CINAR

Cooperative Institute for the North Atlantic Region

Annual Progress Report

Donald M. Anderson, Director

Submitted to:
National Oceanic and Atmospheric Administration
Ocean and Atmosphere Research (OAR)

Gulf of Maine Research Institute

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CINAR
Annual Progress Report

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Submitted by:

Donald M. Anderson, Director

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Executive Summary

CINAR began operation on July 1, 2009 and the CINAR renewal agreement began July 1, 2014. WHOI is the lead institution in partnership with the University of Maryland Center for Environmental Science, Rutgers University, University of Maine and the Gulf of Maine Research Institute.

The geographic domain of CINAR is the U.S. northeast continental shelf from Cape Hatteras to Nova Scotia. Because of the importance of large-scale climate and biological connectivity in the North Atlantic, CINAR's geographic scope also includes basin and global-scale processes that affect the shelf ecosystem. The overall goal of CINAR is to engage NOAA and academic scientists in cutting-edge research that enables NOAA to make informed decisions about sustainable and beneficial management of the U.S. northeast continental shelf ecosystem.

Funding:

- During the first year of operation under the renewal award (July 1, 2014 through March 31, 2015), CINAR received $7,856,027 from OAR, $3,111,641 from NMFS, $648,368 from NOS and $44,245 from NESDIS.
- During the second year of operation (April 1, 2015 through March 31, 2016, CINAR received $6,293,783 from OAR, $3,062,443 from NMFS, $232,044 from NOS and $57,432 from NESDIS.
- During the third year of operation (April 1, 2016 through March 31, 2017, CINAR received $7,221,048 from OAR, $2,983,481 from NMFS, and $283,100 from NOS.

Education and Outreach

CINAR continued its program in summer Minority Traineeships, which offers funds for one minority student to each partner. These students received training through one or more CINAR investigators. Details about the summer 2015 program are provided under Task I activities.

In 2012, we began a partnership with the University of Massachusetts School of Marine Science and Technology (SMAST) and the NEFSC to address issues related to Massachusetts and regional fishing communities. Two components are included: 1) a series of rotating, competitive Fellow awards for WHOI scientists working in areas relevant to the central theme of quantitative fisheries science; and 2) faculty support at SMAST to conduct research and educational activities related to stock assessment and quantitative fisheries science. A competition for three CINAR fellows in Quantitative Fisheries and Ecosystem Science was held in 2012, and three CINAR fellows were funded. A second competition was again held in 2015, and we have appointed three new fellows. Detailed progress reports from each CINAR Fellows and SMAST faculty are provided, beginning on page 193.

In the past year, we continued the program, "*WHOI-NEFSC Special Seminar Series on Fisheries and Ecosystems Acoustics*". That successful seminar series has been well received and will continue for the foreseeable future. More details are provided under the Task I activities section.

CINAR Annual Research Highlights

Mark Baumgartner, WHOI
Passive Acoustic Monitoring from Autonomous Platforms

This project is designed to (1) demonstrate the utility of real-time passive acoustic monitoring from autonomous platforms using the digital acoustic monitoring (DMON) instrument and the low-frequency detection and classification system (LFDCS), (2) validate the accuracy of in-situ detection and classification capability when used on a variety of stationary and mobile autonomous platforms, and (3) incorporate this new technology into NMFS whale and fish monitoring efforts. The project will provide flexible tools for long-term reduction in analytical effort and improved efficiency of existing monitoring technologies (e.g., visual surveys). We anticipate that NOAA will be able to significantly enhance its monitoring efforts using real-time detection information to identify areas of persistent whale occurrence, and to direct airplane- or ship-based surveys to regions that require additional visual surveillance. Project highlights included:

- Several successful 100+ day deployments of Slocum and wave gliders that reported the presence of right, humpback, sei, and fin whales in near real time.
- Our evaluation indicates that DMON-equipped Slocum gliders and moored buoys provide highly accurate estimates of right, humpback, sei, and fin whale occurrence in near real time.
- Significant progress has been made toward making the wave glider a viable mobile autonomous platform for near real-time passive acoustic monitoring.

This project supports the NOAA goal of "Healthy Oceans: Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems" by providing tools with which NMFS can monitor endangered populations of baleen whales. Continuous, long-term and real-time monitoring will improve mitigation of a variety of anthropogenic stressors in these endangered populations, including ship strikes and fishing gear entanglements.

Matthew Campo, Rutgers University
Resilience Planning for Water Dependent Uses

This project will produce a guide for coastal communities on how to locate, evaluate, and assemble publicly available data from federal, state, and local sources to establish a baseline set of geospatial (and related) data needed to inform local land use planning to improve the resiliency of water-dependent uses and their supporting infrastructure. The project will also produce both paper-based and web-based versions of a "Guide to Resilience Planning for Water-Dependent Uses (RPWDU)", and will also use ESRI's ArcGIS Online Story Map templates that will allow interactive mapping demonstrations of how to use these various data sources in preparing land use plans. The research project provides an opportunity for NOAA to enhance the capabilities of water-dependent users that are resource constrained and share practices among all user groups to enhance and coordinate planning for a challenging environment. Project highlights included:

- Developing draft versions of web-based and paper-based guide for "Resilience Planning for Water-Dependent Uses."
- Conducting two focus groups (Chesapeake City, VA and Cape Charles, VA) to engage local

professional planners, recreational users, industrial operators and other stakeholders in waterfront planning discussions.

The results of this research will integrate federal, state and local data sources into a framework that will improve data accessibility and assist users in the application of those data in planning decisions. In doing so, the resulting guidance will allow water-dependent and working waterfront users to communicate a more comprehensive view of water-dependent users and the values of their activities within existing land use planning deliberations and decisions.

Yong Chen, University of Maine

Incorporating Environmental and Ecological Variables to Improve Stock Assessments: An Application to Northern Shrimp in the Gulf of Maine

This project aims to incorporate environmental and ecological variables to improve the assessment of Northern Shrimp in the Gulf of Maine. Specifically, the objectives are to: (1) develop and evaluate approaches to incorporating temperature in modeling recruitment dynamics in the length-structured model; (2) evaluate various functions to link temporal variability of shrimp predator abundance with natural mortality; (3) evaluate approaches to account for time-varying natural mortality resulted from temporal changes in predator abundance in the shrimp assessment model; and (4) evaluate the impacts of incorporating temperature and predators on the quality of the stock assessment in both simulations and the assessment. Project highlights included:

- A new component that links recruitment dynamic to environmental variables has been added to the newly developed shrimp model.
- The inclusion of the environmental data greatly improved the recent estimates of recruitment that are most important to managers.
- The new size-structured assessment model with environmental variables improves the assessment of northern shrimp.
- The inclusion of spatio-temporal abundance index with environmental variables could potentially improve the shrimp assessment.
- Using auxiliary information, e.g., predation index to estimate time-varying natural mortality within the size-structured assessment model is feasible and potentially can improve the shrimp assessment.

The model developed and tested with the support of this grant will be used to assess the northern shrimp resources in the Gulf of Maine, which will improve the assessment quality of this important species, leading to improved management and resolving issues for stakeholders of this fishery.

Alexa Dayton, GMRI

Marine Resource Education Program: Southeast Fisheries Region

The Gulf of Maine Research Institute proposed to continue the collaboration with partners in the Southeast fisheries region to refine and implement another set of Marine Resource Education Program (MREP) Southeast workshops, including one three-day fishery science workshop and one three-day fishery management workshop for commercial and recreational fishermen, tailored

to the region by an 18-member Steering Committee. The format of the workshop creates an open dialogue among participants and presenters in which they explore ways of fostering cooperation among fishermen, scientists and managers. GMRI further proposed to reconvene the regional Steering Committee for a fifth annual meeting, engage them in a program review and evaluation of the third year, and foster industry leadership. Project highlights included:

- Fisheries science education program delivered for 28 fishermen and an additional 20 speakers and other guests, in St Petersburg, FL April, 2016.
- Fisheries management education program delivered for 30 fishermen and an additional 20 speakers and other guests, in Tampa, FL October, 2016.
- Reconvened MREP Southeast Steering Committee in November 2016, and with two new members.
- Fisheries science education program refined based on prior year evaluations.
- Fisheries management education program refined based on prior year evaluations.
- Performed extensive outreach and networking to generate a fifth year of program applicants.

This program enables fishermen and others to participate productively in the fisheries science and management processes, and leads to improved cooperation and trust among fishermen, scientists, and managers. Fundamentally, a co-learning approach is used in this program, where program developers, program participants, and program presenters all learn from one another through their interactions and collaborations. We fostered industry leadership through the Steering Committee construct, and workshop moderator opportunities, and saw new individuals become engaged in fisheries discussions, delivering increased leadership capacity for the region.

Keith Evans, University of Maine

Evaluating Anglers Response to Catch Restrictions: An Application to Atlantic Striped Bass

The objective of this study is to measure the economic value that recreational anglers place on keeping and releasing small, medium-sized, and trophy-sized Atlantic striped bass (*Morone saxatilis*). To meet this objective, we developed a mail/web survey sent to recreational anglers living in 10 coastal states along the east coast of the United States (Maine to Virginia). The survey collected demographic and fishing-related information about anglers and included a choice experiment (CE) mimicking alternative regulatory/cost environments. Data from the CE was the primary data source for the behavioral model in which we measure the economic value of keeping and releasing striped bass. When combined with historical catch data and biological information, the behavioral model predicts impacts of regulatory changes on fishing participation, angler welfare, and future stock levels.

This research will provide managers of the Atlantic striped bass recreational fishery important economic information about angler preferences for slot size and catch/release regulations. This type of information was identified as a research priority in the 2013 Atlantic striped bass benchmark stock assessment, which indicated the need for the "[evaluation of] striped bass angler preferences for the size of harvested fish and trade-offs with bag limits". Our study will enable policymakers to balance socio-economic objectives of fisheries management with biological goals when considering potential regulations.

Yogesh Girdhar, WHOI
Topic Modeling for Automated Underwater Image Analysis

This project aims to develop automated techniques to analyze large image datasets such as those collected by AUVs and static seafloor cameras, for the purpose of rapid visual exploration of these datasets. We explore the use of a Bayesian non-parametric topic modeling technique to automatically compute meaningful labels or tags for the datasets that can be used to identify similar regions. In addition we explore the use of these models to detect anomalous observations that are hard for the model to characterize, which we hypothesize can correspond to scientifically interesting observations. Project highlights included:

- Automatic technique to visualize large volumes of image data efficiently.
- Automatic detection of meaningful anomalies with potential scientific relevance.

This research will help us better understand our oceans, most of which have never been explored. As we increase the deployment of AUVs to collect underwater imagery, the problem now is too much data, and not enough manpower to sift through it. The proposed techniques will enable us to explore these large datasets in a more efficient manner.

Mary Hudson, GMRI
Fish Tank: Enhancing Stock Assessments

In 2015 the Gulf of Maine Research Institute (GMRI) held a series of port meetings as part of the Fish Tank series, *Collaborative Approach to Improving Stock Assessments.* The Fish Tank series brought together commercial and recreational fishermen, scientists, and policy representatives from across the region to spark productive conversations and brainstorm on ideas to improve stock assessment data and processes. *Taking Stock: A Workshop to Collaboratively Improve Stock Assessments,* held in November 2015, was the culmination of the Fish Tank port meetings.

During this workshop scientists and fishermen worked together to develop a set of prioritized research goals focused on improving stock assessments. From these goals, GMRI issued a request for proposals to the Fish Tank meeting and workshop participants, and two projects were subsequently chosen for funding:

- "*Developing Applications of Fishery Catch Rates for New England Groundfish Stock Assessments*" submitted by Steve Cadrin from SMAST, and
- "*Estimating catchability for an industry-based groundfish survey net in the Gulf of Maine*" submitted by Bill Hoffman from the MA Division of Marine Fisheries.

This project aims to further the goals of the *Taking Stock* workshop (and subsequently derived research priorities) by providing funding for the above projects. As grant administrator, GMRI will oversee and distribute monies from NEFMC, CINAR, and GMRI's Moore grant. This research benefits fishery stakeholders by enhancing the quality and completeness of the data and science that informs decision makers. By including fishermen and their data in alternative types of analysis, the PIs of this project are bridging the gap between industry and science, and providing a data perspective that has the opportunity to enhance stock assessments.

Gareth Lawson, WHOI
Developing Indices of Climate and Trophic Linkages of Euphausiids and Atlantic Herring in the Gulf of Maine Ecosystem

Atlantic herring (*Clupea harengus*) is a key prey species at the nexus of ecosystem function in the Northeast U.S. Shelf Large Marine Ecosystem (NES-LME), and supports a large commercial fishery. There is a growing body of evidence suggesting that euphausiids are also a critical component of the NES-LME ecosystem and provide an important forage base for numerous commercially important fishes, including Atlantic herring. Surprisingly little information is available, however, on the spatial and temporal patterns of euphausiid distribution, biomass, and trophic role in the Gulf of Maine/Georges Bank (GOM/GB) region. Project highlights included:

- Multi-frequency methods for identifying euphausiids in acoustic data originally collected to assess herring abundance in the GOM/GB region have been assessed and extended, resulting in time-series of euphausiid abundance, biomass, and distribution. In addition to providing key information for the present herring-focused analyses, these methods can be used in the future to characterize euphausiids based on multi-frequency acoustic data collected during other non-target surveys (e.g., biannual bottom trawl surveys).
- A time-series of consumption of euphausiids by herring and other predators during fall in the study region has also been generated, demonstrating that euphausiid are key prey items in some years and for some species. Further exploration of patterns of variability in euphausiid consumption will be an important part of the project's second year.

Successful completion of the project will provide the basis for integrated scientific advice to managers by addressing a persistent gap in our understanding of the influence of climate, habitat factors, and species interactions on Atlantic herring bioenergetics and population dynamics. The work thus addresses the CINAR themes of Ecosystem Monitoring and Ecosystem Management, is directly aligned with the NEFSC Strategic Science Plan's theme of Science in Support of Ecosystem-Based Fisheries Management, and more generally is consistent with NOAA's Healthy Oceans goal of achieving marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems.

Daphne Munroe, Rutgers University
Forecasting future range of sea scallops using a trophically-linked species distribution model: Will climate change constrain scallop distribution in the Mid-Atlantic Bight?

Population dynamics at the geographic limits of a species' range are notoriously sensitive to environmental fluctuations. The southern-most boundary of the lucrative sea scallop stock range may therefore be especially sensitive to climate change. In this project, we are investigating the effects of climate change on sea scallops in the MAB by using hindcast and forecasts of bottom temperatures and by taking into account both the direct effects of changing bottom temperatures on sea scallops and the indirect effects of temperature on scallops via changes in distribution of one of their major predators, the sea star *Astropecten americanus.* We will determine the realized niche for sea scallops with a correlative Species Distribution Model (SDM) based on habitat variables (primarily thermal parameters and substrate types) and compare this to a fundamental niche model based on documented thermal tolerances and preferred substrates. This

integrated SDM, which includes ecological interactions, can then be used with oceanographic hindcast and forecast simulations to examine how the geographic distribution of sea scallops may change under different climate scenarios. Project highlights included:

- ROMS bottom water hindcast temperature and salinity fields have been acquired and assessed relative to empirical observations obtained during NMFS/NEFSC stock surveys.
- Bottom water temperature and salinity bias has been assessed and bias correction models evaluated. The best performing bias correction model has been identified and will be used to improve temperature and salinity agreement with empirical observations.

The methodologies developed in this study will further develop existing frameworks for modeling spatial and temporal changes in population distribution and predator-prey interactions. In turn, this will provide a mechanism by which to predict the impacts of climate and environmental climate change on fisheries. Additionally, the research will identify links among the scallop fishery and climate change, help predict shifts in this resource, and will provide important information upon which sustainable fishery management decisions can be made.

David Townsend, University of Maine

Nutrient Dynamics on the NE Continental Shelf: Sample Analyses

This project was initiated in response to the need for better data coverage for dissolved inorganic nutrient concentrations in waters of the Gulf of Maine and adjacent regions of the Northeast U.S. continental shelf. This report describes progress made on our CINAR-funded project to analyze samples collected as part of the *NOAA Northeast Fishery Science Center's Ecosystem Monitoring Program* (ECOMON Program). The ECOMON Program conducts survey cruises approximately four times each year in shelf and slope waters of the Gulf of Maine – Georges Bank – Mid-Atlantic Bight. The February 2017 cruise results showed two interesting and important phenomena:

- There was clear evidence of deep winter convective mixing and nutrient recharge of surface waters in Wilkinson Basin (to our knowledge, this is the first such observation of this commonly-assumed oceanographic phenomenon).
- We observed Gulf Stream Water in the Northeast Channel, which was clearly identifiable by high salinity (>35) and warm subsurface temperature (up to 14 ºC), between depths of about 40 and 180 m, but with low nutrient concentrations; without the nutrient data, the origin of this warm and salty water mass might otherwise be confused with Warm Slope Water.

Our continued analyses of the nutrient samples collected on the ECOMON cruises will be extremely important in our interpretations of conditions of Paralytic Shellfish Poisoning (PSP) from *Alexandrium* populations, and are already being used to help initiate simulation models to forecast the severity of Gulf of Maine "red tides" months in advance. This research is also providing baseline data for future interpretations of climate change-induced alterations to the marine environment of the Northwest Atlantic continental shelf. Our data have already provided evidence in support of earlier expressed concerns about far-field effects of Arctic melting.

Robert Weller, WHOI
Ocean Climate Observations and Analyses (2016-2017)

To provide sustained, climate-quality observing of the trade wind region, we have developed surface moorings with the capability of making sustained, accurate observations at the sea surface and in the water column, and have chosen and occupied three key trade wind sites. These surface moorings are known as Ocean Reference Stations (ORS). The three sites are the Stratus ORS, the NTAS (Northwest Tropical Atlantic Station) ORS, and the WHOTS (WHOI Hawaii Ocean Timeseries Site) ORS. Together, the three sites form a comprehensive array by sampling distinct branches of the trade wind regime while focusing on specific regional processes.

In FY2016 we carried out a cruise to each of the three ORS as described above. NTAS was serviced by the RV *Endeavor* in January–February 2017. Stratus was serviced by the Chilean Navy vessel *Cabo de Hornos* during a June 2016 cruise. WHOTS was recovered and redeployed in June 2016 on the NOAA Ship *Hi'ialakai*. Stratus and NTAS involved charter funding and preparation of the associated supplemental proposals for those funds.

Through the year, we have in parallel to the field deployments worked on the analyses and publication. Among the highlights are: 1) continuing analyses of the Stratus ORS significant trends in wind speed, wind stress, latent heat flux, and het heat flux in the first ten years of observations and looking toward potential change in these trends as the PDO (Pacific Decadal Oscillation) index changes sign; 2) following up on links between NTAS ORS upper ocean temperature structure and Atlantic storm activity and working with University of New Hampshire colleagues on salinity anomalies at NTAS; and 3) continuing work with our colleagues at the University of Hawaii on covariability in local and regional surface freshwater fluxes and the WHOTS upper ocean thermohaline structure. These findings highlighted the particular value of the three ORS data sets. To make the ORS data more readily available to modelers and others, in 2015 we added a Reference Data Sets page to our web site (http://uop.whoi.edu/ReferenceDataSets/index.html) and are providing merged, quality controlled time series with the longest possible continuous time series we can construct, with an initial focus on the surface meteorological and air-sea flux time series.

John Wilkin, Rutgers University
Sustaining Development of National Ocean Service Operational Forecast Systems Based on the Regional Ocean Modeling System

NOAA and NOS have the mission and mandate to provide guidance and information to support navigation and coastal needs. To support this mission, NOS develops and implements hydrodynamic model-based Operational Forecast Systems (OFS) for sea ports, estuaries, the Great Lakes, and coastal waters. An OFS consists of the automated integration of real-time observations, hydrodynamic model forecasts, product dissemination, and continuous quality control and monitoring.

The Regional Ocean Modeling System (ROMS; www.myroms.org) is used for OFSs for the Chesapeake Bay (CBOFS), Delaware Bay (DBOFS), and Tampa Bay (TBOFS) to provide maritime community users with real-time operational products that include now-casts and short-term 1- to 2-day forecast guidance of water levels, currents, water temperature, and salinity. These parameters are fundamental physical variables for applications such as emergency response (e.g. oil spills; search and rescue) and ecological forecasting. ROMS-based OFS are in prototype development for Cook Inlet, Alaska, and the Gulf of Maine.

The specific objectives of this project are to facilitate the exchange of information between the ROMS developer group and the ROMS users at NOS so as to ensure that (i) NOS has access to and is aware of the most recent developments in the ROMS source code, (ii) NOS follows ROMS best practices, and (iii) NOS needs and recommendations for code modifications are conveyed to the developers and implemented in the community to make NOS user experience accessible to the broader ROMS user community.

Introduction

The Cooperative Institute for the North Atlantic Region (CINAR) is a regional CI that focuses on the U.S. northeast continental shelf (NES) large marine ecosystem (LME) that encompasses the shelf from Cape Hatteras to Nova Scotia - one of the world's most highly productive marine ecosystems. The structure and dynamics of the NES ecosystem are strongly influenced by local, regional, and basin-scale environmental forcings and by a range of human activities including fishing, the discharge of nutrients and other pollutants, and development along the coast. There is also a growing recognition of ecological impacts from climate change and ocean acidification.

CINAR is a consortium of five partner institutions that together span the geographic range of the NES and provide the required breadth, depth and quality of scientific expertise, instrumentation, models, and facilities to address many of NOAA's needs in the region. Partners include the University of Maryland Center for Environmental Science (UMCES), Rutgers University (RU), the Woods Hole Oceanographic Institution (WHOI), the University of Maine (UME), and the Gulf of Maine Research Institute (GMRI). The CINAR Program Office is located at WHOI.

CINAR Vision, Mission, Goals and Organization

Our vision for CINAR is as an essential component of the NOAA research and management capability in the northeast region, functioning as a mechanism that allows NOAA scientists to easily and rapidly obtain research assistance for ongoing projects, that contributes to the science planning process in NOAA, and that anticipates and responds to technical needs through the development of instruments, models, and approaches that contribute to management decisions.

CINAR's philosophy of operations focuses on research, transition of research to applications specific to NOAA's mission and goals, and a range of education and outreach activities to train new NOAA scientists, enhance knowledge and expertise of existing scientists, and communicate research results. Our overarching goal is to dramatically improve the predictive science that enables sound management, while concurrently informing the general public and stakeholders of the complexities and importance of ecosystem-based management of NES LME resources.

The mission of CINAR is to engage NOAA and academic scientists in cutting-edge research that enables NOAA to make informed decisions about sustainable and beneficial management of the northwestern Atlantic shelf ecosystem.

Working within the geographic framework of the NES LME, the goals of CINAR are:

1. To establish CINAR as a leader in promoting "rational ocean stewardship" and serving as a model for development of similar ecosystem approaches to management in other regions;

2. To coordinate research, education and outreach with NOAA scientists in support of responsible stewardship of coastal and marine resources in the region;

3. To conduct research that identifies and evaluates linkages among productivity, fish and fisheries, pollution, climate change and ecosystem health;

4. To conduct research and develop decision-support tools for sustainable fisheries management;

5. To conduct research and develop tools to restore degraded habitats and support restoration and rebuilding of protected species to healthy population levels;

6. To improve integration and availability of ocean observations from global to local scales;

7. To provide mechanisms for transition of predictive/forecasting and monitoring tools into operational use for management;

8. To improve ability to distinguish shifts in marine resource status caused by human impact from those due to climate and other natural forcing;

9. To develop robust indicators of ecological health and socioeconomic benefits that can be utilized by resource managers; and

10. To develop, carry out, and sustain key observational components of NOAA ocean observing missions.

CINAR Organization

CINAR is managed and administered through the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. Donald M. Anderson, the CINAR Director, has overall management responsibility for CINAR providing leadership with NOAA and with the CINAR Council of Fellows. He is responsible for scientific leadership of CINAR and for ensuring maintenance and development of scientific programs and priorities. The CINAR Director has budgetary authority over Task 1 (administrative) activities and accountability for Task 2 and 3 activities, subject to review and advice of the Executive Board. The administrative structure of CINAR is shown in Figure 1.

