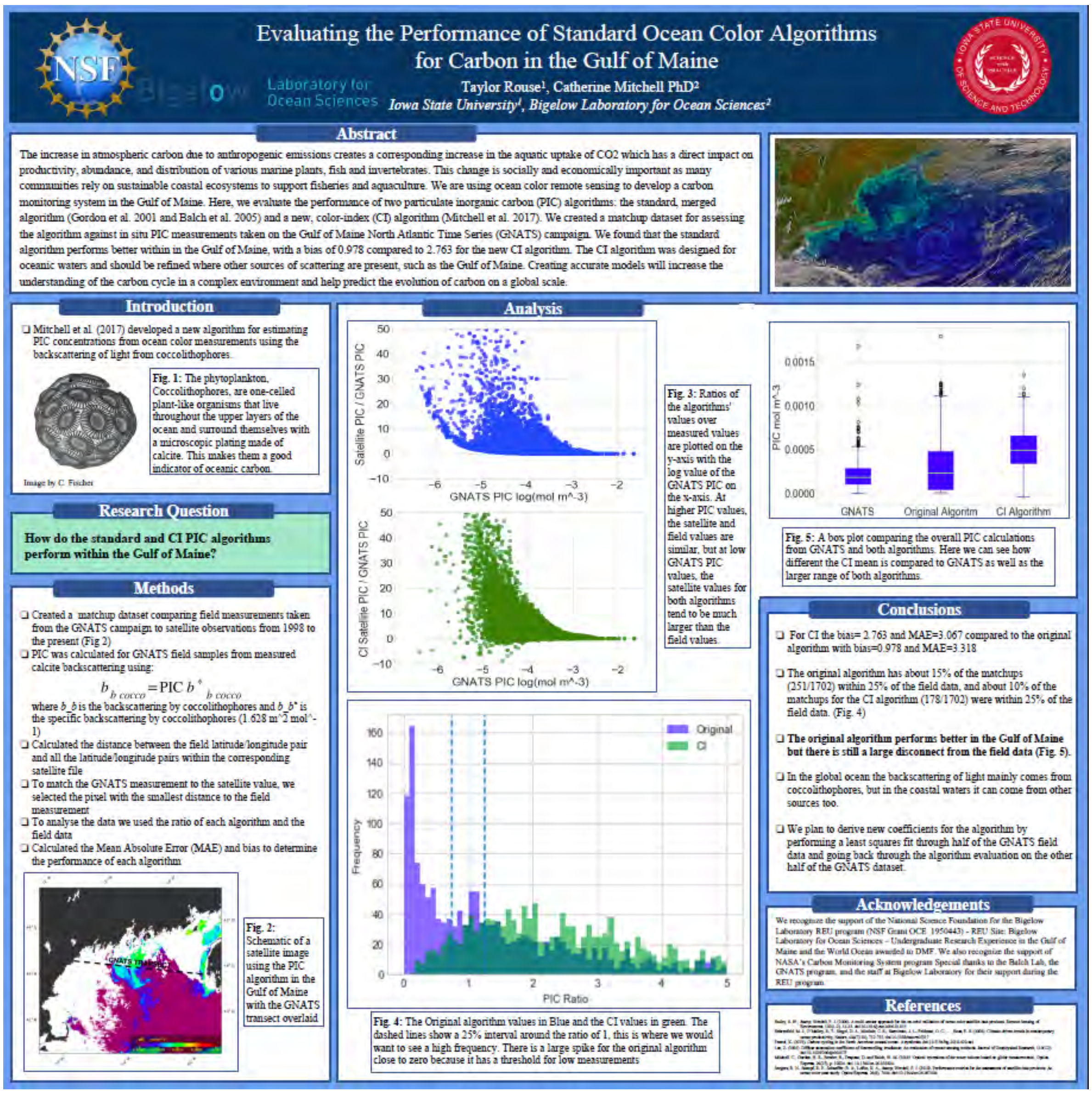
The increase in atmospheric carbon due to anthropogenic emissions creates a corresponding increase in the aquatic uptake of CO2 which has a direct impact on productivity, abundance, and distribution of various marine plants, fish and invertebrates. This change is socially and economically important as many communities rely on sustainable coastal ecosystems to support fisheries and aquaculture. We are using ocean color remote sensing to develop a carbon monitoring system in the Gulf of Maine. Here, we evaluate the performance of two particulate inorganic carbon (PIC) algorithms: the standard, merged algorithm (Gordon et al. 2001 and Balch et al. 2005) and a new, color-index (CI) algorithm (Mitchell et al. 2017). We created a matchup dataset for assessing the algorithm against in situ PIC measurements taken on the Gulf of Maine North Atlantic Time Series (GNATS) campaign. We found that the standard algorithm performs better within in the Gulf of Maine, with a bias of 0.978 compared to 2.763 for the new CI algorithm. The CI algorithm was designed for oceanic waters and should be refined where other sources of scattering are present, such as the Gulf of Maine. Creating accurate models will increase the understanding of the carbon cycle in a complex environment and help predict the evolution of carbon on a global scale.