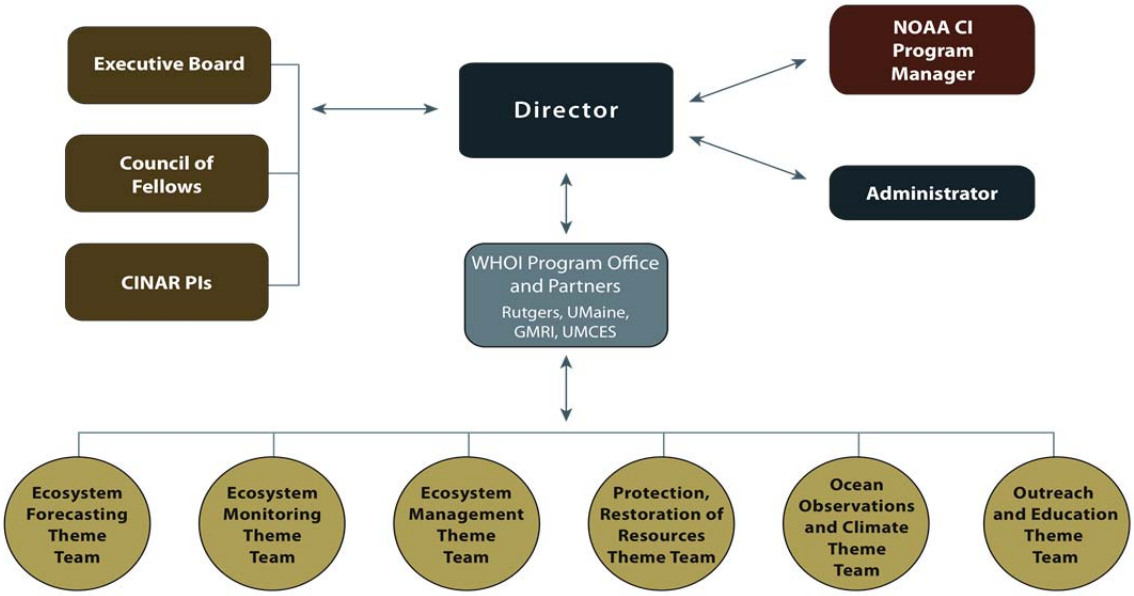


Figure 1. Organizational structure of CINAR.

CINAR PIs

The CINAR PIs include Donald M. Anderson, *CINAR Director, Woods Hole Oceanographic Institution*; Mark Miller, *Professor, Environmental Science, Rutgers University*; Michael Roman, *Director, Horn Point Laboratory, University of Maryland Center for Environmental Science*; Fei Chai, *Director, School of Marine Sciences, University of Maine*; and Andrew Pershing, *Chief Scientific Officer, Gulf of Maine Research Institute*. The CINAR PIs meet regularly in person or via conference call to discuss issues and to ensure that partner institutions are updated on CINAR activities.

CINAR Executive Board

The Executive Board consisting of senior employees from NOAA, WHOI, and at least one of the other CINAR consortium members, provides a senior management linkage to NOAA to guide the programmatic priorities and policy directions of CINAR. Members of the Executive Board participate in annual meetings, and represent the views of their program or branch within NOAA so as to facilitate beneficial interactions between NOAA scientists and CINAR. The Executive Board includes representatives from NOAA line offices and goal teams that have research interests in the North Atlantic region.

The CINAR Executive Board members are:

Jonathan Hare, Chair	NMFS NEFSC
Venkatachalam Ramaswamy	OAR Representative
Russell Callender	NOS Representative
Ned Cyr	NMFS/OST
Donald Anderson	CINAR Director
Fei Chai	CINAR PI, University of Maine
Peyton Robertson	North Atlantic Regional Team Representative
Laurence Madin	WHOI Leadership
Candice Jongsma	OAR CI Program Director

CINAR Council of Fellows

Chaired by the CINAR Director, the Council of Fellows is the primary planning and consultative body of CINAR. Responsibilities include participating in conference calls and occasional in-person meetings and discussion of issues related to the administration and oversight of CINAR. NOAA Council members are expected to serve as a conduit for information in both directions between NOAA and CINAR, including the identification of research opportunities for the CINAR partners.

Membership includes: one senior representative from each CINAR partner institution (GMRI, RU, UMaine, and UMCES), the CINAR Director; a senior manager from the NEFSC; OAR Climate Program Manager (or designee); and NESDIS/NCDC representative. The OAR CI Program Director serves as a special advisor to the Council in an *ex officio* status.

The CINAR Council of Fellows members are:

Donald Anderson, Chair	CINAR Director
Mark Miller	CINAR PI, Rutgers
Michael Roman	CINAR PI, UMCES
Fei Chai	CINAR PI, University of Maine
Andrew Pershing	CINAR PI, Gulf of Maine Research Institute
Paulinus Chigbu	MSI Representative / UMCES
Jonathan Hare	NMFS/NEFSC
Ellen Mecray	NESDIS/NCDC
Candice Jongsma, *ex officio*	OAR CI Program Director

CINAR Theme Leaders

Includes individuals from the partner institutions with long-term and significant interactions with NOAA who will serve as representatives for their respective CINAR research theme. Each leader is supported by Theme Coordinators at each partner institution, each of whom represents a large group of participating investigators, as identified on the CINAR web site (www.cinar.org).

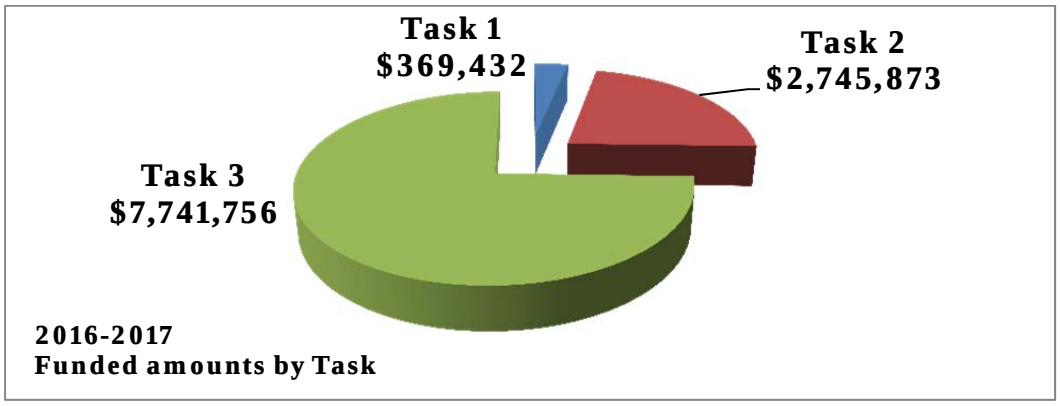
CINAR Research and Administrative staff

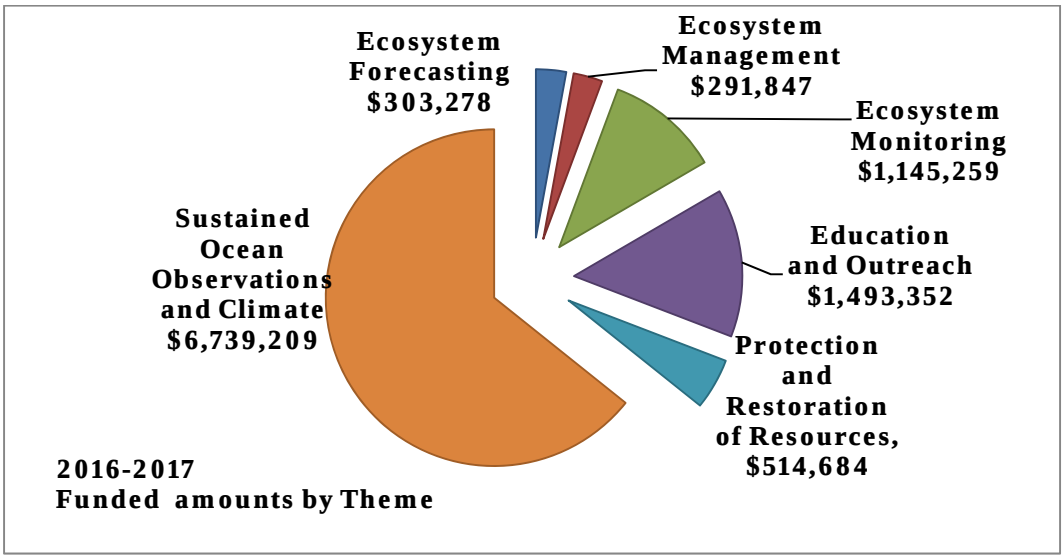
WHOI and the partner institutions provide the administrative staff for grants and contracts management, human resource management, systems administration, procurement, and all necessary support staff roles for CINAR activities. CINAR uses the services of researchers through an appropriate combination of tenured or tenure-track faculty in academic departments, and non-tenure track faculty. Each institution is responsible for appropriate oversight of faculty research activities. CINAR actively promotes undergraduate and graduate education through internships, cooperative experiences, graduate assistantships, and fellowships. CINAR management and administration is carried out by Mindy Richlen and Ann Stone.

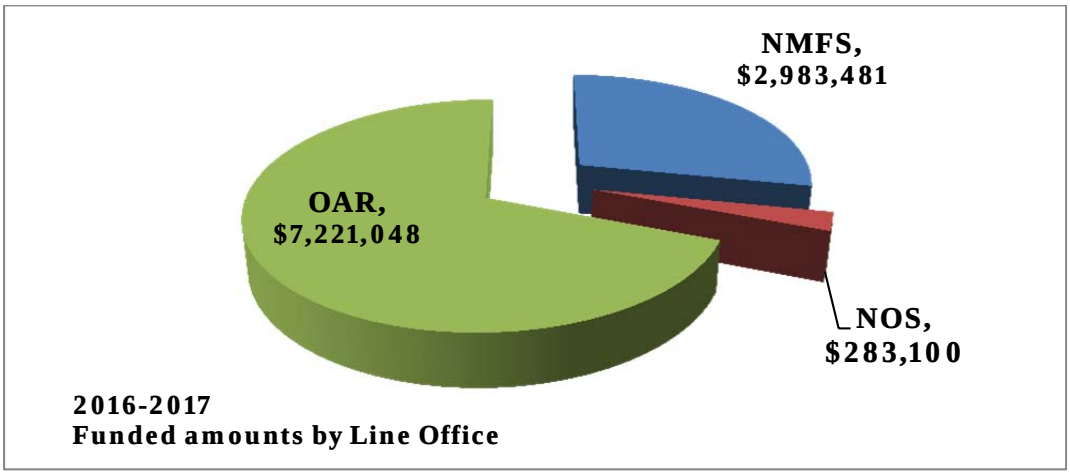
CINAR Program Office

Donald Anderson	CINAR Director
Mindy Richlen	CINAR Associate Director
Ann Stone	CINAR Administrative Professional

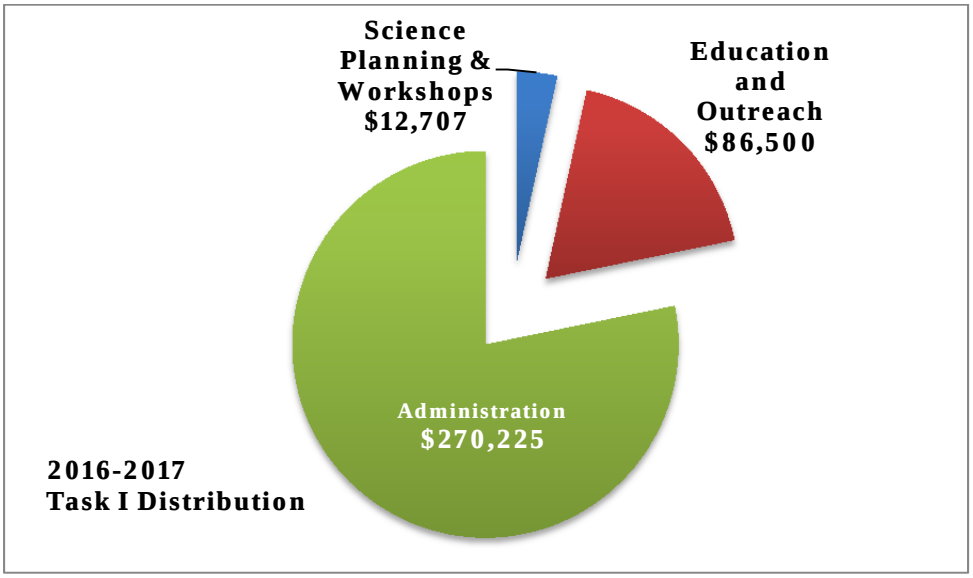
Distribution of NOAA Funding by Task, CINAR Themes and NOAA Line Office







Task I Activities with Distribution of Funding



Task I funding received from NOAA during this period totaled $369,432. WHOI provided $76,141 as cost-sharing to cover salary and related costs for part of CINAR Director Anderson's time.

Data Management

The NSF funded Biological and Chemical Oceanography Data Management Office (BCO-DMO) continues to make available the New England Fisheries Science Center (NEFSC) EcoMon data on the hydrography and biology of Gulf of Maine. These data can be accessed via the following URLs:

Hydrography:
http://www.bco-dmo.org/dataset/3309

EcoMon 10m2:
http://www.bco-dmo.org/dataset/3327

EcoMon 100m3:
http://www.bco-dmo.org/dataset/3328

Additional information about the NEFSC and these projects is available at: http://www.bco-dmo.org/program/2023

Education and Outreach

Undergraduate student training: CINAR continued its Minority Traineeship program in 2016, which provides funding for one undergraduate minority traineeship at each partner institution each summer. This program will continue through the upcoming year, and we are in the process of appointing minority trainees throughout the CINAR consortium for summer 2017.

WHOI-NEFSC Special Seminar Series on Fisheries and Ecosystems Acoustics: This seminar series continued through 2016-2017, sponsored jointly by NEFSC, CINAR, and the WHOI Biology and Applied Ocean Physics and Engineering Departments, and co-convened by CINAR Fellow Gareth Lawson, Andone Lavery, and Tim Stanton of WHOI, together with Michael Jech of NEFSC. The series focuses on bio-acoustics, both passive and active, emphasizing applications and technological developments relevant to fisheries and ecosystem research and management as well as protected species conservation. The intent is to promote interactions between WHOI and NEFSC personnel on these topics and in general. In order to maximize attendance from both institutions, the seminars take place in the NEFSC Clark Conference Room and occur as a special seminar during the regular AOPE time slot. The talks are also distributed live as a webinar, via the OneNOAA Science Seminar series.

The seminar series has been very well received. The presentations have covered a variety of topics, including how new newly developed broadband acoustic techniques can be used to classify swimbladder-bearing fish (Tim Stanton, WHOI), an overview of estimated euphausiid biomass in the Georges Bank region from 1999 – 2012 (Michael Jech and Gareth Lawson), and how soundscapes can be used to identify differences in the composition of coral reef communities (T. Aran Mooney, WHOI).

Remote attendance via the webinar has equally been high, with participants joining in from as far away as the PIFSC in Hawaii (despite the time change). The webinar system has successfully allowed these participants to engage fully in the seminars by asking questions and making comments, and the large number of remote attendees indicates a strong interest in this topic. In the coming year the seminar series will continue with talks from WHOI and NEFSC scientists, and increasingly with speakers drawn from the greater region.

CINAR Research Summaries

The following pages provide research summaries of the CINAR projects funded through the period April 1, 2016 through June 30, 2017, organized by theme.

Theme I. Ecosystem Forecasting

Donald Anderson, WHOI: *Gulf of Maine Annual Cyst Cruise and Sample Analysis*

Robert Beardsley, WHOI: *Technical Support and Improvement of FVCOM for NOAA Modeling Activities*

Klaus Huebert, UMCES*: OA- Specific IBMs as Synthesis Tools for Northeast USA Finfish*

Maria Kavanaugh, WHOI: *Multi-scale Predication of California Current Carbonate System Dynamics*

Daphne Munroe, Rutgers: *Forecasting future range of sea scallops using a trophically-linked species distribution model: Will climate change constrain scallop distribution in the Mid-Atlantic Bight?*

David W. Townsend, UMaine: *Nutrient Dynamics on the NE Continental Shelf: Sample Analyses*

John Wilkin, Rutgers: *Sustaining Development of National Ocean Service Operational Forecast Systems Based on the Regional Ocean modeling System*

Theme II. Ecosystem Monitoring

Mark Baumgartner, WHOI: *Passive Acoustic Monitoring from Autonomous Platforms*

Yong Chen, UMaine: *The Annual Eastern Gulf of Maine Sentinel Jigging/Longline Survey/Fishery in 2014 to 2018*

Cabell Davis, WHOI: *Construction and testing of a plankton imaging and identification system in gliders and drifters for use in low-cost plankton observing systems*

Steve Eayrs, GMRI: *Supplement to: Application of electronic vessel trip reporting by the New England fishing industry*

Scott Gallager, WHOI: *Operational Support for HabCam Data Processing during 2016*

Yogesh Girard, WHOI: *Interactive Visualization of Large Benthic Image Datasets using Topic Modeling*

Mary Hudson, GMRI*: Fish Tank: Enhancing Stock Assessments*

Michael Moore, WHOI*: Assessing the pathogenesis and host susceptibility to dolphin morbillivirus in cetaceans*

Michael Moore, WHOI: *Drone-derived measures of respiratory microbiome and girths: non-invasive indicators of right whale health*

Donald Peters, WHOI: *A Passive Acoustic Ocean Observing System for Monitoring and Mapping Marine Mammals and Noise in the Chukchi Sea Ecosystem*

Yogesh Girard and Hanumant Singh, WHOI: *UHIS 2015 Cruise*

Yogesh Girard: *Topic Modeling for Automated Underwater Image Analysis*

Theme III. Ecosystem Management

Andrew Bowen, WHOI: *2016 ROV Jason R/V Sikuliaq*

Yong Chen, UMaine: *Incorporating Environmental and Ecological Variables to Improve Stock Assessments: An Application to Northern Shrimp in the Gulf of Maine*

Keith Evans, UMaine*: Evaluating Anglers' response to Catch Restrictions: An Application to Atlantic Striped Bass*

Gareth Lawson, WHOI: *Developing Indices of Climate and Trophic Linkages of Euphausiids and Atlantic Herring in the Gulf of Maine Ecosystem*

Theme IV. Protection and Restoration of Resources

Enrique Curchitser, Rutgers: *Assessing Regional Sea Ice Predictability in the U.S. Arctic: A Multi-Model Approach*

Matthew Campo, Rutgers: *Addressing Coastal Hazards in the Mid-Atlantic*

Kathy Mills, GMRI: *Impacts of a Changing Ecosystem on Atlantic Salmon Marine Productivity*

Michael Moore, WHOI: *Developing a Biocompatible Large Whale Tracking Tag*

Michael Moore, WHOI: *Effects of Oil, Chemical Disperant and Dispersed Oil on the Functional Characteristics of Mysticete Whale Baleen:*

Theme V. Sustained Ocean and Observations and Climate

Donald Anderson, WHOI: *Global Ocean Observing Coordination Activities*

Heather Benway, WHOI*: Ocean acidification coordination and community building: The 4th International Symposium on the Ocean in a High-CO2 World and the 3rd Global Ocean Acidification Observing Network Science Workshop*

Steven Jayne, WHOI: *The Argo Project: Global Observations for Understanding and Prediction of Climate Variability*

Malin Pinsky, Rutgers: *Tracking Changes in North American Marine Species Distributions*

Robert Weller, WHOI: *Ocean Climate Observations and Analyses (2016-2017)*

Robert Weller, WHOI: *Ocean Climate Observations and Analyses - ORS Buoy Logger Iridium Upgrade*

Robert Weller, WHOI: *Ocean Reference Stations Supplement: 2016 NTAS Ship Charter*

Riley Young Morse, GMRI: *Accessing and visualizing satellite data for use by fisheries managers in the Northeast*

Lisan Yu, WHOI: *50 Year Global Ocean Surface Heat Flux Analysis*

Theme VI. Education and Outreach

Donald Anderson, WHOI: *Research and Education in Quantitative Fisheries and Ecosystem Science*

CINAR Fellow: Scott Gallager, WHOI
CINAR Fellow: Joel Llopiz, WHOI
CINAR Fellow: Heidi Sosik, WHOI
SMAST Faculty, Gavin Fay

Donald Anderson, WHOI: *U.S. National Office for Harmful Algal Blooms*

Andrew Bowen, WHOI: *2016 AUV Sentry Nizinski Cruise, 2016 ROV Jason R/V Sikuliaq Cruise*

Alexa Dayton, GMRI: *Marine Resource Education Program (MREP): Serving the Needs of Fishing Communities and Fishery Management in the Northeast Region*

Alexa Dayton, GMRI: *Marine Resource Education Program – Southeast*

Hudson, GMRI: *Enhancing Industry Input in Stock Assessments*

Timothy Shank, WHOI: *Advancing the International Deep-Sea Coral Symposium Supplement*

Gayle Zydlewski, UMaine: *UMaine Cooperative Education*

THEME I . ECOSYSTEM FORECASTING

Gulf of Maine Annual Cyst Cruise and Sample Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Donald Anderson, WHOI

NOAA Sponsor – Richard Stumpf, NOS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Education and Outreach***

Amount Funded: $ 68,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

Over the past several years, an important management tool for red tides or toxic *Alexandrium* blooms in the Gulf of Maine (GOM) region has been a numerical model of bloom dynamics developed at the Woods Hole Oceanographic Institution (WHOI). Each week during the bloom season, this model is run, providing a "hindcast" simulation of *Alexandrium* distribution and abundance for the preceding weeks and months, as well as a one-week short-term forecast based on weather predictions. These weekly forecasts are distributed to managers and researchers in the region via the Northeast PSP listserv (over 200 members). The model is initiated from a map of *Alexandrium* cyst abundance in GOM bottom sediments, and a new map is produced each year from the samples collected from annual cyst surveys. A secondary goal of project activities is to evaluate qPCR as an alternative to traditional enumeration of cysts using fluorescence microscopy.

Cysts are an important part of the organism's life cycle. Cysts are formed when asexually dividing vegetative cells in the overlying bloom waters undergo sexual reproduction and produce new cysts that are deposited to the surface sediments. Those cysts form "seedbeds" that germinate and inoculate the overlying waters in the following year(s) to re-establish subsequent blooms. Past studies have shown that the abundance of cysts in the region varies dramatically year-to-year, and that the cyst abundance measured during the fall or winter in one year is a first-order predictor of the regional bloom magnitude in the next year. This knowledge, as well as the observation of a very high cyst abundance in 2007, led to a seasonal forecast of a major red tide in the GOM in 2008, a forecast that was borne out with extensive shellfish closures in Maine, New Hampshire, and Massachusetts, as well as offshore federal waters. Seasonal forecasts have been made every year since, based on the annual cyst map. Information generated from this project will be used to provide the annual seasonal forecast of harmful algal bloom (HAB) in the GOM and weekly forecasts during each bloom season.

Year 2 of this project was not funded, necessitating modifications to the scope of work. Samples were collected this year for both microscopic enumeration and qPCR analysis; however, beginning in 2017, sample collection, processing, and analysis will focus on microscopic

enumeration of cysts only, and will not include analyses using qPCR.

ACCOMPLISHMENTS

Samples were collected during the NOAA Pisces Cyst Cruise from November 12-18, 2016. Approximately 60 stations were occupied during the cruise, and sample collection and processing procedures were very similar to last year's cruise. At each station, a Craib corer was deployed and a relatively undisturbed surface sediment core was collected. The core was extruded onboard and sectioned into two layers; the top 0-1 cm and the underlying 1-3 cm layers. The sediment samples were processed onboard using standard cyst techniques that are routine in the Anderson lab but were transitioned to NOAA personnel that served on the cruise. That processing included protocols for dilution of the raw sediment, sonifying and sieving the sample to yield a 20-100 µm particulate fraction that was initially preserved in 2% formalin and exchanged onboard into 100% methanol for long term storage until counting began.

As in 2015, a portion of each sediment layer was subsampled for analysis using a qPCR assay for *Alexandrium* cysts. This work is evaluating qPCR as an alternative to cyst enumeration using fluorescence in situ hybridization (FISH) and microscopy. Sample collection, processing, and DNA extraction followed procedures established in 2015. Samples were first treated with freshwater to remove extracellular DNA debris and heat to improve cyst lysis and increase DNA yield. Analysis is currently underway, and will follow the same procedures as last year.

Cyst concentrations obtained using traditional counting methods were provided to Dr. Dennis McGillicuddy (WHOI) for preparation of contour plots and cyst abundance calculations for each layer and sub-regions within the GOM (Fig. 1), and to McGillicuddy, Ruoying He (NCSU), and Rick Stumpf (NOAA) for *Alexandrium* GOM model simulations under a separately funded project.

HIGHLIGHTS

- Model simulations based on the 2016 cyst abundance were completed during winter in 2017, and the bloom prediction was released (https://coastalscience.noaa.gov/news/habs/small-bloom-predicted-gulf-maine-red-tide-2017/).
- Cyst abundances in 2016 were similar to 2015, but low compared to prior survey years (2004-2014).
- Efforts contribute to the successful transition of the cyst cruise from WHOI to NOAA personnel for long term operations of that program.

SOCIETAL BENEFITS

Harmful algal blooms are a serious and growing threat to the nation's fisheries, coastal ecosystem and human coastal communities. Surveys of the *Alexandrium fundyense* cyst seedbed in the GOM provide a critical piece of information for forecasting future blooms in the region. Data from this project are used to improve an important management tool for HABs.

EDUCATION AND OUTREACH ACTIVITIES

This project included the participation of a Northeastern University cooperative program (undergraduate) student, who received training in *Alexandrium* cyst identification and enumeration as well as training in sample processing techniques.

Results of the cruise were discussed at a meeting of academic researchers, regional stakeholders (ME, NH, and ME shellfish resource managers), and NOAA managers as part of the 2017 seasonal PSP forecast discussion.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

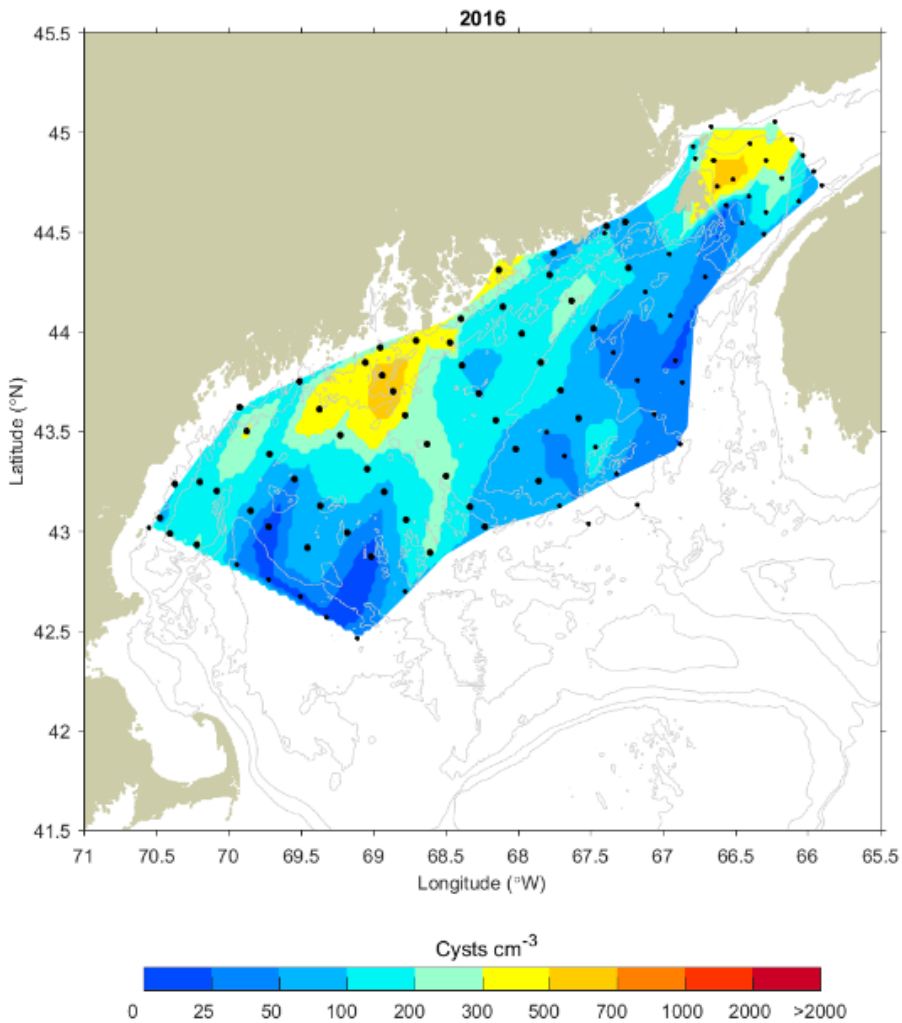


Figure 1. Concentrations of *Alexandrium* cysts in Gulf of Maine bottom sediments, 2016, determined using microscopic enumeration. These data were used in forecasting models to determine the intensity of future blooms in the region.

Technical Support and Improvement of FVCOM for NOAA Modeling Activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Robert Beardsley, WHOI

NOAA Sponsor – Eugene Wei, NOS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 50,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

The objectives of this project are to: 1) hold an FVCOM workshop at NOAA Coast Survey Development Laboratory (CSDL) to update NOAA modelers on FVCOM and to address NOAA questions; 2) host CSDL modelers for technical consultation at UMASSD as needed; 3) hold conference calls with CSDL modelers as needed; and 4) support CSDL in applying FVCOM multi-domain nesting techniques. Advanced new techniques are being developed for the US Northeast Coastal Ocean Forecast System (NECOFS). FVCOM teams will provide updated examples of techniques used for NECOFS to support the NOAA modeling activities.

ACCOMPLISHMENTS

- CSDL-WHOI-UMASSD organized a FVCOM workshop at CSDL on September 13-14, 2016. Robert Beardsley (WHOI) and Changsheng Chen (UMASSD) gave a joint presentation entitled *Update of FVCOM Development and Improvement* and *FVCOM multi-domain nesting couplers*. During the workshop, Beardsley and Chen addressed questions about the use of the updated FVCOM codes, and worked together with CSDL scientists to solve code issues in the NOAA FVCOM applications. The CSDL scientists gave several reports on the FVCOM forecast system development in the Gulf of Mexico shelf, San Francisco Bay, and Great Lakes, including both the hydrodynamics and freshwater icing. The workshop was very productive and many questions were addressed and solved during the open discussion.
- We have been upgrading FVCOM by implementing: a) a new vector matrix approach in the surface wave iteration, b) ice embedding process, and c) current-wave-sediment interactions with inclusion of cohesive sediment processes as well as re-constructing the offline ecosystem model codes. We have provided NOAA with the new version of FVCOM (FVCOM v4.0).
- We arranged several conference calls with CSDL and GLERL scientists to help them solve several code issues. Prior to each conference call, CSDL collected questions from NOAA

FVCOM users and delivered these to us. We then reviewed these questions and provided our answers and explanations during the conference calls or via email.

- We upgraded the FVCOM code by implementing the corrections and changes made by the NOAA FVCOM users.
- We shared results of the NOAA-UMASS-WHOI collaboration in the FVCOM improvement with the FVCOM users at the *2016 FVCOM User Workshop* at Bedford Institute of Oceanography, Halifax, October 17-20, 2016.

HIGHLIGHTS

- Provided regular technical support for CSDL and GLERL during development of the FVCOM-based forecast system in NGOM, San Francisco Bay, and the Great Lakes.
- Shared the updated FVCOM code (version 4.0) with NOAA CSDL and GLERL.
- Helped modify the FVCOM modules to meet NOAA CSDL and GLERL needs in the forecast system development.
- Debugged NOAA FVCOM codes and upgraded the FVCOM with inputs from CSDL and GLERL scientists.
- Upgraded the FVCOM ice modules for options used for the freshwater system. The modification was made based on the NOAA FVCOM users' inputs.

SOCIETAL BENEFITS

- Shared FVCOM development with public users, which helped individuals from other coastal regions utilize the applications of FVCOM.
- The development of the FVCOM forecast system provided the public with real time ocean environmental conditions, to the benefit of marine health evaluation, navigation, ocean rescues, and storm-induced coastal inundation.
- Updated the existing NOAA forecast system to improve nesting approaches.

EDUCATION AND OUTREACH ACTIVITIES

- Helped trained the new generation modelers in NOAA labs and users from the Canadian government agencies, particularly in the use of unstructured grid models.
- Enhanced communication between graduate students in academic universities and scientists in NOAA laboratories.

PUBLICATIONS

Released the FVCOM version 4.0 by adding all new modules developed for NOAA forecast operations.

Siqi Li, S., Chen, C., Wu, X., Beardsley, R.C., Li, M. (in review) *Impacts of ocean dynamics and parameterizations on hurricane simulation: an experiment for Hurricane Sandy with ARW,* submitted for publication by the Monthly Weather Review.

OA-Specific IBMs as Synthesis Tools for Northeast USA Finfish

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Klaus Huebert, UMCES

NOAA Sponsor – Chris Chambers, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 42,811

PROJECT OVERVIEW, GOALS, AND MILESTONES

We are undertaking a modeling effort to help synthesize experimental information on the biological responses of fish to elevated CO_2, and to more fully understand fish population consequences of the observed experimentally induced effects of CO_2 on individuals. At its core, this project uses experimental data on biological effects of CO_2 on winter flounder, *Pseudopleuronectes americanus*. Most studies providing such CO_2-specific data were conducted at the NOAA Howard Laboratory. We are using the experimental data along with basic life history and ecological rate parameters to construct computer models of ecological and population processes in winter flounder, but we expect the results to be translatable to other marine fish species in other habitats. In general, these models simulate interactions between the environment and fish life-history, including detailed biological responses of highly sensitive fish eggs and larvae to CO_2. Importantly, this approach allows exploration of population-level consequences carried beyond the early life stages. Such information is fundamental to understanding the community and ecosystem effects of ocean acidification on living marine resources.
Initially, we are using winter flounder as our model species. It is an economically important, well-studied fish, and prior studies provide measurements of CO_2 effects on key life-history parameters (e.g., egg fertilization, larval growth, development, and survival). The winter flounder model will be used to evaluate population responses under multiple scenarios, such as high and variable CO_2 depicting future inshore, estuarine habitats. Other environmental stressors (e.g., warmer water with less dissolved oxygen) will also be included.

Beyond providing a quantitative evaluation of responses of winter flounder to future climate and OA scenarios, this work will also develop a web-based modeling tool that would allow users to add details appropriate for other marine fishes. With this tool, researchers can tailor the model's parameters for fish life history and environmental variance as appropriate for the species and habitat of interest, then probe the consequences of shifts in life history and changes in the environment as might be expected under various IPCC scenarios for carbon combustion and atmospheric CO_2.

ACCOMPLISHMENTS

Please note that the CINAR contract funding this research was not finalized until late October 2016. We have already made progress towards several project milestones.

First, we have conducted an extensive literature search for field and laboratory data that can be used to parameterize or validate our winter flounder individual-based model (IBM), and make improvements over previous modeling studies by Chambers et al. (1995) and Rose et al. (1996). We are continuing to collect and incorporate additional data from NOAA and the literature specific to variation in traits and rate parameters for winter flounder.

Second, we have developed much of the required *R*-language code for our winter flounder IBM. Our model is based loosely on the *FORTRAN* code used by Chambers et al. (1995) and Rose et al. (1996), with similar characterizations of egg attributes (size, survival) and yolk-sac larvae (size, yolk depletion rate). We also adapted existing *R* code from the Quirks model (Huebert and Peck 2014) for larvae and juveniles (foraging, growth rates). Our model approximates the effects of mortality by modeling 'super-individuals' (Scheffer et al. 1995) in contrast to the earlier formulation by Rose et al. (1996) wherein dead individuals were replaced by a resampling process from the pool of survivors. Our improvements to the Quirks code include an allowance for previously fixed biological traits to vary during ontogeny. Reproduction (fecundity, spawning season duration) is represented by novel formulations, based on our literature review.

Third, we are testing preliminary model parameterizations by using our IBM to mimic the conditions described in published winter flounder studies and then comparing our model output to the original data. For example, model predictions of larval growth are already quite accurate, including the loss of dry mass observed in laboratory starvation trials (Fig. 1).

Fourth, a university web server was set up with "*R Shiny*" software to host web interfaces for our models. We have also modified the *R Shiny* Quirks web interface, which is our starting point for developing the NE finfish portal, to allow user-defined larval fish parameterizations and simulations.

HIGHLIGHTS

We have developed a new computer model that simulates one year of winter flounder growth, including the development from eggs to juveniles, in great detail.

SOCIETAL BENEFITS

Improved fish population models, which include the long-term effects of ocean acidification on fish early life stages, can aid in the management of living marine resources.

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FIGURES/PHOTOGRAPHS/ILLUSTRATION

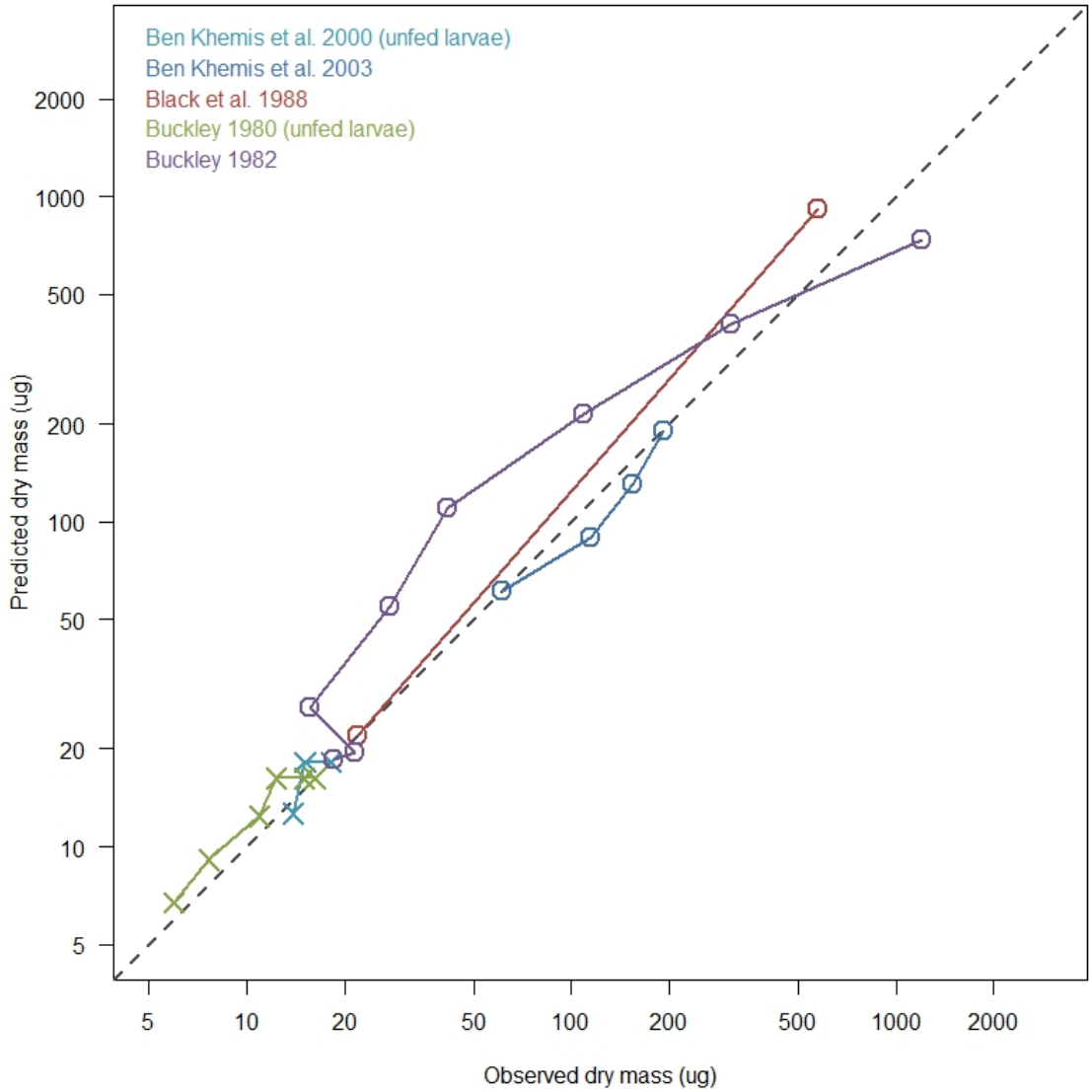

Figure 1. Growth of winter flounder larvae observed in five published studies and predicted by our model. Model simulations were set up to match each study with respect to temperature, photoperiod, prey conditions, and initial fish length and mass. Points near the dashed 1:1 line indicate a good match between observed and predicted mass. Note that both positive growth of fed larvae and negative growth of unfed larvae are considered.

Multi-scale Prediction of California Current Carbonate System Dynamics

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Maria Kavanaugh and Scott Doney, WHOI

NOAA Sponsor – Libby Jewett (OAP) and Dwight Gledhill (OAP)

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 46,561

PROJECT OVERVIEW, GOALS, AND MILESTONES

We are embedding the existing semi-analytical and carbonate prediction model within a dynamic classification of pelagic seascapes derived from satellite remotely sensed variables, including, but not limited to, phytoplankton standing stock (chl-a), SST, SSS, and wind stress. We will produce synoptic time series and nowcasts of surface TCO_2, TALK, pH and Ω that will facilitate regional comparisons of interannual trends in OA parameters. We will include metrics of model and spatiotemporal uncertainty to better inform management decisions. These maps will be validated with the wealth of multi-parameter OA data from coastal moorings, West-coast OA cruises, and shore-based Burke-O-Lators with which the PIs are intimately familiar. Finally, statistical analyses of local deviations from seascape-based predictions will disentangle basin-scale oceanic vs. local drivers of the carbonate system.

***Products (and timeline) will include*:**

- *Dynamic maps of carbonate system parameters for the California Current system (10-01/2016-9/31/2017).* Maps will be tuned using a semi-analytical model using historical in situ data, extended with abundant new measurements, embedded within a dynamic classification of pelagic seascapes. Seascape maps have been produced and running of the semi-analytical algorithm is underway. Maps will be validated with data for the shelf from existing archives and generated in near real-time with associated probabilistic distributions. Uncertainty will be parsed out as a function of spatiotemporal variability and skill of the regional model. For example, pCO_2 in a given feature or region may have high predictive potential, even while region boundaries may vary greatly.
- *Synthesis of existing very nearshore and within-embayment carbonate system and environmental data* (including Level 1 and 2 satellite data at 1 km and daily resolution) *to link open shelf conditions to local sites of ecological and economic interest (10/01/2017-6/30/2018).*
- *Analysis of oceanic (regional and global) vs. local drivers of change to the carbonate system (05/01/17-9/30/2018)* Deviations of local conditions from that predicted from seascape conditions may indicate local sources of nutrients and freshwater leading to local to

embayment effects of bacterial respiration (DIC) and reduced alkalinity on the carbonate system.

ACCOMPLISHMENTS

Seascape maps of the CCS have been produced and the semi-analytical algorithm has been modified to run in the dynamic space. Preliminary results have been presented at the NOAA OAP meeting (January, 2017; Seattle WA).

WHOI Partnership in Education Program student, Kanieka Neal, validated patterns of salinity and alkalinity in dynamic seascapes using GLODAP V2 data and identified robust, yet distinct relationships within dynamic seascapes.

SOCIETAL BENEFITS

- *Seascape-based predictions will provide both visualization and syntheses of changing ocean carbonate chemistry at multiple scales* within the CCS, providing a synoptic time series of a range of OA parameters.
- Nowcasts will serve as *early indicators for vulnerable ecologically and economically important populations on the shelf*. Historical analyses and nowcasts will have estimates of model and spatiotemporal uncertainty to inform management decisions.
- *Synthesis and integration of existing very nearshore carbonate system data collected as part of OAP funded research* with high-resolution (1 km) seascape information will allow determination of the contribution of regional drivers to local conditions.

EDUCATION AND OUTREACH ACTIVITIES

Kanieka Neal presented a poster at the Summer Student Fellow Symposium (WHOI; August 2016)

Kavanaugh presented a poster at the OAP Annual meeting (Seattle; January 2017), entitled *Multiscale Prediction of California Current Carbonate System Dynamics*.

Forecasting Future Range of Sea Scallops using a Trophically-linked Species Distribution Model: Will Climate Change Constrain Scallop Distribution in the Mid-Atlantic Bight?

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Daphne Munroe, Rutgers University

NOAA Sponsor – Deborah Hart, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 38,867

PROJECT OVERVIEW, GOALS, AND MILESTONES

Population dynamics at the geographic limits of a species' range are notoriously sensitive to environmental fluctuations. The southern-most boundary of the lucrative sea scallop stock range may therefore be especially sensitive to climate change. In this project, we are investigating the effects of climate change on sea scallops in the MAB by using hindcast and forecasts of bottom temperatures and by taking into account both the direct effects of changing bottom temperatures on sea scallops and the indirect effects of temperature on scallops via changes in distribution of one of their major predators, the sea star *Astropecten americanus.* We will determine the realized niche for sea scallops with a correlative Species Distribution Model (SDM) based on habitat variables (primarily thermal parameters and substrate types) and compare this to a fundamental niche model based on documented thermal tolerances and preferred substrates. This integrated SDM, which includes ecological interactions, can then be used with oceanographic hindcast and forecast simulations to examine how the geographic distribution of sea scallops may change under different climate scenarios.

ACCOMPLISHMENTS

The project has been initiated and bottom water temperatures have been extracted from ROMS results and transferred to project postdoc, Jui-Han Chang. Bottom water conditions observed during the NMFS/NEFSC stock surveys, conducted in spring and fall of each year (which occur near the annual minimum and maximum bottom temperatures) have been used to analyze the accuracy of the hindcast ROMS model bottom temperature and salinity solutions. A bias was detected in the ROMS output; therefore, a bias correction effort was undertaken. Roughly 150 different bias correction models were tested using five-fold cross validation for each model variable. The performance of the bias correction was assessed using RMSE for overall predictions and Moran's I for spatial autocorrelations of residuals (summed over all years and month). The bias correction model substantively improved the fit of ROMS model temperature

and salinity output relative to CTD cast observations. Next steps will include production of species distribution correlations, and generation of fundamental and realized niche models. Once these are generated, we will use these niche models to examine their predictions of scallop species range under climate change scenarios.

HIGHLIGHTS

- ROMS bottom water hindcast temperature and salinity fields have been acquired and assessed relative to empirical observations obtained during NMFS/NEFSC stock surveys.
- Bottom water temperature and salinity bias has been assessed and bias correction models evaluated. The best performing bias correction model has been identified and will be used to improve temperature and salinity agreement with empirical observations.

SOCIETAL BENEFITS

- The methodologies developed in this study will further develop existing frameworks for modeling spatial and temporal changes in population distribution and predator-prey interactions. It will provide a mechanism by which to predict the impacts of climate and environmental climate change on fisheries.
- The research will identify links among the scallop fishery and climate change, help predict shifts in this resource, and will provide important information upon which sustainable fishery management decisions can be made.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

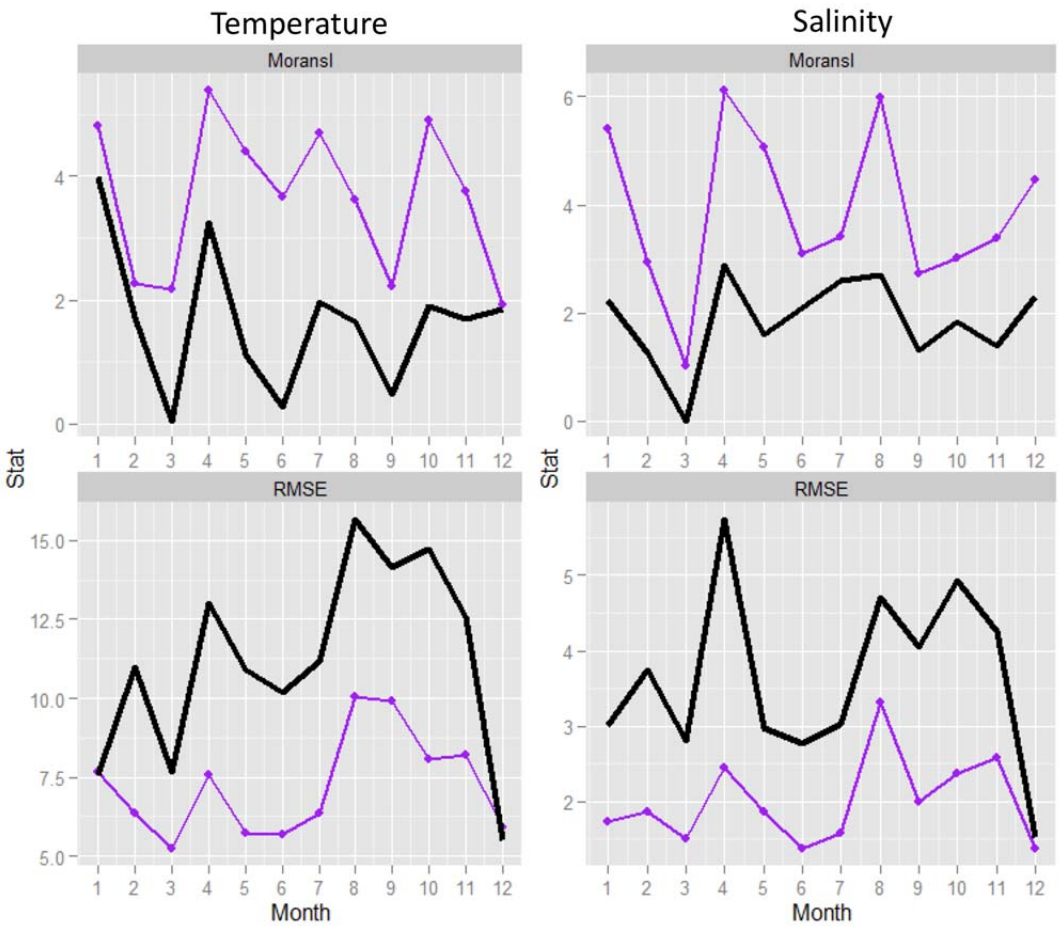

Figure 1. Bottom temperature (left) and salinity (right) performance relative to empirical observations using MoransI (top) and RMSE (bottom). Black lines show performance statistics calculated using original ROMS uncorrected output, purple lines show statistics calculated using bias model corrected data.