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Predicting the Dissolved Organic Matter-Water Partitioning for Short-Chain Chlorinated Paraffins

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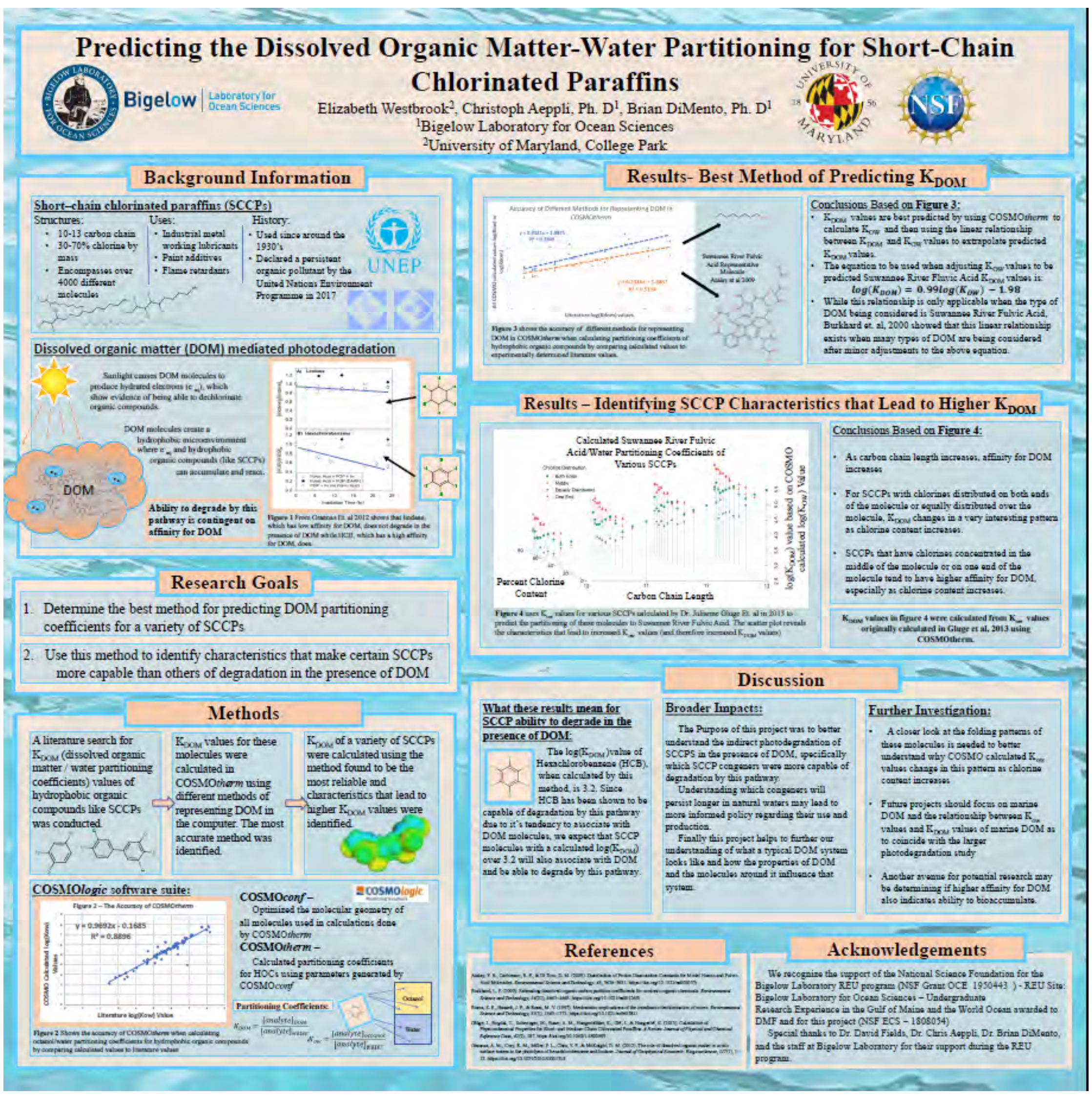
Short-chain chlorinated paraffins (SCCPs) were declared a persistent organic pollutant by the United Nations Environment Programme in 2017 due to their potential carcinogenicity, ability to bioaccumulate, and persistence in the environment. The goal of this project was to better understand the fate of these molecules in the ocean by studying their dissolved organic matter (DOM) mediated photodegradation. Previous studies involving other hydrophobic organic compounds (HOCs) show that a molecule's affinity for the hydrophobic micro-environment created by DOM molecules is an important factor in its ability to degrade by this pathway. In order to predict the ability of a variety of SCCPs to degrade in the presence of DOM, a method for predicting the DOM-water partitioning coefficient (Kdom) of any SCCP molecule was determined. COSMOtherm calculated octanol-water partitioning coefficients (Kow) were found to be the most accurate method of predicting Kdom when adjusted based on the linear relationship that exists between Kow and Kdom for HOCs. This method was then used to predict Kdom for a variety of SCCPs and identify characteristics that correlated with higher affinity for DOM. The primary characteristics identified were longer carbon chains and generally increased chlorine content. Results also show that the distribution of chlorine substituents effects affinity for DOM. While Kdom values were highly variable for SCCPs, most of them are expected to be capable of at least some DOM mediated photodegradation based on previous studies of this pathway.



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