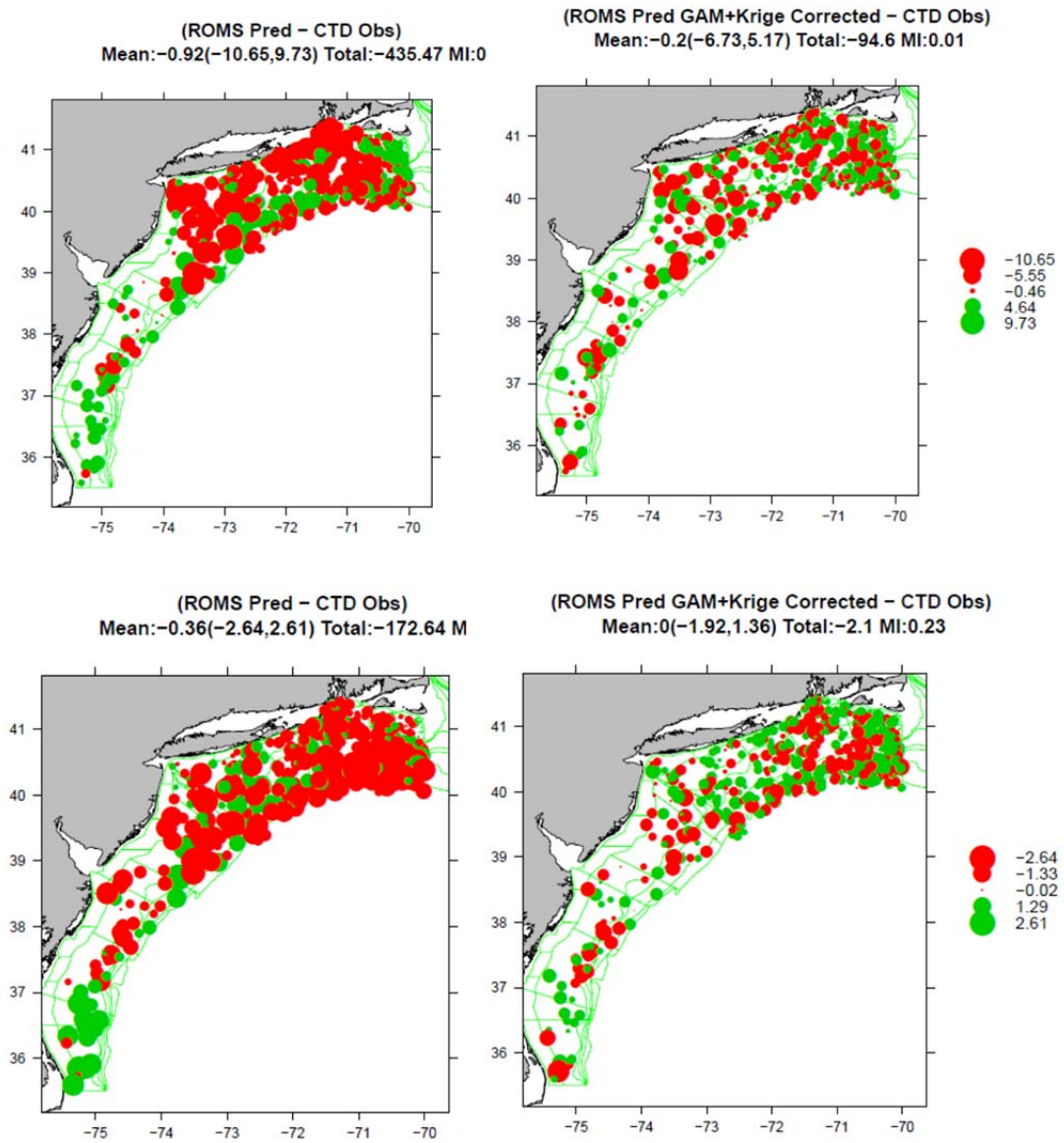

Figure 2. Maps of bias in temperature (top row) and salinity (bottom row) for uncorrected (left) ROMS output, and bias-corrected output (right). Bias correction significantly improves output agreement to empirical observations both in terms of correcting spatial bias and reducing the magnitude of error.

Nutrient Dynamics on the NE Continental Shelf: Sample Analyses

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – David Townsend, University of Maine

NOAA Sponsor – Jonathan Hare, NEFSC

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 13,039

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project was initiated in 2011 in response to the need for better data coverage for dissolved inorganic nutrient concentrations in waters of the Gulf of Maine and adjacent regions of the Northeast U.S. continental shelf. In a study we published in 2010 (Townsend et al., 2010) we speculated that changes in the concentrations of silicate and nitrate in the interior Gulf of Maine over the past several decades might be driven by larger scale changes in shelf and slope currents farther "upstream" form the Gulf, in the Labrador Sea and off Nova Scotia. Accelerated melting of the Greenland ice sheet and the Arctic ice cap in recent decades may have changed the dynamics of the baroclinic transport of low salinity shelf waters to regions farther south, in an episodic fashion, thus altering the nutrient fields in the Gulf. Our analyses have revealed that deep proportions of nitrate and silicate are highly variable among years (Townsend et al., 2014). In addition, there is growing evidence that those changes in the nutrient regime may also be forcing changes in the structure of the planktonic ecosystem (McGillicuddy et al., 2011; Townsend et al., 2014). Most recently, we have shown that shelf water flows into the Gulf of Maine (Scotian Shelf Water) alternate with deep Slope Water flows into the Gulf with periods from several months to several years (Townsend et al., 2015).

We were funded by the NOAA IOOS Program in 2014 to deploy *in situ* optical nitrate sensors (Satlantic, Inc., SUNAs) on Gulf of Maine buoys (UMOOS, the University of Maine Ocean Observing System, a subset of NERACOOS, The Northeast Regional Associate of Coastal Ocean Observing Systems). Along with the continuation of this CINAR project analyzing nutrient samples collected on ECOMON cruises, we hope to understand better the nature of water mass variability in the Gulf of Maine and its influence on the nutrient field, which is of fundamental importance to our understanding of basic biological phenomena from red tides to changing fish abundances and distributions.

We report here progress made on our CINAR-funded project to analyze samples collected as part of the ***NOAA Northeast Fishery Science Center's Ecosystem Monitoring Program*** (ECOMON Program) in collaboration with Dr. Jon Hare. The ECOMON Program conducts survey cruises approximately four times each year in shelf and slope waters of the Gulf of Maine – Georges Bank – Mid-Atlantic Bight. As part of their standard sampling, they perform a CTD cast at each station and, when possible (given constraints for water sample allocation) they collect water samples for nutrient analyses. Samples are filtered and frozen at sea and then delivered by overnight courier to the University of Maine where they are analyzed for nitrate plus nitrite, silicate, phosphate and ammonium using standard autoanalyzer techniques. Those data are delivered to NOAA following each cruise.

ACCOMPLISHMENTS

As of this writing (March 30, 2017) we have received and processed samples from the ECOMON cruises shown in Table 1, with station locations plotted in Figure 1 for each cruise. In addition, Townsend's Research Associate, Ms. Maura Thomas from the University of Maine, has participated on at least one ECOMON cruise each year since 2014.

Once we have analyzed the water samples in our nutrient analysis laboratory here at the University of Maine, for concentrations of nitrate+nitrite, silicate, phosphate and ammonium, we combine the resulting data with the CTD data and produce profiles of the hydrography and nutrient properties. Those processed data in table format and vertical profile station plots are then sent to NOAA Narragansett (c/o Dr. Jon Hare). We plan to continue to study – with our NOAA and Woods Hole Oceanographic Institution colleagues – the hydrographic and nutrient data collected on future ECOMON cruises, as the data density becomes suitable for more in depth analysis. As with all of our nutrient data processed in our laboratory, we are incorporating them into our regional nutrient and hydrographic database (Rebuck et al., 2009).

HIGHLIGHTS

The February 2017 cruise results showed two interesting and important phenomena:

- There was clear evidence of deep winter convective mixing and nutrient recharge of surface waters in Wilkinson Basin (this is the first such observation of this commonly-assumed oceanographic phenomenon that I am aware of);
- We observed Gulf Stream Water in the Northeast Channel, which was clearly identifiable by high salinity (>35) and warm subsurface temperature (up to 14 ºC), between depths of about 40 and 180 m, but with low nutrient concentrations; without the nutrient data, the origin of this warm and salty water mass might otherwise be confused with Warm Slope Water.

SOCIETAL BENEFITS

- Our continued analyses of the nutrient samples collected on the ECOMON cruises will be extremely important in our interpretations of conditions of Paralytic Shellfish Poisoning

(PSP) from *Alexandrium* populations, and are already being used to help initiate simulation models to forecast the severity of Gulf of Maine "red tides" months in advance.

- This research is providing baseline data for future interpretations of climate change-induced alterations to the marine environment of the Northwest Atlantic continental shelf. Our data have already provided evidence in support of earlier expressed concerns about far-field effects of Arctic melting.

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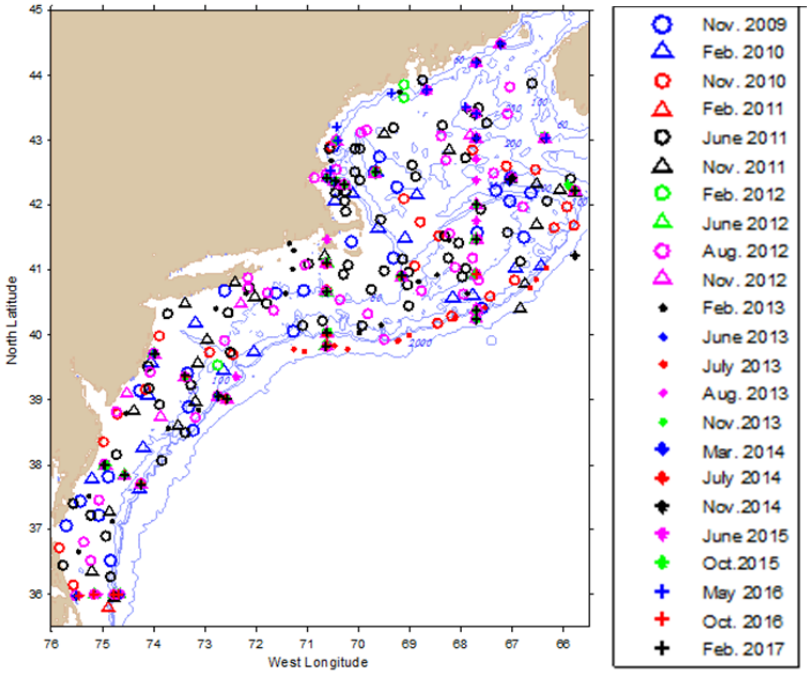
FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Table 1. Cruise dates, number of stations samples for nutrients, and number of water samples analyzed for nutrient concentrations at UMaine from the start of the program to date.

Date	Number of Stations	Number of Nutrient samples analyzed
Nov. 2009	26	88
Feb. 2010	19	64
Nov. 2010	25	94
Feb. 2011	1	11
June 2011	3	182
Nov. 2011	3	65
Feb. 2012	22	130
June 2012	19	100
Aug. 2012	63	300
Nov. 2012	34	210
Feb. 2013	41	170
June 2013	27	194
July 2013	14	138
Aug. 2013	15	108
Nov. 2013	23	135
Mar. 2014	19	115
July 2014	3	19
Nov. 2014	36	225
June 2015	35	244
Oct. 2015	24	180
May 2016	39	281
Aug. 2016	19	125
Feb. 2017	24	181

Figure 1. Station Map: NOAA ECOMON Surveys 2009 to February 2017.



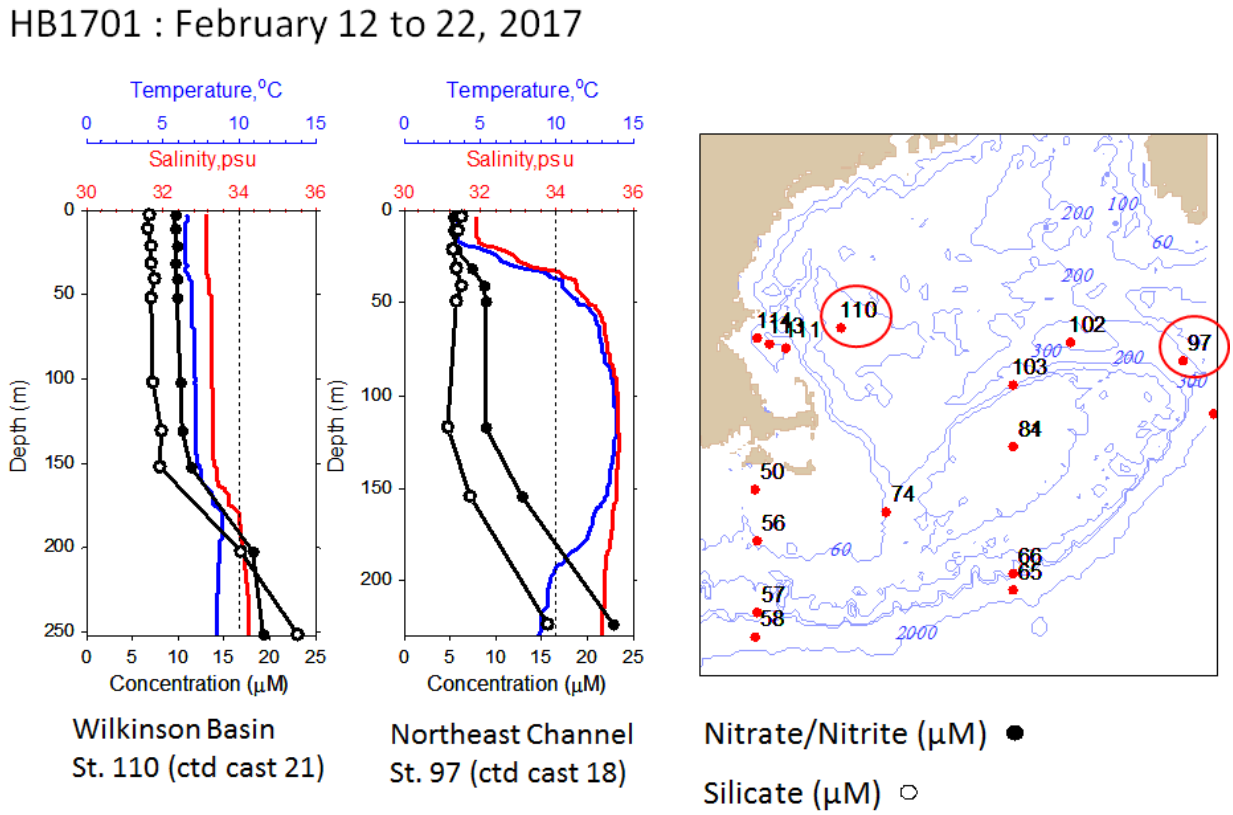


Figure 2. Example results from February 2017 cruise. Station 110 (left panel) shows that winter convection has mixed the water column to > 150 m, producing a vertically isothermal, isohaline structure to that depth, and approximately 8 µM silicate and 11 µM nitrate from the surface to 150 m. These data may be the first example of such winter convective mixing in the Gulf of Maine that demonstrates recharge of nutrients into surface waters, which fuel the spring phytoplankton bloom.

Sustaining Development of National Ocean Service Operational Forecast Systems Based on the Regional Ocean Modeling System

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – John Wilkin, Rutgers University

NOAA Sponsor – Aijun Zhang, NMFS

Related NOAA Strategic Plan Goal: ***Resilient Coastal Communities and Economics***

CINAR Theme: ***Ecosystem Forecasting***

Amount Funded: $ 50,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

NOAA and NOS have the mission and mandate to provide guidance and information to support navigation and coastal needs. To support this mission, NOS develops and implements hydrodynamic model-based Operational Forecast Systems (OFS) for sea ports, estuaries, the Great Lakes, and coastal waters. An OFS consists of the automated integration of real-time observations, hydrodynamic model forecasts, product dissemination, and continuous quality control and monitoring.

The Regional Ocean Modeling System (ROMS; www.myroms.org) is used for OFSs for the Chesapeake Bay (CBOFS), Delaware Bay (DBOFS), and Tampa Bay (TBOFS) to provide maritime community users with real-time operational products that include now-casts and short-term 1- to 2-day forecast guidance of water levels, currents, water temperature, and salinity. These parameters are fundamental physical variables for applications such as emergency response (e.g. oil spills; search and rescue) and ecological forecasting. ROMS-based OFS are in prototype development for Cook Inlet, Alaska, and the Gulf of Maine.

The specific objectives of this project are to facilitate the exchange of information between the ROMS developer group and the ROMS users at NOS so as to ensure that (i) NOS has access to and is aware of the most recent developments in the ROMS source code, (ii) NOS follows ROMS best practices, and (iii) NOS needs and recommendations for code modifications are conveyed to the developers and implemented in the community to make NOS user experience accessible to the broader ROMS user community.

ACCOMPLISHMENTS

On April 19-20, 2016, the Rutgers project team met with NOS scientists in Silver Spring to present an overview of recent enhancements to the ROMS modeling system. These are primarily 2-way synchronous downscaling nesting capabilities that have matured and are being adopted by

the general ROMS user community for science applications. NOS were given an overview of the real-time U.S. East Coast forecast system (called "*doppio*") being developed by Rutgers University and MARACOOS that uses four-dimensional variational (4DVAR) data assimilation to combine satellite temperature and sea-level data, HF-radar surface currents, and all IOOS in situ observations in a regional hydrodynamic model for Cape Hatteras to Cape Cod. The system is in pre-operational status and undergoing skill assessment. The data assimilation techniques demonstrate the capabilities that the Rutgers team recommends are useful for the NOS West Coast Operational Forecast System (WCOFS). Following discussion with senior NOS staff, the Rutgers team agreed to being planning an opportunity to run a small workshop in 2017-2018 to develop 4DVAR system knowledge within the NOS group for future operational systems. These plans are developing further in the context of a proposal to NOAA Operational Technology Transfer RFP.

Specific action items identified during the April 2106 meeting have been completed in the last 12 months. These include (i) porting the "REDTIDE" harmful algal bloom prediction model for use in the prototype Gulf of Maine (GOM) forecast system, and its public release for NCEP operations, (ii) porting the COMT estuarine hypoxia prediction model ("HYPOXIA_SRM") for Chesapeake Bay, and its had-over for acceptance testing by NOS and VIMS, (iii) creating a surface-ocean-only NetCDF file output option to reduce the I/O and storage burden on operational systems, and (iv) various troubleshooting consultations on updates to the CBOFS configuration for a new release and the Cook Inlet model (CIOFS) with respect to wetting and drying during tidal inundation.

SOCIETAL BENEFITS

Improved quality in the model-based scientific information conveyed to maritime industry and resource managers operating in the Chesapeake, Delaware and Tampa Bay ports. Development of ecosystem prediction systems for Harmful Algal Blooms in the GOM and hypoxia in Chesapeake Bay.

THEME II. ECOSYSTEM MONITORING

Passive Acoustic Monitoring from Autonomous Platforms

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Mark Baumgartner, WHOI

NOAA Sponsor – Sophie Van Parijs, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 158,393

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project is designed to (1) demonstrate the utility of real-time passive acoustic monitoring from autonomous platforms using the digital acoustic monitoring (DMON) instrument and the low-frequency detection and classification system (LFDCS), (2) validate the accuracy of in-situ detection and classification capability when used on a variety of stationary and mobile autonomous platforms, and (3) incorporate this new technology into NMFS whale and fish monitoring efforts. The project will provide flexible tools for long-term reduction in analytical effort and improved efficiency of existing monitoring technologies (e.g., visual surveys). We anticipate that NOAA will be able to significantly enhance its monitoring efforts using real-time detection information to identify areas of persistent whale occurrence, and to direct airplane- or ship-based surveys to regions that require additional visual surveillance.

Several objectives involving passive acoustic monitoring from autonomous platforms will be met during the project. These objectives and plans are as follows:

1. Demonstration and validation of DMON/LFDCS from a moored buoy, Slocum glider, and wave glider in the Gulf of Maine (*ESTCP demonstration and evaluation*)
    - Deploy a moored buoy near Mount Desert Rock in the northern Gulf of Maine (GOM) and conduct proximate visual surveys from the Mount Desert Rock lighthouse during summer 2015 and 2016.
    - Deploy a Slocum glider in the Great South Channel of the southwestern GOM and conduct proximate visual surveys from the NOAA Ship *Gordon Gunter* during spring 2015 and 2016.
    - Deploy a wave glider in the GOM to do broadscale surveys and coordinate visual surveys with the NOAA aerial survey team.
2. Persistent real-time detection, classification and reporting of baleen whales near a Coast Guard gunnery range (*Nomans Land moored buoy*)
    - Deploy a moored buoy near Nomans Land Island and report real-time detections to the Coast Guard to help them minimize impacts to whales during gunnery exercises in the area.

3. Passive acoustic surveys for Atlantic cod in the Stellwagen Bank National Marine Sanctuary (*Cod glider surveys*)
    - Deploy two gliders (jointly funded by NOAA/CINAR and The Nature Conservancy) in Stellwagen Basin during December 2014 and 2015 to acoustically survey for Atlantic cod.
4. Real-time passive acoustic surveys for baleen whales in the GOM (*GOM glider surveys*)
    - Conduct Slocum glider surveys in areas of ecological or conservation importance to baleen whales in the GOM.
5. Real-time passive acoustic surveys for baleen whales in the New York Bight (*NYB wave glider surveys*)
    - Deploy a wave glider in the New York Bight during 2015 and 2016 to survey for baleen whales
6. Development of improved detection and classification software (*DCS development*)
    - Support use of the desktop LFDCS by NEFSC and other users.
    - Modify DMON/LFDCS as needed to improve performance.
    - Develop wide-band detection and classification system to monitor sounds from blue whales to dolphin whistles

ACCOMPLISHMENTS

(1) *ESTCP demonstration and evaluation:* During the reporting period, the Slocum G2 glider acquired for the project was deployed in the southwest GOM for 117 days from April 13 to August 8, 2016. Detection data were analyzed in near real time, and the occurrence of right, sei, fin, and humpback whales were made publically available at dcs.whoi.edu in near real time. A DMON-equipped NAVO glider was also deployed in the southwest GOM from April 13 to May 13, and near real-time occurrence of large whales was estimated by marine mammal specialists at the Naval Facilities Engineering Command (NAVFAC). A DMON whale-detection buoy was also deployed near Mount Desert Rock on June 24, 2016, and a DMON-equipped wave glider was deployed in the Gulf of Maine for 114 days from August 8 to November 29, 2016. Significant analysis was completed during the reporting period that (1) compared audio from the 2016 WHOI Slocum glider deployment to near real-time estimates, and (2) inter-compared near real-time occurrence estimates from 3 separate analysts.

(2) *Nomans Land moored buoy:* Near real-time occurrence data from the 2015-2016 Nomans Land DMON buoy were compared to audio recorded by the buoy. Results indicate that the analyst is nearly 100% correct when determining the presence of right, fin, sei, and humpback whales in near real time. Aerial survey data from the NOAA NEFSC and New England Aquarium have been collected and preliminary analyses have been completed to compare near real-time detections to visual sightings of large whales. The Nomans Land buoy was refurbished and redeployed on September 28, 2016 and is still operating; recovery is planned for October 2017.

(3) *Cod glider surveys:* This project is completed and other project investigators are preparing final manuscripts.

(4) *GOM glider surveys:* No funds were disbursed for this objective during the reporting period, so no work was accomplished.

(5) *NYB wave glider surveys:* Quieting mechanical noise on the wave glider was successful during the reporting period, and new work was undertaken to mitigate (1) flow noise with a hardware solution and (2) surface noise with a software solution. In October 2016, specifications for a low-frequency hydrophone array were developed to reduce flow noise, and in late December 2016, GeoSpectrum Technologies, Inc. fabricated and delivered the array. The array consists of 21 acceleration-compensated low-frequency hydrophones, a mid-frequency hydrophone, and a high-frequency hydrophone. The end of the array was designed to accommodate a DMON or DMON2 instrument, and WHOI fabricated a hydrophone input distribution board. The system was initially tested in Buzzard's Bay during March 2017 with the output of all 21 hydrophones summed together as input to a DMON instrument. This configuration allows the pressure signal of small incoherent eddies (those responsible for flow noise) to be averaged out and the signal-to-noise ratio of far-field signals to be boosted by a factor of 4.6. Initial tests were very promising and a wave glider with the array was deployed at the Nomans Land DMON buoy during April 2017 using software modifications to the DMON firmware to reduce pitch tracking of surface noise. If this deployment is successful, the hydrophone array will be used for a 3-4 month wave glider deployment in the New York Bight during summer 2017.

(6) *DCS development:* No funds were disbursed for this objective during the reporting period, so no work was accomplished.

HIGHLIGHTS

- The project now has several successful 100+ day deployments of Slocum and wave gliders that reported the presence of right, humpback, sei, and fin whales in near real time
- Our evaluation indicates that DMON-equipped Slocum gliders and moored buoys provide highly accurate estimates of right, humpback, sei, and fin whale occurrence in near real time
- Significant progress has been made toward making the wave glider a viable mobile autonomous platform for near real-time passive acoustic monitoring

SOCIETAL BENEFITS

This project supports the NOAA goal of "Healthy Oceans: Marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems" by providing tools with which NMFS can monitor endangered populations of baleen whales. Continuous, long-term and real-time monitoring will improve mitigation of a variety of anthropogenic stressors in these endangered populations, including ship strikes and fishing gear entanglements.

EDUCATION AND OUTREACH ACTIVITIES

Several conference presentations have been made:

Gurnee, J., M.F. Baumgartner, T.V.N. Cole, P. Corkeron, S.M. Van Parijs. 2016. Comparison of real time vs. archival acoustic detection of North Atlantic right whales for a moored buoy system. North Atlantic Right Whale Consortium Annual Meeting, New Bedford, Massachusetts, November 2-3, 2016.

Baumgartner, M.F. 2017. Near real-time detection of marine mammals from autonomous platforms. IOOC U.S. Underwater Glider Workshop, Stennis Space Center, Mississippi, January 18-19, 2017.

Baumgartner, M.F. 2017. Monitoring marine mammals via passive acoustics from long-endurance autonomous vehicles. Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, Louisiana, February 6-9, 2016.

Baumgartner, M.F. 2017. Using autonomous platforms and near real-time acoustic monitoring to mitigate interactions between large whales and human activities. Marine Mammal Commission Annual Meeting, Falmouth, Massachusetts, April 5-7, 2017.

Hotchkin, C., S.M. Van Parijs, P. Corkeron, and M.F. Baumgartner. 2017. Near real-time passive acoustic monitoring of baleen whales in the Gulf of Maine. NAVFAC Annual Monitoring Meeting, Virginia Beach, Virginia, April 10-12, 2017.

Hotchkin, C., S.M. Van Parijs, P. Corkeron, and M.F. Baumgartner. 2017. DMON-glider integration demonstration and evaluation. NAVFAC Annual Monitoring Meeting, Virginia Beach, Virginia, April 10-12, 2017.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

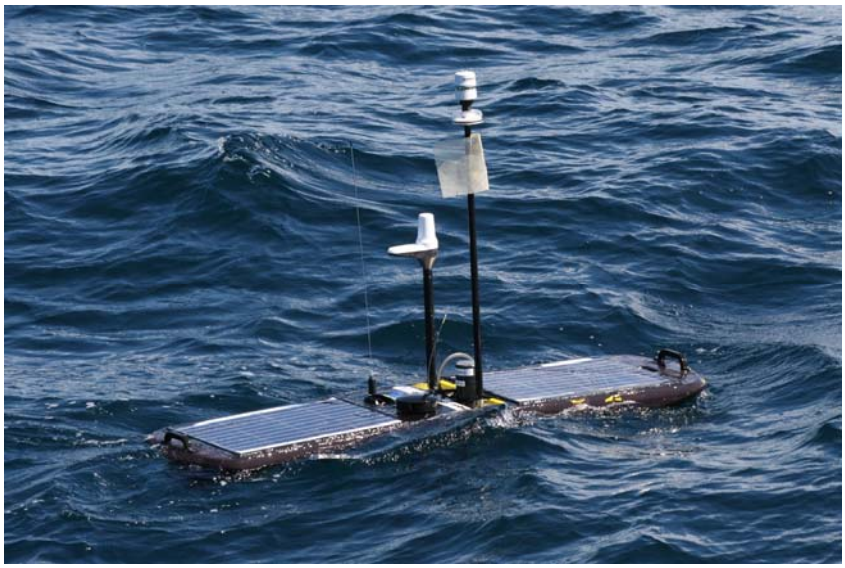


Figure 1. Wave glider shortly after deployment from the R/V *Tioga* on August 8, 2016.

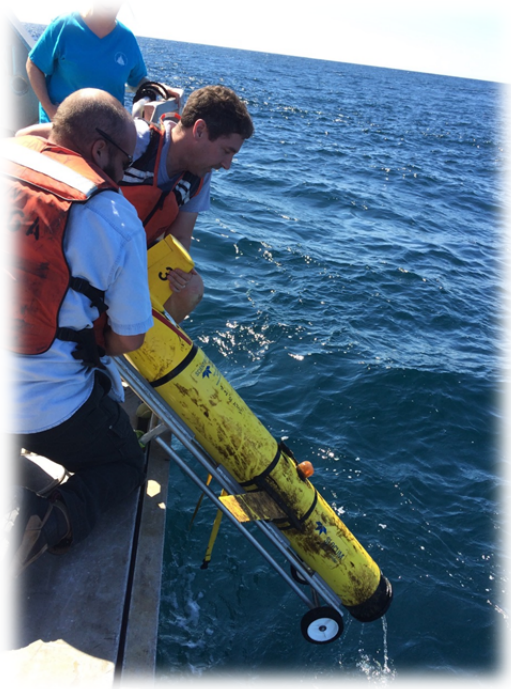


Figure 2. Recovery of Slocum glider we03 on August 8, 2016 after 117 days at sea.

Figure 3. DMON buoy moored off Mount Desert Rock, Maine.

Figure 4. Wave glider equipped with hydrophone array (long black cylinder suspended below glider sub).

The Annual Eastern Gulf of Maine Sentinel Jigging/Longline Survey/Fishery in 2014 to 2018

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Yong Chen, University of Maine

NOAA Sponsor – John Hoey, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 98,420

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Eastern Gulf of Maine (EGOM) Sentinel Survey/Fishery is a groundfish survey conducted in the summer from the western edge of Penobscot Bay to the eastern border with Canada. The survey consists of stratified random stations that are sampled with both demersal longline gear and jigging gear. A portion of the stations is also allocated for fishermen to select where they want to fish based on their knowledge of historic fishing grounds and suitable habitat. The primary objective of the survey is to provide an annual index of abundance as well as habitat preference information for groundfish species (including Atlantic cod, cusk, white hake and Atlantic halibut) in an area that was traditionally important for the commercial groundfish fishery, but is not currently well covered by either commercial fisheries or other bottom-trawl – based monitoring programs.

ACCOMPLISHMENTS

In 2016, the overall allocation of sampling effort consisted of a jig-only stations. This was different than previous years; between 2010-2011 the survey sampling was conducted using longline gear only, and between 2012-2015 the sampling was conducted using both longline and jig gear. However, in 2016 there was a financial constraint that allowed sampling with one gear type only, and in a limited capacity. Therefore, though stations were randomly allocated and stratified by depth just as in previous years, sampling was conducted with jig gear only, and in Strata 0-2 as opposed to Strata 0-3. Because jig gear was the only gear type used to sample survey stations in 2016, the survey became primarily one targeting Atlantic cod, pollock, and mackerel as opposed to a more diverse portfolio of groundfish species. This is because there is low catchability of other species on jig gear. However, jig gear is highly efficient, especially in areas with high gear congestion and rocky, complex bottom habitat structure. This report will focus on results from jig stations between 2012-2016.

There were 62 total randomly selected jig stations sampled in 2016, spanning depths in Strata 0-2

(Figure 1). These stations are labeled based on the depths they encompass; all stations in Stratum 0 are called "JJ Stratum 0", and all stations in Strata 1-2 are called "JJO". All random jigging stations together are simply called "JJ". In Stratum 0 (0-50m), there were 36 stations sampled, which made up 50.7% of the total sampling effort (Table 1). There were 9 stations in Stratum 1 (50-80m), which comprised 12.7% of the total sampling effort (Table 1). Stratum 2 (80-150m) contained 17 stations, which made up 23.9% of the total sampling effort for 2016 (Table 1). In addition to the randomly selected jigging stations, there was also a "fishermen's choice" component included in the overall sampling effort. These stations were selected by fishermen anywhere in the survey area. Therefore, these stations were not part of the stratified random, or "fisheries-independent" design, but were instead considered to be "fisheries-dependent". These stations were also sampled with jigging gear, and spanned depth ranges between 0-150 m. The stations that are considered to be fishermen's choice are labeled as "JF". There were nine JF stations in 2016, comprising 12.7% of the total sampling effort (Table 1).

In 2016, Atlantic cod were caught at 58.3% of all random jig stations. Atlantic cod were caught at thirteen total stations in stratum 0 (0-50m), or at 36.1% of inshore jig stations; a decrease from 2015. However, Atlantic cod were caught at 66.7% of jig stations in stratum 1 (50-80m), and at 11.8% of jig stations in stratum 2 (80-150m) (Table 1). This was a dramatic increase from previous years. Finally, Atlantic cod were caught at 66.7% of jigging at fishermen's choice stations (Table 1).

The random jigging stations were then divided into inshore and offshore components for analysis. The JJ stations at stratum 0 sites were referred to as inshore stations, while JJ stations in strata 1-3 were referred to as offshore stations (JJO). First, the JJO stations were analyzed independently of jigging at longline (JL) stations. Then JJO and jigging at random longline stations (JL) were combined because they both encapsulated strata 1-3, and combining the two station types increased sample size of Atlantic cod.

Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, then sharply increased from 2013-2014 (Table 2). In 2015, the mean abundance of Atlantic cod increased slightly from 2014 . Finally, the mean abundance of cod decreased again in 2016. While the CV was large in 2012, it decreased dramatically between 2013-2016. For the offshore jigging-only stations (JJO), mean cod abundance decreased from 2013 to 2014; in 2014 there were no cod caught at any offshore jig-only stations (Table 2). However, there was a continuous increase in the mean abundance of cod at offshore jigging-only stations between 2014-2016, coupled with increasing CVs. Once combined with the offshore jigging-at-longline sites (JL), however, the sample size increased. A similar trend was shown, with a decrease from 2013-2014 followed by an increase through 2016 (Table 2). It is important to note that CVs decreased in all years after increasing the sample size of cod at offshore jig stations.

Finally, all random jigging stations for strata 0-3 were combined and assessed (JJ+JJO+JL). Mean abundance of cod for all random jigging stations decreased from 2013 to 2014; the CV also decreased (Table 2). In 2015 and 2016, mean abundance increased with a slightly increased CV. The abundance indices show that jigging was highly efficient at coastal waters (i.e., Stratum 0) where fixed gear congestion makes it almost impossible for other sampling gear types (including trawl and longline). The increase in mean abundance of cod at JJ Stratum 0 stations

between 2012 and 2016 is important information not previously obtainable by other survey programs in the Gulf of Maine. In addition, the CVs were relatively low, indicating a good confidence of abundance index data obtained. The abundance index highlights the importance of this inshore jigging component, especially when the survey is faced with logistical issues preventing longline sampling.

HIGHLIGHTS

- Continuity of a rigorous time series of data for groundfish species in a region not well-sampled by other monitoring programs
- Inshore jig sampling provides highly efficient sampling methods in areas typically impossible to monitor for groundfish
- Inshore jig stations show a slight decrease of the relative abundance of cod
- Offshore jig stations show an increase in relative abundance of cod
- Fishermen involved in this project are crucial to the scientific processes involved in data collection, analysis, and design evaluation.
- Though this year we sampled with jig-gear only (due to financial constraints), we have robust time-series collected for other groundfish species such as Atlantic halibut, and cusk. These are also species with limited catchability in current monitoring programs.

SOCIETAL BENEFITS

Coastal Communities in eastern Maine are almost entirely dependent on marine resources to survive economically. Increasing collaborative, effective fisheries monitoring programs can help provide information about those resources. Collaboration with fishermen who live and work in these communities is crucial toward forging connections between scientists and managers toward building more resilient coastal communities through transparent science.

EDUCATION AND OUTREACH ACTIVITIES

Participation in the following:

- Midcoast Regional Planning Commission Meeting, 2016
- Maine Fishermen's Forum, 2016, 2017
- Canadian Conference For Fisheries Research: Montreal, Canada, 2017
- Regional Association for Research on the Gulf Of Maine: Portsmouth, NH, 2016
- International Council for the Exploration of the Seas Annual Science meeting, Riga, Latvia, 2016

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

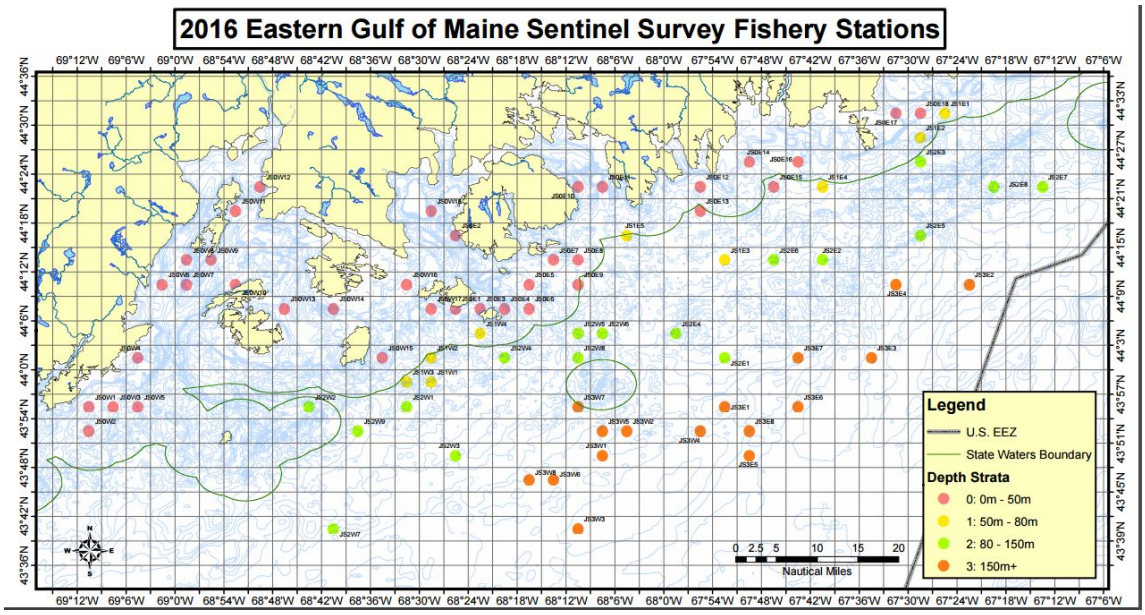


Figure 1. Survey area including 2016 sampling locations.

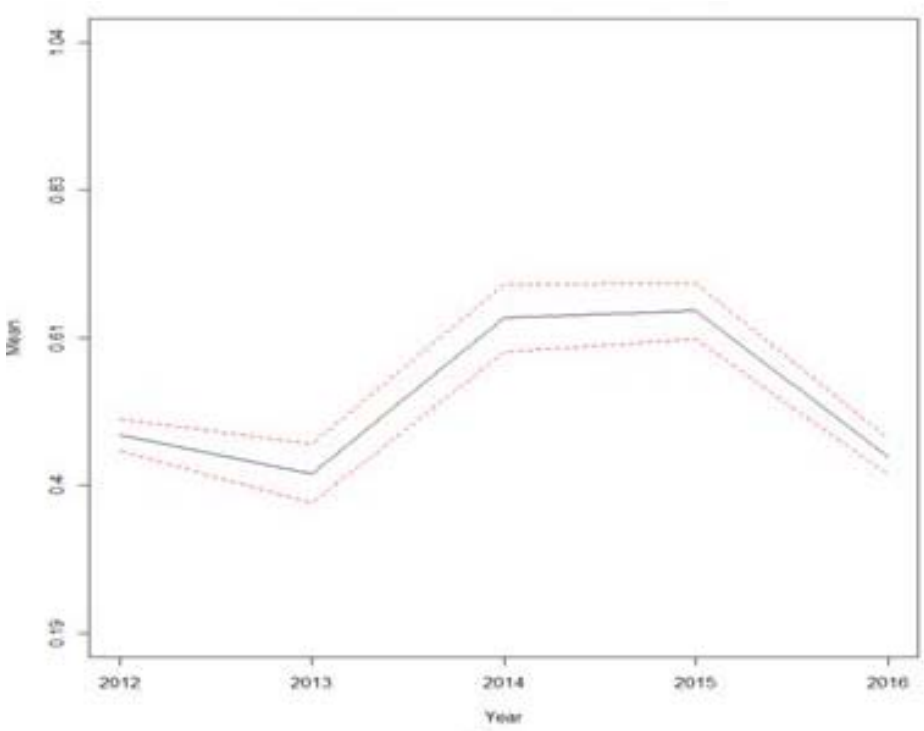


Figure 2. Relative Abundance of Atlantic cod at all Inshore Jig (JJ Stratum 0) Stations from 2012-2016.

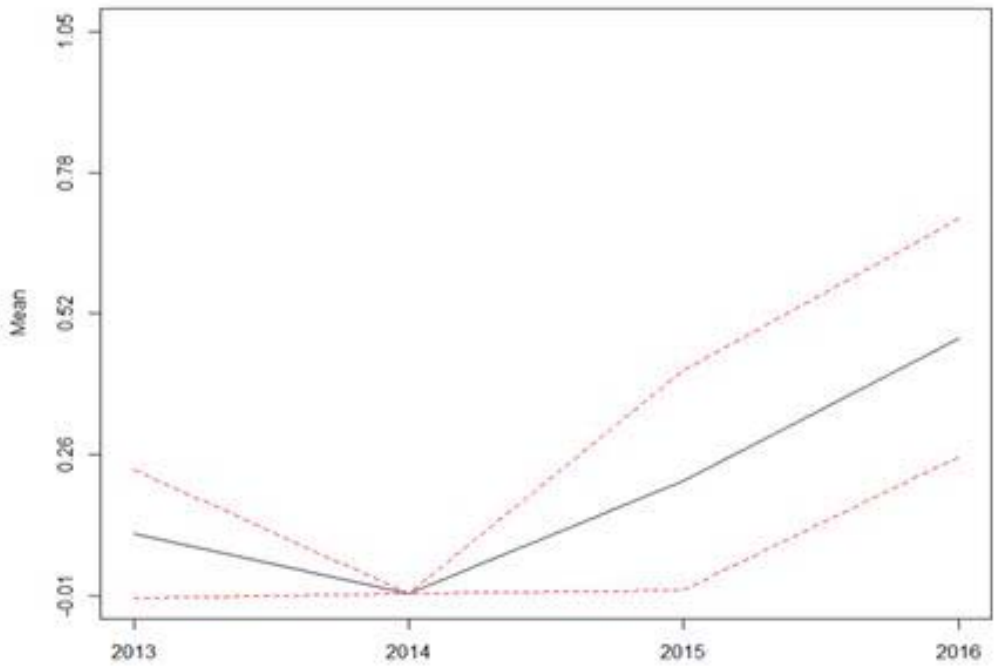


Figure 3. Relative Abundance of Atlantic cod at Offshore Jig Stations from 2012-2016.

Table 1. Breakdown of station allocations and number of stations where Atlantic cod were caught in the 2016 jig survey.

			Stations where species present					
	Stations		Cod					
	no.	%	no.	%	no.	%	no.	%
Jigging at jigging only station(JJ)	**62**	**87.3**						
Stratum 0 (0-50)	36	50.7	13	36.1				
Stratum1 (50-80)	9	12.7	6	66.7				
Stratum2 (80-150)	17	23.9	2	11.8				
Jigging at fisherman's choice(JF)	**9**	12.7	6	66.7				
All (cod/other species)	71							

Table 2. Mean abundance and coefficient of variation (CV) of groundfish species of interest.

Year/Station Type	Species							
	Cod		Cusk		White Hake		Halibut	
	mean	CV	mean	CV	mean	CV	mean	CV
2012 LL	0.15	2.89	0.56	0.19	27.52	0.12	3.90	0.095
2013 LL	0.35	0.78	0.07	0.19	32.28	0.11	1.05	0.090
2014 LL	0.21	0.24	0.04	0.96	16.01	0.09	2.30	0.097
2015 LL	0.12	0.71	0.20	0.26	8.77	0.03	1.2	0.11
2013 JJ	0.23	0.06						
2014 JJ	0.19	0.31						
2015 JJ	0.28	0.27						
2016 JJ	0.45	0.15						
2012 JJ Stratum 0	0.50	0.27						
2013 JJ Stratum 0	0.42	0.51						
2014 JJ Stratum 0	0.64	0.06						
2015 JJ Stratum 0	0.65	0.03						
2016 JJ Stratum 0	0.44	0.03						
2013 JJO	0.11	0.56						
2014 JJO	0.00	0.00						
2015 JJO	0.21	0.49						
2016 JJO	0.48	0.24						
2013 JJO+JL	0.19	0.28						
2014 JJO+JL	0.05	0.47						
2015 JJO+JL	0.13	0.16						
2016 JJO+JL	0.43	0.09						

Construction and Testing of a Plankton Imaging and Identification System in Gliders and Drifters for Use in Low-cost Plankton Observing Systems

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Cabell Davis, WHOI

NOAA Sponsor – Jonathan Hare, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 91,221

PROJECT OVERVIEW, GOALS, AND MILESTONES

Rationale: Understanding plankton distributions and abundance is fundamental to understanding marine ecosystems. Recruitment success in marine fish populations is linked to the timing of spawning in relation to spring phytoplankton blooms. Zooplankton serve as the critical link between primary producers and higher trophic levels including exploited fish and protected marine mammals. Marine snow represents the downward flux of matter that feeds the benthos. A fundamental limitation to our understanding of plankton and marine snow dynamics is sparseness of data. Traditional sample collection and processing methods are arduous, destructive to ubiquitous fragile forms, and grossly undersample submesoscale patches, where the bulk of productivity and predator-prey interactions occur. The time consuming nature (and coupled expense) limits the amount of data that can be generated to inform assessments.

Objective: We are designing and building a modular, low power, compact plankton imager incorporating it into a glider for ocean observations of plankton taxonomic and size composition together with environmental variables. We are using low-power image acquisition and processing hardware and satellite telemetry of processed plankton data together with CTD and navigation data.

ACCOMPLISHMENTS

During the past year, we completed the design and have built and tested the imaging system and incorporated it into the glider (Figs. 1-5). The glider itself is capable of 300 m depth profiling with an along-axis speed of 25cm/s and a glide angle of 25 degrees. We completed an energy budget and found that the battery pack chosen will enable two months operation at sea depending on duty cycle. The in-line digital holographic imaging system has a larger image volume than the VPR and minimizes avoidance by zooplankton. The imaging system uses a fiber coupled diode laser (658 nm wavelength) that is not visible to zooplankton. The relatively large separation distance between the camera and laser housings (16 cm) reduces flow disturbance that can

trigger escape response in zooplankton. The imaging method allows reconstruction of in-focus images with 5.5 micron/pixel and axial resolution of 100 microns, yielding a 20 ml image volume per hologram and 1 liter per vertical meter. We have had several team meetings to discuss the new system design and construction. Seascan developed drawings of the component assemblies and selected components based on group discussions. The internal chassis and housings were designed and constructed, and the system was assembled (Fig. 2-3). Buoyancy tests were conducted on the integrated imaging glider system (Fig. 2). We tested the imaging system on the benchtop using standard resolution targets and a small glass chamber with live plankton (Fig. 4). We then tested the imaging system in the sea-well at the WHOI dock. Software development has included laser can camera control and image capture and storage. We have begun work on the image analysis plan. The remainder of the project will be devoted to extraction of images from the system and identification of those images using a combination of our existing holographic extraction and image identification methods.

HIGHLIGHTS

- A small modular low-power imaging system has been designed, built, and incorporated into a low-cost glider.
- The imaging design comprises in-line digital holographic imaging.
- The imaging system has a large image volume and minimizes plankton avoidance behavior.

SOCIETAL BENEFITS

Use of multiple low-cost plankton imaging gliders for routine surveys of ocean and freshwater environments will enable better assessment of aquatic ecosystems and incorporation into ecosystem models for better ecosystem based management.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

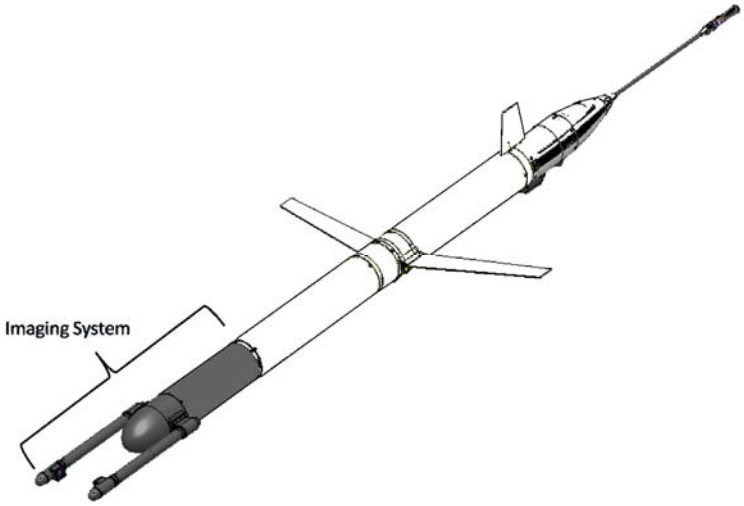


Figure 1. Drawing of the complete imaging glider system showing imaging system in front.

Figure 2. Photo of completed system during buoyancy test in pool.

Figure 3. Photo of imaging system front end of glider.

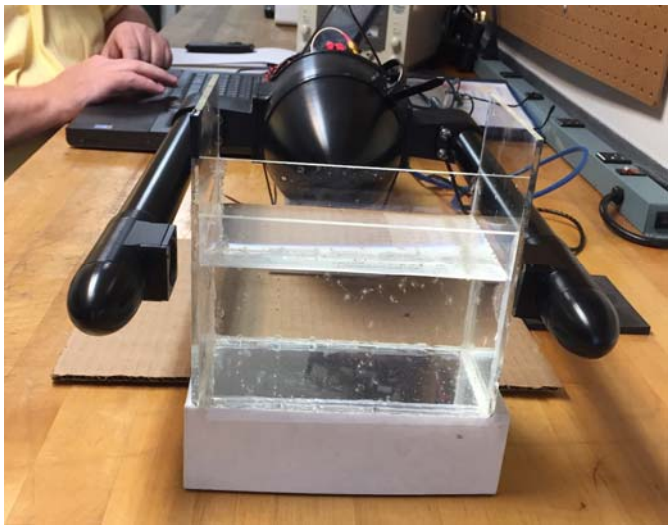


Figure 4. Photo of benchtop testing of imaging system viewing glass chamber with live plankton.

Figure 5. Photo of dockside testing of imaging system in the WHOI sea well.

Supplement to: Application of Electronic Vessel Trip Reporting by the New England Fishing Industry

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Steve Eayrs, GMRI

NOAA Sponsor – Joan Palmer, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 81,495

PROJECT OVERVIEW, GOALS, AND MILESTONES

The purpose of this project is to test the feasibility of replacing paper recording of vessel trip reports and adopting electronic solutions for vessel reporting requirements across a range of sector and common pool vessels in the northeast groundfish fleet. This includes testing a range of electronic logbook products in conjunction with the NMFS web-based data entry system to identify obstacles to their use and to ensure their compatibility with NMFS data collection systems.

The objectives of this project are:

- Support and expand the use of electronic logbooks within the New England groundfish fleet for the purpose of transmitting electronic vessel trip reports (eVTRs).
- Encourage at least 10 other fishermen to adopt electronic logbook software to regularly transmit their VTRs electronically.

Since this project's inception, there have been no significant changes in the objectives, approach, methodology, or rationale.

ACCOMPLISHMENTS

We have now equipped a total of 48 vessels with electronic logbook software and trained fishermen on each vessel to electronically transmit their vessel trip report. This is an increase of seven vessels since the initiation of this project. We also have verbal commitments from an additional five fishermen interested in submitting eVTRs. In total, a total of 1500 electronic trip reports have been submitted over the past fishing year.

As a result of using electronic software, the accuracy of catch and fishing effort data reported by participating fishermen is substantially increased, in part because fishermen can more easily identify and amend reporting errors, and end-users can easily document this data with minimal

risk of transcription error. The data is also received by end-users sooner and in a more timely manner. Collectively, this means the impact of fishing activity of groundfish stocks can be more accurately and quickly evaluated and remedial action taken sooner than otherwise. Subsequently, inherent in the utility of eVTRs is an abilty to improve response time and cost-effective management of fish stocks.

HIGHLIGHTS

- A total of 48 ground fishing vessels are now equipped electronic logbook software to enable trained fishermen electronically transmit their vessel trip report.
- This is an increase of seven vessels since the project commenced; our project goal was an increase of ten vessels.
- Fishermen continue to be satisfied with submitting eVTRS, citing user-friendliness, convenience, and simplicity as key reasons for their satisfaction.

SOCIETAL BENEFITS

The core societal benefit is the ability of eVTRs to reduce the period between commercial fishing activity and the ability of authorities to respond to this activity and protect fish stocks.

EDUCATION AND OUTREACH ACTIVITIES

A project progress report was included in the summary of projects by country in the International Council for the Exploration of the Sea (ICES) Fishing Technology and Fish Behaviour Working Group meeting. In 2017 this meeting was held in Nelson, New Zealand.

Operational Support for HabCam Data Processing During 2016

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Scott Gallager, WHOI

NOAA Sponsor – Robert Johnston, NMFS

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 232,880

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Northeast Fisheries Science Center (NEFSC) and the Woods Hole Oceanographic Institution (WHOI) have developed a towed stereo camera system for estimating scallop and demersal finfish abundance and distribution, together with substrate and habitat assessment. This system was used in the 2012, 2013, 2014, 2015, and now in the 2016 annual scallop survey and will continue to do so for many years to come. Quantitative stereo imaging is becoming central to measuring targets on the seafloor. We will continue to assist NOAA personnel in the operation and maintenance of the HabCamV4 vehicle, go to sea to ensure smooth operations during surveys, and provide software upgrades for recording data at sea and for manual annotation of images on shore.

The HabCam imaging system (Howland et al. 2006) is "flown" 1.5 to 2.5 meters above the seafloor while being towed at 4 to 5 knots (~2 – 2.5 m/sec), thus a track of approximately 100 to 120 nautical miles is imaged each 24 hours of operations. Optical imagery is collected at a width of approximately 0.75 to 1.25 meters (total ~170,000 - 260,000 square meters/day) and at a rate of 5-6 images per second, providing about 50% overlap to aid in mosaicing continuous strips. On the NOAA stereo HabCamV4 system, side by side stereo pair images are fused into a single image at the time of acquisition. Images are given precise stereo referencing with metadata such as latitude, longitude, temperature, salinity, chlorophyll, light absorption, dissolved oxygen, and other environmental data. In addition, the Teledyne Benthos C3D side scan acoustic system on the NOAA vehicle collects 3D bathymetry and backscatter to a range of ~100m on either side of the vehicle.

Using a 2D manual annotation tool, we are currently able to identify over 450 taxonomic categories and classify substrate to 51 categories. We generate habitat maps by combining information on substrate and geomorphology with biological distributions of organisms using multivariate clustering.

Objective 1:
Continue development and integration of automated substrate classification, scallop

identification, and demersal fish segmentation and classification into the HabCam real-time workflow (S Gallager and S Lerner).

Automated substrate classification (Honig, Stewart and Gallager, 2016) is currently in routine operation on all HabCamV4 cruises and surveys. However, updates to the software and extended testing and training of the classified are still required. On every survey we encounter a variety of new substrates and habitats that provide a rich foundation of imagery for optimization of the substrate classifier. In 2016 we completed the following tasks: 1) Conducted k-fold cross-validations of the classifier's output relative to itself; and 2) Conducted cross-evaluations of the output for the entire 2016 survey image data set (we have collected over 2.8 million images in Legs I, II and III.a while the vehicle is currently out on Leg IIIb completing the northern edge of Georges Bank where the substrate varies tremendously from image to image). We hired a trained professional image annotator Patti Keating to annotate 1 out of 100 images for substrate type, thereby providing the ground truth for the automated classifier. A second manuscript will be assembled based on the new training data and cross-validations, both internally and by human annotation.

Secondly, we continued work on the scallop classifier that was started in 2015. We are currently training the substrate classifier to identify pixel groups that belong to class-scallop based on color and texture. Each pixel group so identified is then "grown" outwards towards an edge of curvature defined from a Canny edge detection and circular Hough transform. The probability that the identified circular object is a scallop then falls to a hierarchical operation that includes nearest neighbors, overlap of circular probabilities, size distributions in a population, and probabilities that the defined circular target is other than a scallop such as a sand dollar.

Objective 2:
Support for development and testing of image processing and machine vision tools for segmentation and classification of yellowtail flounder and other difficult targets (in collaboration with Lakshman Prasad, Los Alamos National Laboratory) – *Multiscale Image Decomposition and Shape Analysis Capability to NOAA Fisheries Image and Video Data Analysis*.

NOAA's new image data server that hosts representative image datasets provides an exciting opportunity to develop novel, custom image analysis routines to address a wide array of fisheries-related detection, recognition, biomass estimation, and census needs. Marine imagery is extremely challenging to automatically analyze due to wide variations in visibility, color attenuation, fauna types, viewing distances and angles, habitat, background, camouflage, and texture, to name a few. LANL's patented image analysis capability employs edge information in images to enhance robustness against such variations and extract structural information about objects and features in images at multiple scales.

In this project we adapted this broad-based capability to marine image analysis using the NOAA representative datasets as benchmark imagery to test and evaluate performance of algorithmic workflows that will be developed to address core functionalities of fish detection and delineation. Specifically, we use edge-based polygonal image decomposition to achieve feature extraction that is relatively robust to color and contrast variations. The edge-based features are subjected to shape characterization and parts-based decomposition, with attributes customized to identify and

recognize fish type and size by their distinguishing features. This will ultimately enable the development of annotated shape databases against which matching and recognition can be performed. Multiscale image decomposition will also be used to develop methods to evaluate fine-scale composition of larger-scale features and statistically discriminate fish against complex, textured backgrounds.

ACCOMPLISHMENTS

This project has provide stock assessment managers the ability to assess the impact of changing habitats on the following specific elements: 1) abundance uncertainty of key commercially important stocks, 2) improved projection of biomass estimates to areas with minimal or no sampling effort, 3) impact of habitat disturbance on abundance of target species specifically and biodiversity in general, 4) the ability to increase efficacy of sampling design and maximizing precision of a survey by stratifying on habitat, 5) minimizing by-catch of key species, and 6) to asses impact of invasive species. Moreover, while we are using HabCam image data as a test set for developing these tools, broad application to other optic and acoustic imaging systems in wide use by NOAA is anticipated.

Deliverables and Scientific Merit.
The outcome of this collaboration has been the following:

1. Updated standardized image test sets representing substrate (e.g., mud, sand, gravel, cobble, boulder, and combinations thereof) and biological categories (e.g., epifauna, scallops, yellowtail flounder, etc.).
2. Abilities to better utilize HabCam imagery through development of automated tools for scallop classification.
3. Ability of segment of depth in stereo images thereby providing access to targets just millimeters above the seafloor.
4. This research project has had immediate and practical applicability to population assessments for the additional target species while demonstrating the applicability of assessing benthic living marine resources within the northeast as well as other regions that fall under NOAA's jurisdiction.

Data and algorithms developed here are also being shared with Kitware, Inc. who is working with NOAA in developing software under their VIAME workflow.

The proposed work has resulted in 1a platform with an easy to use Python/Matlab API that exposes functionalities of the capability and the project's algorithmic workflow for NOAA and WHOI researchers.

HIGHLIGHTS

1. Updated standardized image tests for mud, sand, gravel, cobble, boulder, and epifauna, scallops, yellowtail flounder, are now being used worldwide in habitat characterization projects.
2. Developed much improved automated tools for scallop classification.
3. Segmenting images on depth in stereo images provided dramatic improvement in flat fish

identification.

4. HabCam was run directly into the largest wreck on the northeast continental shelf within the first four hours of Leg 1 off the coast of Delaware. The cable snapped and the vehicle was lost in the wreck. With the whole survey in front of us I was able to make contact with the owners and operators of the Kracken LL, a large ROV that could handle the strong currents (2 kts) and depth (100m) where the vehicle lay. Within two days the ROV was on the deck of the Hugh Sharp and we were steaming out to the wreck site. Fours later we had HabCamV4 back on deck and two hours later I had the system up and running again with a new termination. We offload the Kracken II in Lewes and went back out to complete the scallop survey. This was a tremendous effort on all parties and resulted in only losing five days total of survey time.

SOCIETAL BENEFITS

This research project has had immediate and practical applicability to population assessments for the additional target species while demonstrating the applicability of assessing benthic living marine resources within the northeast as well as other regions that fall under NOAA's jurisdiction.

EDUCATION AND OUTREACH ACTIVITIES

Gallager had two summer student fellows and Guest Students on board each of the survey legs. The students learned first-hand about what it takes to produce a survey of the entire offshore scallop resource, which is worth $800 M.

PUBLICATIONS

Prasad, L, H Singh, SM Gallager. Edge-based Cuing for Detection of Benthic Camouflage Methods in Oceanography. 2016.15-16, pp.35-48

Gallager, SM, and V Norhdal. HabCamV4: An Integrated Habitat Mapping Camera System for Stereo Optical and Acoustic Benthic and Pelagic Assessments in Coastal Oceans. Submitted to IEEE Journal of Oceanic Engineering.

Honig, P, C Stewart, and SM Gallager. Automated substrate classification from HabCam, a stereo benthic imaging system. In Review. J Ocean. Engineering.

Shank, B, D Hart, SM Gallager and K Stokesbury. Abundance and spatial distribution of Yellowtail Flounder in Closed Area II South, 2010 vs. 2012, from an image-based survey. ICES. Submitted for NOAA internal reporting.

Kaplan, K, D Hart, K Hopkins, SM Gallager, AD. York, R Taylor, P Sullivan. The distribution of the invasive tunicate Didemnum vexillum in Atlantic sea scallop *Placopecten magellanicus*

habitat on fishing grounds and closed areas of Georges Bank. ICES in press.

Kaplan, K, D Hart, K Hopkins, SM Gallager, AD. York, R Taylor, P Sullivan. The invasive tunicate *Didemnum vexillum* limits Atlantic sea scallop *Placopecten magellanicus* habitat on fishing grounds and closed areas of Georges Bank. ICES In Press.

Interactive Visualization of Large Benthic Image Datasets using Topic Modeling

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Yogesh Girdhar, WHOI

NOAA Sponsor – Elizabeth Clarke, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 40,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

Our ongoing work on Bayesian non-parametric topic modeling can be used to automatically compute (topic) labels for image datasets that are representative of the image content. This project aims to develop interactive tools for visualizing these large image datasets that taking advantage of the topic modeling analysis. These tools will enable scientists to analyze the contents of large datasets, such as image datasets collected by AUVs, and assist in focusing their attention to only the relevant portions of the data, independent of the research problem at hand.

ACCOMPLISHMENTS

We have developed TopicExplorer, a web based software tool for interactive exploration of large image sequence datasets, such as those produced by an AUV. The visualization tool works in combination with the Bayesian non-parametric topic modeling tools, which can be used to automatically compute discrete labels for image data and identify "surprising" regions.

The software presents an interactive timeline based visualization of the image sequence dataset, marking images that have similar content with the same colors. The web based interface makes it easy for scientists to explore large datasets, without explicitly installing any software on their computer. Figure 1 shows a screen shot of the software in action.

In addition to the proposed research, the funds from this project are being used for a summer guest student: Naveen Tripathi. The student will explore the use of stereo vision in an underwater context.

HIGHLIGHTS

- Open source web based visualization tools that enables interactive exploration of large image datasets.

- Enables rapid exploration of datasets based, taking advantage of the image content.
- Automatic detection of meaningful anomalies with potential scientific relevance.
- An example of visualizations of AUV dives is available online at: http://warp.whoi.edu/panama2015-vis/.

SOCIETAL BENEFITS

The visualizations tools developed under this funding are freely available under an open source license at: https://gitlab.com/warplab/topicexplorer

EDUCATION AND OUTREACH ACTIVITIES

- *2016 IEEE International Conference on Robotics and Automation (ICRA)*
- *2017 IEEE International Conference on Robotics and Automation (ICRA)*

Relevant Web Links:

- Source code available at: https://gitlab.com/warplab/topicexplorer
- Visualization of AUV dives at Hannibal Seamount: http://warp.whoi.edu/panama2015-vis/

PUBLICATIONS

Following fully peer reviewed conference publications were supported in part by this project:

- Girdhar, Y., Walter Cho, Campbell, M., Pineda, J., Clarke, E., & Singh, H. (2016). Anomaly detection in unstructured environments using Bayesian nonparametric scene modeling. In *2016 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 2651–2656). IEEE. http://doi.org/10.1109/ICRA.2016.7487424
- Kalmbach, A., Girdhar, Y., Sosik, H., & Dudek, G. (2017). Phytoplankton Hotspot Prediction Using an Unsupervised Spatial Community Model. In *IEEE International Conference on Robotics and Automation (ICRA)*. Preprint available at: https://arxiv.org/abs/1703.07309

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

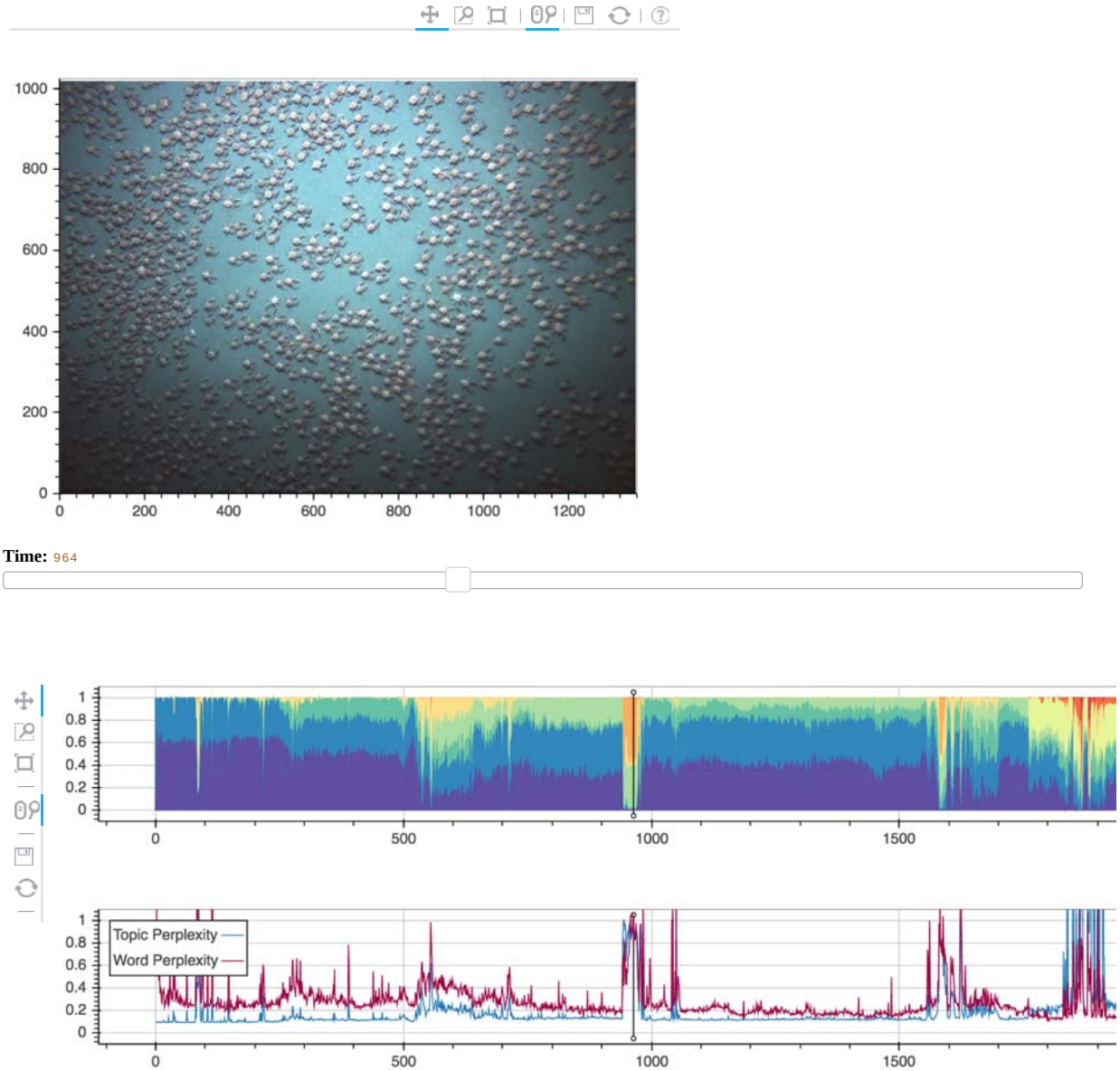


Figure 1. TopicExplorer is a web based visualization tool that can be used to interactively explore large image datasets such as those collected by AUVs and stationary cameras. The colors here are representative of the image content, such that time-steps with similar color are likely to have similar image content (in this case substrate types). The plot at the bottom shows a model perplexity score, which can be interpreted as interesting temporal regions in the dataset.

Fish Tank: Enhancing Stock Assessments

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Mary Hudson, GMRI

NOAA Sponsor – Mike Simkins, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 29,999

PROJECT OVERVIEW, GOALS, AND MILESTONES

In 2015 the Gulf of Maine Research Institute (GMRI) held a series of port meetings as part of the Fish Tank series, *Collaborative Approach to Improving Stock Assessments.* The Fish Tank series brought together commercial and recreational fishermen, scientists, and policy representatives from across the region to spark productive conversations and brainstorm on ideas to improve stock assessment data and processes. *Taking Stock: A Workshop to Collaboratively Improve Stock Assessments,* held in November 2015, was the culmination of the Fish Tank port meetings.

During this workshop scientists and fishermen worked together to develop a set of prioritized research goals focused on improving stock assessments. From these goals, GMRI issued a request for proposals to the Fish Tank meeting and workshop participants. Two projects were chosen for funding:

- *"Developing Applications of Fishery Catch Rates for New England Groundfish Stock Assessments*" submitted by Steve Cadrin from SMAST, and
- "*Estimating catchability for an industry-based groundfish survey net in the Gulf of Maine*" submitted by Bill Hoffman from the MA Division of Marine Fisheries.

This project aims to further the goals of the *Taking Stock* workshop (and subsequently derived research priorities) by providing funding for the above projects. As grant administrator, GMRI will oversee and distribute monies from NEFMC, CINAR, and GMRI's Moore grant.

CINAR funding will be sub-awarded to SMAST for the project, "*Developing Applications of Fishery Catch Rates for New England Groundfish Stock Assessments*". This study will improve the data and models used to manage New England groundfish by developing standardized fishery catch-per-unit-effort (CPUE) series for application to current and future New England groundfish stock assessments.

The project will develop series of standardized CPUE for groundfish stocks through several stages. Stage 1 will expand a CPUE review conducted previously, and will compile previously

developed series of CPUE to test their correlation with estimated stock trends. Stage 2 will convene fishermen and scientists to identify factors related to groundfish catch rates and targeting to provide *a priori* information for consideration in model building. Analysis of vessel trip report (VTR), observer, and study fleet data, as well as model building, will occur in Stage 3. Lastly, Stage 4 comprises the dissemination of results, particularly by presenting a working paper at the witch flounder stock assessment workshop.

All four stages for witch flounder have been completed. With significant amount of funding still remaining, SMAST requested a no cost extension to continue developing standardized CPUEs for other species. They are currently working on halibut CPUE.

ACCOMPLISHMENTS

SMAST held several meetings with fishermen to gather input on factors aside from abundance that would influence catch rates of witch flounder, as well as on how they might identify trips that targeted witch flounder. This information was applied to data from NOAA's Northeast Fisheries Science Center (NEFSC) so as to filter targeted trips and develop a standardized series of catch (or landings) per unit effort from dealer and observer datasets. We presented our work at the SAW/SARC 62 meeting, where reviewers decided to include a CPUE series based on 40% catch of witch flounder in sensitivity runs of the proposed ASAP model.

Ultimately, the model was rejected as the basis for management due to strong retrospective patterns (among other factors), and the review panel suggested an empirical approach that could consider landing per unit effort (LPUE). The Stock Assessment Review Committee (SARC) review panel suggested time-varying selectivity and catchability components in future work; SMAST will incorporate this feedback into work with other species.

This work was also presented at the Flatfish Biology Conference in Westbrook, CT in December 2016. With guidance from fishermen and Groundfish PDT members, SMAST determined to apply their standardization methods to halibut and white hake assessments, and are currently in the process of doing so.

HIGHLIGHTS

- Completion of witch flounder standardized CPUE series
- Inclusion of CPUE in several alternatives stock assessment, and fully considered in all model runs
- Further interest in CPUE work, and application to halibut and white hake

SOCIETAL BENEFITS

This research benefits fishery stakeholders by enhancing the quality and completeness of the data and science that informs decision makers. By including fishermen and their data in alternative types of analysis, the PIs of this project are bridging the gap between industry and science, and

providing a data perspective that has the opportunity to enhance stock assessments.

EDUCATION AND OUTREACH ACTIVITIES

- Presentation at SAW/SARC 62 meeting for witch flounder assessment
- Presentation at 2016 Flatfish Biology Conference in Westbrook, CT

Assessing the Pathogenesis and Host Susceptibility to Dolphin Morbillivirus in Cetaceans

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Michael Moore, WHOI

NOAA Sponsor – Teresa Rowles, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 21,629

PROJECT OVERVIEW, GOALS, AND MILESTONES

Over the last 25 years, marine morbilliviruses have caused high mortality in cetaceans and pinnipeds worldwide, resulting in the death of tens of thousands of marine mammals. The severity of infection has resulted in population level consequences in susceptible species. In 1988 and in 2002 phocine distemper virus (PDV) killed over half the population of harbor seals in Europe. Relatively conserved strains of PDV that exhibit little genetic variability appear to induce few differences in host adaptation, pathogenesis, and epidemiology, while the more divergent group of cetacean morbillivirus (CeMV) exhibits a broader range of host adaptation, pathogenesis, and epidemiological patterns, making it increasingly difficult to predict and manage outbreaks in cetaceans. Dolphin Morbillivirus (DMV) was implicated in an Unusual Mortality Event (UME) in 2013 involving over 1,600 bottlenose dolphin deaths in the U.S. Northeast and Southeast Atlantic. Despite several large scale epizootic events due to various strains of DMV, susceptibility, pathogenesis and epidemiology are still not fully understood. To predict the effects of the virus and to develop effective individual or population wide models and interventions, including the possibility of vaccination programs for small endangered populations, an understanding of susceptibility, transmission, and reservoir dynamics of the viruses are necessary.

The objectives of this study are therefore to undertake a multidisciplinary approach over two years to determine mechanisms of host susceptibility and pathogenesis of DMV by examining tissues to determine distribution of infection, identifying host reservoir species, and understanding host susceptibility.

Objectives: Samples have been analyzed to improve our understanding of how DMV infection progresses within bottlenose dolphins following infection, specifically by determining in which tissues and cells the virus replicates. Assessment of viral distribution in chronic and acute infections can provide information on the relationship between presence of virus and pathology associated with these states, how the virus may be transmitted between individuals in the marine environment, and potential impacts on the health of individuals that survive infection. We are

also investigating the potential species that may harbor the virus between outbreaks, i.e., acting as reservoir hosts in the US Atlantic. Additionally, we are using immune cells collected from various species to investigate differences in susceptibility. This laboratory-based approach may allow for a better interpretation of what we see in different cetacean species in the wild.

Hypotheses:
H1: Tissue tropism of DMV in bottlenose dolphins reflects pathology, routes of exposure and shedding of the virus.
Sample collection is completed and lab work is in progress for Hypothesis 1 to determine what tissues the virus is most likely to infect. Animal data from initial stranding, histopathology, immunohistochemistry (IHC) staining, sequencing and nested PCR are being analyzed and interpretation is underway.

H2: Reservoir species harboring DMV exist.
Sample collection is completed and lab work in progress for Hypothesis 2. RNA from pairs of tissues (brain and lung; or spinal cord and lung; or brain and lymph node; or spinal cord and lymph node) has been extracted and tested by nested PCR for DMV. Retrospective samples have been acquired ranging from 2002-2016. Currently 69 cetaceans have been screened and putatively positive samples are being sequenced and testing repeated to confirm results for the presence of DMV. This will be conducted in August of 2017.

ACCOMPLISHMENTS

The majority of work for the first objective of this project has been completed. Dr. Deborah Fauquier (NOAA Marine Mammal Health and Stranding Response Program) provided data on bottlenose dolphin cases collected during the 2013 UME to select cases. In total, 440 tissues from 50 individual bottlenose dolphins have been screened for DMV using nested PCR. Sequencing remains to be completed for 20 of the 202 positive samples. This work was performed at the University of California, Davis under mentorship by Dr. Tracey Goldstein. Nine cases from these 50 were further investigated to assess tissue distribution of DMV using IHC for morbillivirus antigen under the guidance of Dr. Katie Colegrove at the University of Illinois. Up to 26 tissues from each case were evaluated. Analysis of nested PCR, sequence, IHC, and histology data is ongoing to correlate the detection and distribution of DMV in bottlenose dolphin tissues with potential health outcomes.

The goal for the second objective, to screen a minimum of 50 cetaceans sampled retrospectively as potential reservoirs of DMV, is ongoing. Dr. Deborah Fauquier provided the master list from the National Marine Mammal Stranding Database of all cases where necropsy samples were collected since 2000. Pairs of tissues (brain and lung; or spinal cord and lung; or brain and lymph node; or spinal cord and lymph node) from 69 cetaceans have been extracted and tested by nested PCR. One hundred and five additional cetaceans from North Carolina have recently been obtained for further screening. Sequence analysis and repeat testing is ongoing to confirm results from the initial 138 samples.

Identification of DMV in multiple tissues from bottlenose dolphins affected during the UME has

already allowed for a better understanding of the distribution of the virus in infected animals. We can visualize morbillivirus antigen to determine the presence of virus in different tissues over the course of infection and begin to understand if acute vs. chronic infections occur. Dolphins with acute infection tend to have a greater number of tissues with morbillivirus detected by IHC (and PCR). Dolphins with chronic infection have no staining in tissues by IHC (using the CDV antibody), for morbillivirus antigen. Similarly, in cases thought to represent more chronic infections, fewer tissues were PCR positive for DMV. Coupled with PCR data using a sensitive nested primer set, we can also hypothesize on the routes of exposure and transmission as well as detect virus in tissues where low virus presence is not detected by IHC. For example, positive IHC staining and presence of DMV by PCR have been detected in penile lesions and skin lesions. Bottlenose dolphins are extremely tactile, and these areas of the body may be where other dolphins encounter virus from conspecifics. Feces, urine, and blow swabs have also been confirmed to be PCR positive. These routes of exposure may also be a means for viral transmission between dolphins.

One significant change to the project is the overall completion date for the project. A one year extension was granted to A. Bogomolni to complete this traineeship project due to health concerns.

HIGHLIGHTS

- Over 440 samples from 50 bottlenose dolphins have been identified to understand DMV tissue tropism and have been processed to detect DMV.
- A retrospective analysis of samples available from 2008-2012 is underway to test for CeMV reservoir species. 138 samples from 69 cetaceans have been tested and sequences from these cases are being evaluated.
- A nested PCR protocol was designed for more sensitive detection of CeMV strains in reservoir species.
- All reservoir samples and tropism samples were re-evaluated using the nested PCR.
- Initial results combining several diagnostics suggest vast differences in acute and chronic infection patterns of DMV in bottlenose dolphins.
- The differences seen in IHC vs. PCR diagnostics between acute and chronic cases emphasizes the need to use multiple diagnostic methods to detect the presence of virus or viral proteins.

SOCIETAL BENEFITS

This research complements the theme of ecosystem monitoring within the goals to conduct research and develop tools to rebuild protected species to healthy population levels, and to develop robust indicators of ecological health that can be utilized by resource managers.

Drone-derived Measures of Respiratory Microbiome and Girths: Non-invasive Indicators of Right Whale Health

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Michael Moore, WHOI

NOAA Sponsor – Peter Corkeron, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 99,884

PROJECT OVERVIEW, GOALS, AND MILESTONES

Understanding the relationship between health and environmental stressors is important for large whale conservation. However, robust measurements of health are challenging to acquire, but methodology to non-invasively assess the health of large whales is being developed. Here we propose to utilize small, unmanned multicopter drones to develop non-invasive health indices for right whales (*Eubalaena glacialis* and *E. australis*). We will remotely acquire high resolution vertical images to assess body condition from girth (fat) levels and lesion markings, and also collect blow samples of the respiratory microbiome, the assemblage of microorganisms residing in the respiratory tract, which is the most common source of cetacean disease. We plan to conduct a comparative study by obtaining body condition images and respiratory microbiome samples from North Atlantic right whales in the North Atlantic, a highly industrialized coastal ecosystem that is heavily overfished and is substantially used for maritime activities, and also Southern right whales in the western South Atlantic (where southern right whale die-offs have been recorded in recent years) and/or South Pacific, which are relatively pristine habitats. PCR analyses of specific respiratory tract bacteria have been undertaken using an unmanned helicopter, however the entire respiratory microbiome for any large whale has not been studied as far as we are aware. Morphometric and respiratory microbiome data sets will be compared and contrasted with known ecosystem status data. This will be the first time a comprehensive respiratory survey is conducted on animals from different habitats and in varying health conditions. The potential correlation of the respiratory microbiome with health features is of particular importance for the right whale and other endangered or threatened populations of large whales, for which rigorous non-invasive health assessment techniques are limited.

Specific Goals for this Project Period:

Working in three right whale habitats: Auckland Islands, New Zealand, East of Amelia Island, Florida, and Cape Cid Bay Massachusetts, U.S.A.

- Obtain photogrammetric quality, vertical images of right whales. Such images enable a measurement of total body length and body – length ratios.

- Obtain blow samples to better understand the basis for any observed variation in body condition.

ACCOMPLISHMENTS

We have successfully developed safe, reliable methods for boat based aerial photogrammetry and blow collection using a small hexacopter, the APH-22. After various blow collection arrangements were tested, we found that the optimal location for a blow collection device was on the upper aspect of the UAS. UAS fly by creating a downdraft, thus rather than trying to sample an up-welling sample below the down-welling UAS, we found that it was better to entrain the blow in the down draft and sample as it reached the upper surface of the UAS. Thus a sterile petri dish, 18 cm in diameter was attached to the UAS using double sided suction cups (Figures 1 and 2).

The following six field periods were completed:

- Peninsula Valdes: Data were collected between September 21 and 30 (2015). A total of 23 mother calf pairs and 13 single whales were imaged (Figure 3a), and 13 blow samples were collected.
- Florida: Data were collected between February 16 and 22 (2016) (Figure 3b). Images were acquired from four mother calf pairs (Catalog #'s 3405, 3101, 1281, and 3317), and one lone, very compromised female (#1968) (Figure 4). Blow samples were acquired from the 4 mothers (Figure 5), and one calf. Data were also collected between January 11 and 15, 2017 from two mother and calf North Atlantic right whale pairs.
- Auckland Islands, New Zealand. Data were collected between July 17 and August 22, 2016, and 30 Southern right whales were imaged and blow sampled.
- Cape Cod Bay, Massachusetts. Data were collected from North Atlantic right whales between March 23 and April 9 2016, and 27 whales were sampled. Between March 13 and 31, 2017 between 23 North Atlantic right whales were sampled.

Next steps are to analyze images and blow samples. However preliminary analysis of representative images from the two locations shows a marked difference in body condition for mothers and calves from the two locations. Thus our initial premise was borne out. Blow sample analysis has been dependent on full development of analysis protocol, using more plentiful humpback blow samples for method optimization. We are now ready to start the right whale blow analysis. Images will be measured in collaboration with Fredrick Christensen, Murdoch University, Australia.

HIGHLIGHTS

- Large whale photogrammetry is possible with a small unmanned hexacopter.
- The method is repeatable and far safer than having humans in small low flying aircraft.
- We met our field objective of a comparison of right whale body and blow condition between the N and S hemispheres. The laboratory work is ongoing.

SOCIETAL BENEFITS

Understanding the relationship between right whale body condition and health as measured by respiratory microbiome diversity is important. It contextualizes global differences in right whale exposure to human disturbance and is critical to a societal understanding of how human activity affects wildlife.

EDUCATION AND OUTREACH ACTIVITIES

A press release on this method https://www.whoi.edu/news-release/whalecopter received substantive media attention.

A presentation was made at the North Atlantic Right Whale Consortium in New Bedford, MA, on November 2nd 2016 as follows: "Integrating Photogrammetry from Manned and Unmanned Aircraft to Monitor the Growth of North Atlantic Right Whales," Durban, J., Fearnbach, H., Moore, M., Lynn, M., Pettis, H., Perryman, W.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. APH-22 hexacopter in flight, modified with sterile blow collection dish mounted on the upper aspect of the apparatus. Image Credit: Jen Jakush, Florida Wildlife Conservation Commission.

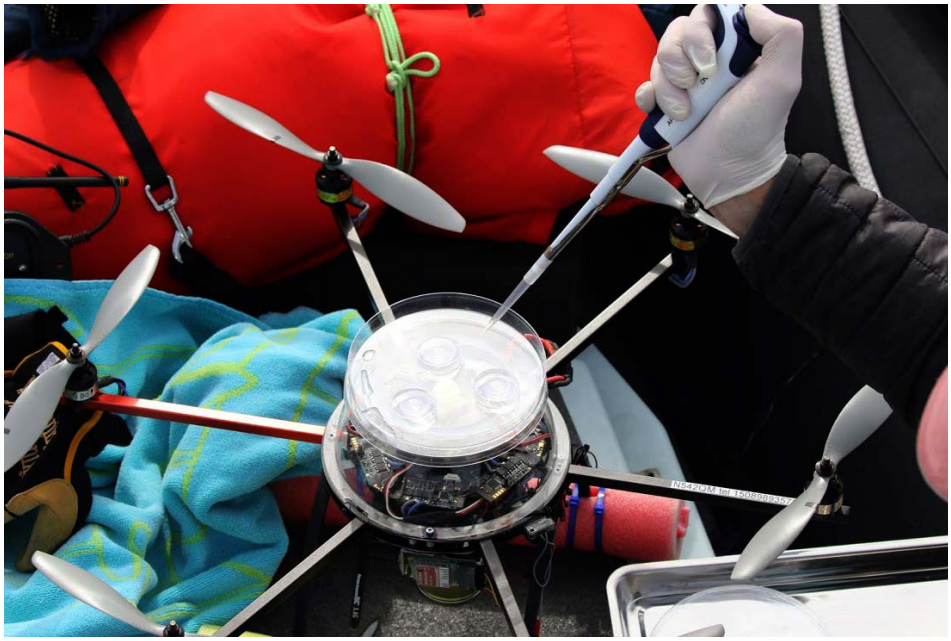


Figure 2. Close up view of blow collection dish. The blow droplets have been eluted with 4 ml of phosphate buffered saline, which is now being harvested. Image Credit: Jen Jakush, Florida Wildlife Conservation Commission.

Figure 3. Comparison of body condition between Southern and North Atlantic mother calf pair right whales. Top: a) Southern right whales from Peninsula Valdés, Argentina. Bottom: b) North Atlantic right whales from Florida, USA. Image Credits: a) Iain Kerr, Ocean Alliance and Carolyn Miller, Woods Hole Oceanographic Institution Permit Sub Secretaría de Conservación y Areas Protegidas #095-SsCyAP/15 Permit Dirección de Fauna y Flora Silvestres #65/2015 DFyFS. b) NOAA Permit #7355, FAA 333 Exemption #12618.

Figure 4. Aerial image of North Atlantic right whale #1968, off Florida. This extremely emaciated animal has been sighted in Feb/ March 2016. It is unlikely to survive. We measured it photogrammetrically. Colleagues from Duke University acquired a blow sample, which has been added to our collection. NOAA Permit #7355, FAA 333 Exemption #12618.

Figure 5. Hexacopter hovering above a North Atlantic right whale waiting to acquire a blow sample. NOAA Permit #7355, FAA 333 Exemption #12618.

A Passive Acoustic Ocean Observing System for Monitoring and Mapping Marine Mammals and Noise in the Chukchi Sea Ecosystem

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Donald Peters, WHOI

NOAA Sponsor – Julie Ann Mocklin, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 158,407

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project was a continuation of the ongoing Chukchi Acoustic, Oceanography, and Zooplankton (CHAOZ) project, which finished its final field season in 2012, and was a component of the Chukchi Acoustic, Oceanography and Zooplankton Extension study, referred to as CHAOZ-X. This CHAOZ-X work was a collaboration between Woods Hole Oceanographic Institution (WHOI) and the Bioacoustics Research Program (BRP) at the Cornell Laboratory of Ornithology (Cornell).

ACCOMPLISHMENTS

In 2016 an Autodetection Buoy (AB_2016) was deployed in the Chukchi Sea on 23 August. It operated for a few hours but then failed to successfully collect or transmit any data through until 5 November, when it was recovered. The specific cause of the AB_2016 failure remains unknown. Upon its return to Cornell, the electronics package operated properly in the lab, so we suspect that there was some sort of connectivity failure in the at-sea configuration.

Data from the marine autonomous seafloor recording units (MARU) array were used to develop bowhead whale acoustic occurrence probability distributions. Double-bubbles were successfully deployed and recovered in this period: DB15_01 from 18 September 2015 through 15 September 2016. Data from these recorders were used to develop and apply unsupervised acoustic event detection processes by which to quantify seasonal changes in the Chukchi Sea acoustic environment, including marine mammals, natural sounds (e.g., ice and wind) and anthropogenic sounds (e.g., vessels and seismic airguns).

HIGHLIGHTS

- AB (AB_2014) was deployed and successfully operated in the Chukchi Sea from 20 August through 7 October.

- AB (AB_2016) was deployed in the Chukchi Sea on 23 August but suffered a premature failure.
- Four MARUs were deployed on 4-5 August 2014 and recovered on 13 October near the area of Shell drilling operations. Those MARU data were used to develop bowhead whale acoustic occurrence probability distributions.
- Four double-bubbles were successfully deployed and recovered: DB13_01 from 27 August 2013 through 04 August 2014; DB14_01 and DB14_02 from 20 August 2014 through 18 September 2015; and DB15_01 from 18 September 2015 through 15 September 2016.
- Data from these recorders were used to develop and apply unsupervised acoustic event detection processes.
- Development of a computational system, referred to as the Acoustic Ecology Toolbox (AET), and analytical paradigm that enables quantification of a marine acoustic environment based on well-established physical acoustic sound transmission models, marine animal auditory data, and empirical acoustic data.
- AET and empirical data from the CHAOZ project were used to model future acoustic environment conditions in the Arctic given expected decreases in ice condition, increases in open water areas and seasons, increases in commercial ship traffic, and energy exploration.
- Results show the utility of our AET analytical paradigm, as well as demonstrating the relative influences on bowhead whale acoustic habitat as a result of different scenarios that involve different combinations of acoustic factors (e.g., wind, behavioral context, shipping, energy exploration).

SOCIETAL BENEFITS

A primary goal has been achieved in that this system and paradigm allow rapid assessment of the relative risks to acoustic habitats under different scenarios, thereby providing a viable mechanism for evaluating environmental risk and for making scientifically-based decisions.

EDUCATION AND OUTREACH ACTIVITIES

A primary objective of this research was to create a logical, analytical system that was systematic and relatively easy to use. The AET has numerous visualization tools – including animations – that allow an audience to experience how an acoustic environment changes under different conditions. This is an excellent example where “a picture (especially an animation) is worth a thousand words!” The result is a system that is highly flexible (generalized) and that offers students and teachers a viable way to explore and understand sound in the marine environment.

UHSI 2015 Cruise

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Yogesh Girdhar (WHOI), Hanumant Singh (NEU)

NOAA Sponsor – Dr. Elizabeth Clarke

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 83,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

The NMFS Untrawlable Habitat Strategic Initiative (UHSI) team is working on a field experiment to evaluate tools and methods appropriate for estimating sampling efficiency of camera systems mounted on stationary-arrays, ROV, AUV, and towed vehicles to count fish within a measureable sampling path. This project is aimed at helping NOAA NMFS managers work on this problem.

ACCOMPLISHMENTS

The NMFS Untrawlable Habitat Strategic Initiative (UHSI) team conducted a multi-tiered field experiment to evaluate tools and methods appropriate for estimating sampling efficiency of camera systems mounted on stationary-arrays, ROV, AUV, and towed vehicles to count fish within a measureable sampling path. Our methodology involved putting MOUSS cameras on the seafloor and running different platforms within their view, which allowed us to compare the fish counts and behavior we observed in (1) an undisturbed setting corresponding to the MOUSS cameras alone, and (2) while observing a robotic platform transiting the area.

Our contribution in this regard was to enable the rapid analysis of the (literally) hundreds of thousands of images that were collected during the deployment through the use of automated techniques that identify perplexing or anomalous observations. Through the use of such techniques we can focus the attention of the human expert on a small subset of the collected data that is most likely to contain relevant information. We used Bayesian non-parametric (BNP) topic modeling to detect and characterize such anomalies. Compared to other kinds of sensor data, image data typically exists in millions of dimensions, corresponding to the number of pixels in the image, which makes it challenging to build an automatic anomaly detection technique. Moreover, detecting anomalous events in a non-stationary unstructured environment, such as coral reefs is even more challenging due to its higher visual complexity, compared to urban scenes. Our proposed approach to dealing with the anomaly detection problem was a novel method that yielded very good results.

We observed species-specific responses of attraction and displacement relative to the transiting vehicles. Abundance of scamp (*Mycteroperca phenax*), and pelagic predators (*Seriola sp., Sphyraena barracuda*) showed significant differences in site density given exposure to transiting vehicles (e.g. before, during, after). Species of the family Pomacentridae showed no significant difference in site density given exposure to a transiting vehicle. Scamp showed highest local densities following the transit of the vehicle and generalized patterns observed on video show they were somewhat displaced by the approaching vehicle. Jacks and barracuda showed highest densities during transit and tended to closely track vehicles from behind. Pomacentrid densities did not significantly change, and there was a marked response of a quick decent down into the habitat during vehicle transit, which were observable in the MOUSS videos.

HIGHLIGHTS

- Conducted the first set of experiments off of Florida in a reef setting
- Showed that the attraction and avoidance behavior in fish is highly species dependent and is a function of the platform and its characteristics (towed vs. autonomous, speed, sensing, lighting, etc.).

SOCIETAL BENEFITS

Sustainable fisheries is an important goal for fisheries management. Part of the solution is to be able to conduct fisheries independent stock assessment by using robotic platforms. This work is an important step in understanding how we can use robots to understand and quantify fish stocks in their natural habitat without actually catching them.

EDUCATION AND OUTREACH ACTIVITIES

Campbell, Matthew et al. "Towards Quantifying Avoidance and Attraction of Reef Fish to Mobile Video Survey Platforms." *145th Annual Meeting of the American Fisheries Society*. Afs, 2015.

Girdhar, Yogesh, et al. "Anomaly detection in unstructured environments using bayesian nonparametric scene modeling." *Robotics and Automation (ICRA), 2016 IEEE International Conference on*. IEEE, 2016.

Figure 1. The Seabed AUV as seen by the bottom mounted MOUSS camera systems. The navigation accuracy of the vehicle allows us to conduct repeat transects close to the MOUSS systems to help determine fish avoidance and attraction biases.

Topic Modeling for Automated Underwater Image Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Yogesh Girdhar, WHOI

NOAA Sponsor – Elizabeth Clarke, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Monitoring***

Amount Funded: $ 49,931

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project aims to develop automated techniques to analyze large image datasets such as those collected by AUVs and static seafloor cameras, for the purpose of rapid visual exploration of these datasets. We explore the use of a Bayesian non-parametric topic modeling technique to automatically compute meaningful labels or tags for the datasets that can be used to identify similar regions. In addition we explore the use of these models to detect anomalous observations that are hard for the model to characterize, which we hypothesize can correspond to scientifically interesting observations.

ACCOMPLISHMENTS

We conducted several experiments which show that the proposed technique is automatically able characterize the underlying terrain, and detect anomalous flora in image data collected by an underwater robot (Fig. 1). Another set of experiments show that the same technique can be used on images from a static camera in a dynamic unstructured environment. In this second dataset, consisting of video data from a static seafloor camera capturing images of a busy coral reef, the proposed technique was able to detect all three instances of an underwater vehicle passing in front of the camera, amongst many other observations of fishes, debris, lighting changes due to surface waves, and benthic flora (Fig. 2).

In addition to the originally proposed research, the funds from this project were used for a summer guest student: Arnold Kalmbach from McGill University. In collaboration with Arnold, and WHOI biologist Heidi Sosik, we applied Bayesian non-parametric topic modeling to model phytoplankton community structure. We experimented with the use of this phytoplankton community model to predict future phytoplankton distribution given weather data, and for detection of phytoplankton hotspot regions in the ocean.

HIGHLIGHTS

- Automatic technique to visualize large volumes of image data efficiently.
- Automatic detection of meaningful anomalies with potential scientific relevance.

SOCIETAL BENEFITS

This research will help us better understand our oceans, most of which have never been explored. As we increase the deployment of AUVs to collect underwater imagery, the problem now is too much data, and not enough manpower to sift through it. The proposed techniques will enable us to explore these large datasets in a more efficient manner.

EDUCATION AND OUTREACH ACTIVITIES

- *2016 IEEE International Conference on Robotics and Automation (ICRA)*

PUBLICATIONS

The following peer reviewed conference publications were supported in part by this project:

- Girdhar, Y., Walter Cho, Campbell, M., Pineda, J., Clarke, E., & Singh, H. (2016). Anomaly detection in unstructured environments using Bayesian nonparametric scene modeling. In *2016 IEEE International Conference on Robotics and Automation (ICRA)* (pp. 2651–2656). IEEE. http://doi.org/10.1109/ICRA.2016.7487424
- Kalmbach, A., Girdhar, Y., Sosik, H., & Dudek, G. (2017). Phytoplankton Hotspot Prediction Using an Unsupervised Spatial Community Model. In *IEEE International Conference on Robotics and Automation*. Preprint available at: https://arxiv.org/abs/1703.07309

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

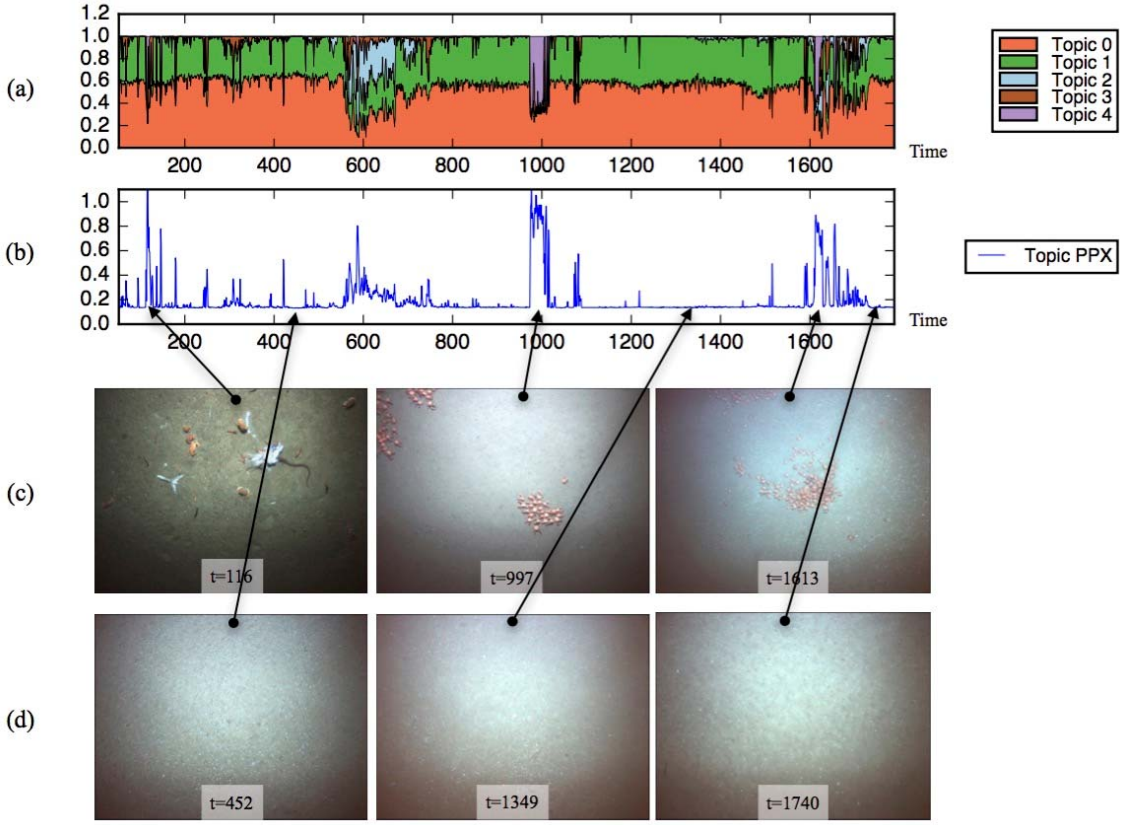


Figure 1. Application of the proposed methods on the Galatheid crab dataset. (a) A stacked plot showing distribution of topic labels at each time step in the dataset, computed using the proposed technique. We see that Topic 0 and 1 are characteristic of the underlying terrain, whereas other topic labels are representative of other phenomena such as galatheid crab aggregations. (b) Shows the normalized perplexity scores for each time step. (c) Shows examples of images with high perplexity scores, corresponding to anomalous observations. Image with *t=116* shows various animal species feeding off a fish carcass, and is the most anomalous scene in the dataset. Other anomalous observations are of galatheid crabs. (d) Shows examples of some typical images in the dataset, represented by their low perplexity scores.

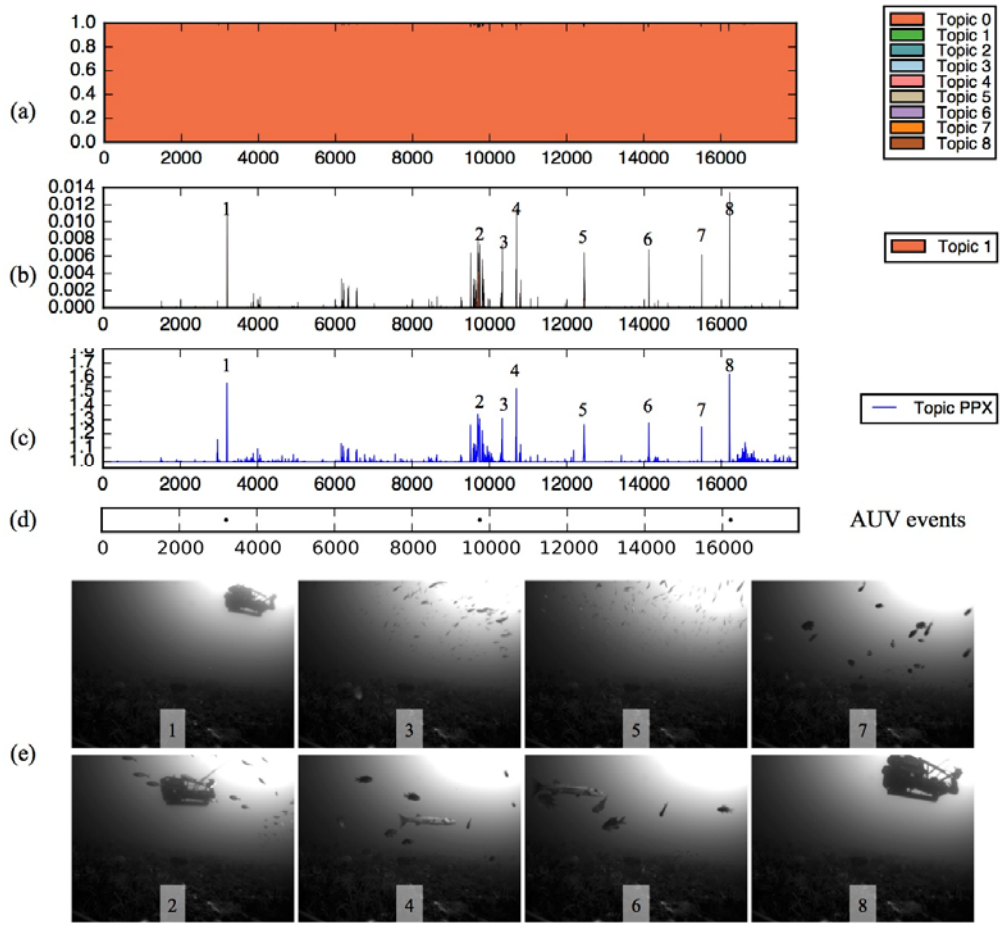


Figure 2. Application of the proposed methods on a coral reef dataset captured with a static camera. (a) Shows topic label distribution of the dataset across each time step. We see that the distribution is dominated with Topic 0, which characterizes the scene background. (b) Shows the normalized distribution of the next highest weighted topic. (c) Shows the perplexity score for each time step. We see that the perplexity scores correlate well with Topic 1 distribution, which is expected because Topic 1 is relatively rare in the dataset compared to the topic label representing the background. (d) Marks the hand labeled locations of events where the AUV was sighted, which corresponds to peaks 1, 2 and 8. (e) Shows images corresponding to the eight highest peaks in the perplexity scores. We see that the perplexity model is able to detect all three events of an underwater vehicle passing in front of the camera. The other perplexity peaks correspond to sightings of barracuda, and schools of fish, both of which are anomalous.

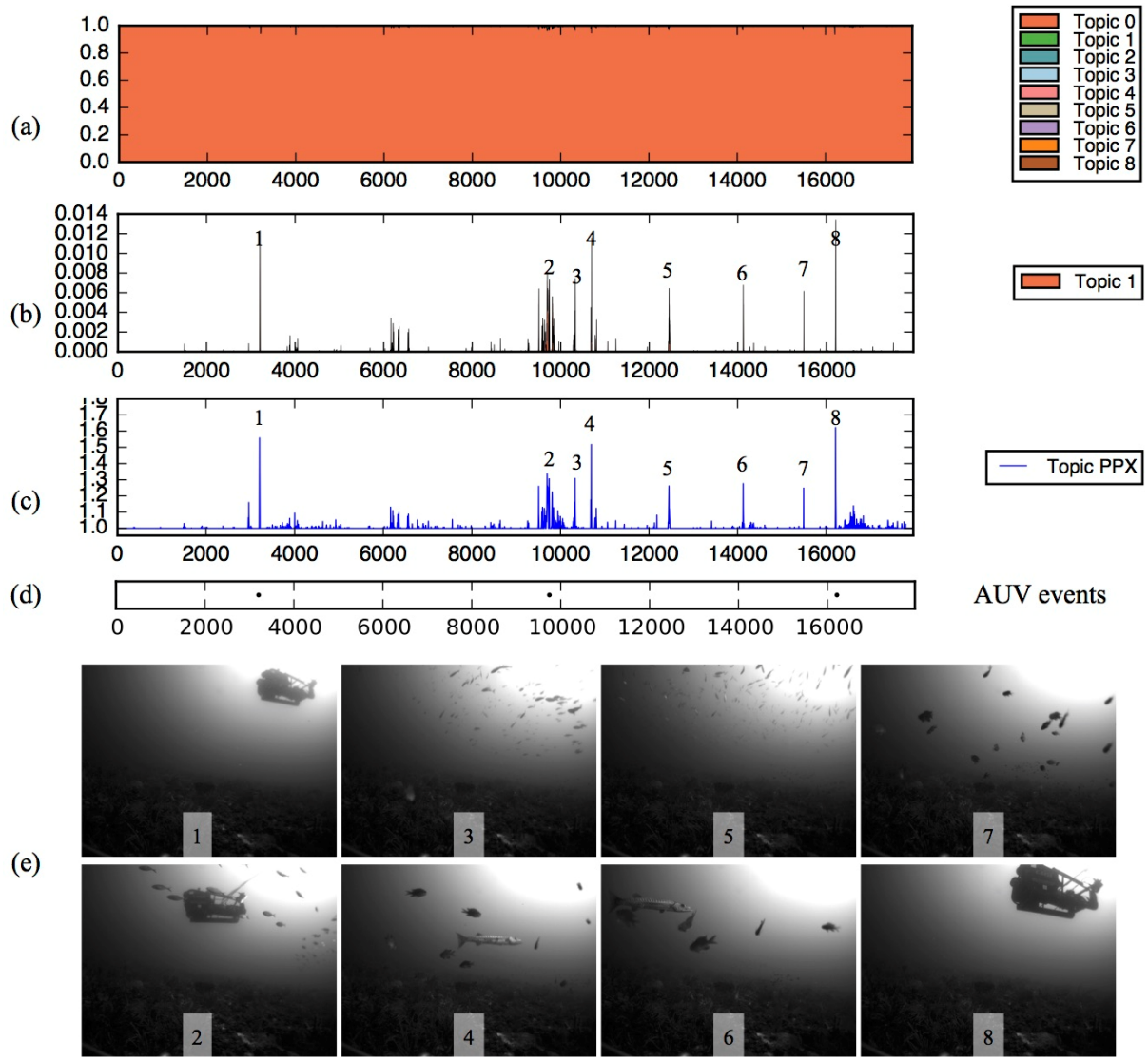


Figure 2. Application of the proposed methods on a coral reef dataset captured with a static camera. (a) Shows topic label distribution of the dataset across each time step. We see that the distribution is dominated with Topic 0, which characterizes the scene background. (b) Shows the normalized distribution of the next highest weighted topic. (c) Shows the perplexity score for each time step. We see that the perplexity scores correlate well with Topic 1 distribution, which is expected because Topic 1 is relatively rare in the dataset compared to the topic label representing the background. (d) Marks the hand labeled locations of events where the AUV was sighted, which corresponds to peaks 1,2 and 8. (e) Shows images corresponding to the eight highest peaks in the perplexity scores. We see that the perplexity model is able to detect all three events of an underwater vehicle passing in front of the camera. The other perplexity peaks correspond to sightings of barracuda, and schools of fish, both of which are anomalous.

THEME III. ECOSYSTEM MANAGEMENT

2016 AUV Sentry Nizinski Cruise

2016 ROV Jason R/V Sikuliaq Cruise

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Andrew Bowen, WHOI

NOAA Sponsor – Martha Nizinski (NMFS) and Thomas Peltzer (OAR)

Related NOAA Strategic Plan Goal: ***Healthy Oceans / Climate Adaptation and Migration***

CINAR Theme: ***Education and Outreach / Ecosystem Management***

Amount Funded: $ 26,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

2016 AUV Sentry Nizinski Cruise: Provide Sentry AUV for 15 days (8/22/16-9/05/16) in support of Dr. Martha Nizinski's investigation of deep-sea coral habitats in canyons and slope areas off of Virginia, North Carolina, and South Carolina on NOAA R/V *Pisces*.

2016 ROV Jason R/V Sikuliaq Cruise: Provide Jason AUV for one day to recover samples during Brian Ittig and David Butterfield's cruise (7/08/16-8/15/16) on R/V Sikuliaq.

ACCOMPLISHMENTS

Vehicle operations were successful on both cruises.

SOCIETAL BENEFITS

The impact on society derived from these oceanographic expeditions can be extensive, and includes technological advances to be achieved in sensing and imaging the deep ocean and seafloor, knowledge to be gained from historical climate records stored in the deep sea, and the effect of an open house tour of the manned and unmanned submersibles on a group of high school students. The general public, and the U.S. and international scientific communities all benefit from the work done with the vehicles operated by the National Deep Submergence Facility (NDSF).

EDUCATION AND OUTREACH ACTIVITIES

Over the past several years an increased awareness of our collective responsibility to bring this science into the public forum has resulted in new avenues for sharing these scientific findings. Previous expeditions and engineering trials utilizing NDSF assets include the University of

Washington's REVEL program, the *Jason* Project, and the NOAA Vents Program. Our vehicle operations and associated science programs have reached the public through a variety of television and internet outlets, including programs on National Geographic Explorer, National Geographic Channel, Discovery Channel, PBS, the History Channel, the National Geographic Society and NOAA's Ocean Explorer web sites. The cruise website concept has been effective in reaching the classroom with near real-time images and two-way communications between the scientists and students in schools across the country. Several cruises in 2017 are planning to use this tool. Past examples of websites of this nature are:
http://science.whoi.edu/DiveDiscover/
http://www.ridge2000.org/SEAS/

Several 2017 cruises will involve collaborative efforts involving the international community. The joining of scientific minds without regard for ethnicity or political background strengthens these expeditions and brings the world closer together.

Incorporating Environmental and Ecological Variables to Improve Stock Assessments: An Application to Northern Shrimp in the Gulf of Maine

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Yong Chen, University of Maine

NOAA Sponsor – Anne Richards, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme*: Ecosystem Management*

Amount Funded: $ 87,202

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project aims to incorporate environmental and ecological variables to improve the assessment of Northern Shrimp in the Gulf of Maine. Specifically, the objectives are (1) develop and evaluate approaches to incorporating temperature in modeling recruitment dynamics in the length-structured model; (2) evaluate various functions to link temporal variability of shrimp predator abundance with natural mortality; (3) evaluate approaches to account for time-varying natural mortality resulted from temporal changes in predator abundance in the shrimp assessment model; and (4) evaluate the impacts of incorporating temperature and predators on the quality of the stock assessment in both simulations and the assessment.

ACCOMPLISHMENTS

1. A new component that links recruitment dynamic to environmental variables has been added to the newly developed shrimp model. This allows the model to use environmental time series to further explain the recruitment variability. The importance of this new feature added to the assessment model has been evaluated by simulation study. The results show that failure to incorporate environmental signals when the recruitment dynamic was environmentally-driven led to bias in recent estimates of spawning stock biomass, recruitment, and fishing. The inclusion of the environmental data greatly improved the recent estimates, which are most important to managers.

2. Simulations have been conducted to evaluate the performances of the new shrimp model with temperature incorporated. Specifically, we focus on the demonstration of how the new model can improve the assessment by comparing to the model that simplifies the ecological complexity, i.e., with no consideration of the seasonal variations and/or environmentally-driven recruitment dynamics. The simulation study shows that: (i) the inclusion of the environmental data resulted in better estimates of historical recruitment, compared to the assessment without considering environmental variables, especially for the years when

recruitment was extremely poor; however, not including the environmental data would not deteriorate the estimates of historical productivity and exploitation rate; (ii) ignoring the seasonality in the fishery resulted in risk-prone outcome, i.e., considerable over-estimation of SSB, recruitment and under-estimation of exploitation rate; (iii) mis-specifying seasonal growth as constant during a year did not result in degraded estimates of SSB, recruitment and exploitation rate if the contrast of growth rate between two seasons were relatively small. These results suggest that the newly developed assessment model could greatly improve the shrimp assessment by taking environmentally-driven recruitment dynamic and seasonality in fishery and growth into account.

3. We applied a recently developed spatio-temporal model that incorporates environmental variables to estimate a model-based abundance index for northern shrimp in the Gulf of Maine. We contrasted this spatio-temporal index with a classical design-based index and evaluate the impacts of differences between the two abundance indices on the stock assessment. We showed that using the spatio-temporal index in the assessment model greatly alters the estimates of recruitment and spawning stock biomass and the determination of stock status. Also, incorporating the spatio-temporal index leads to less retrospective bias and outperforms the model with design-based index in terms of predictive performance through a retrospective cross-validation test. Our results suggest that temporal variability of population abundance could be exaggerated by the design-based estimator and such imprecision may greatly affect the performance of a stock assessment and subsequent development of management decisions.

4. Simulation experiments were conducted to evaluate the performance of the size-structured assessment model with various methods of specifying natural mortality. A variety of true population dynamics with different temporal patterns of natural mortality were simulated. We modified the shrimp assessment model to allow estimating time-specific deviations from the average natural mortality. The performance of the assessment model with different natural mortality configurations differed greatly among scenarios where temporal pattern of natural mortality differed. This suggested that temporal pattern of natural mortality was important in choosing the method of modeling time-varying natural mortality. Fixing time-varying natural mortality at the average value in the assessment model resulted in acceptable estimates of spawning stock biomass and recruitment, when the underlying temporal variability of natural mortality was small. However, this was not true when the temporal variability increased. Estimating a single natural mortality in the assessment when it actually varied over time led to large bias. The temporal deviations of natural mortality were biasedly estimated without auxiliary data when there were pronounced one-way trends present. When auxiliary information on deviations is available, using it as data to estimate deviations outperformed pre-specifying the weights for scaling average natural mortality.

HIGHLIGHTS

- A new component that links recruitment dynamic to environmental variables has been added to the newly developed shrimp model.
- The inclusion of the environmental data greatly improved the recent estimates of recruitment which are most important to managers.

- The new size-structured assessment model with environmental variables improves the assessment of northern shrimp.
- The inclusion of spatio-temporal abundance index with environmental variables could potentially improve the shrimp assessment.
- Using auxiliary information, e.g., predation index to estimate time-varying natural mortality within the size-structured assessment model is feasible and potentially can improve the shrimp assessment.

SOCIETAL BENEFITS

The model developed and tested with the support of this grant will be used to assess the northern shrimp resources in the Gulf of Maine, which will improve the assessment quality of this important species, leading to improved management and resolving issues for stakeholders of this fishery.

EDUCATION AND OUTREACH ACTIVITIES

"Spatial and interannual variability in northern shrimp (*Pandalus borealis*) distribution in the Gulf of Maine: implications for stock assessment and management", CCFFR 2017 – General Contributed Presentations, Montreal, Canada, January 2017.

"When is enough, enough?" Methods for optimising, evaluating, and prioritising of marine data collection", ICES Annual Science Conference – Session O, Riga, Latvia.

"Geostatistical index standardization improves the performance of stock assessment model: an application to northern shrimp in the Gulf of Maine", September 2016.

PUBLICATIONS

Chen, Y., Cao, J., Richards, A. (2016) Improving assessment of *Pandalus* stocks using a seasonal, size-structured assessment model with environmental variables. Part I: Model description and application. Canadian Journal of Fisheries and Aquatic Sciences, 4(3): 349-362.

Chen, Y., Cao, J., Richards, A. (2017) Improving assessment of *Pandalus* stocks using a seasonal, size-structured assessment model with environmental variables: Part II: Model evaluation and simulation. Canadian Journal of Fisheries and Aquatic Sciences, 74(3): 363-376.

Chen, Y., Cao, J., Thorson, J., Richards, A. (2017) Spatio-temporal index standardization improves the stock assessment of northern shrimp in the Gulf of Maine. Canadian Journal of Fisheries and Aquatic Sciences, 10.1139/cjfas-2016-0137

Evaluating Anglers Response to Catch Restrictions: An Application to Atlantic Striped Bass

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Keith Evans, University of Maine

NOAA Sponsor – Scott Steinback, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Management***

Amount Funded: $ 92,819

PROJECT OVERVIEW, GOALS, AND MILESTONES

The objective of this study is to measure the economic value that recreational anglers place on keeping and releasing small, medium-sized, and trophy-sized Atlantic striped bass (*Morone saxatilis*). To meet this objective, we developed a mail/web survey sent to recreational anglers living in 10 coastal states along the east coast of the United States (Maine to Virginia). The survey collected demographic and fishing-related information about anglers and included a choice experiment (CE) mimicking alternative regulatory/cost environments. Data from the CE was the primary data source for the behavioral model in which we measure the economic value of keeping and releasing striped bass. When combined with historical catch data and biological information, the behavioral model predicts impacts of regulatory changes on fishing participation, angler welfare, and future stock levels.

ACCOMPLISHMENTS

The recreational striped bass angler survey was developed from May to September of 2016. During this time, the survey underwent extensive pretesting and incorporated valuable feedback from six separate focus groups sessions; two sessions were held at each of three locations (Massachusetts, New York, and Maryland). The purpose of these focus groups was to identify survey questions that proved difficult for participants to answer and to ensure that anglers living in different regions of the study area interpret the questions the same way.

A primary objective of the research is to determine the recreational value associated with keeping and releasing striped bass. To this end, we included a choice experiment (CE) in the angler survey. The CE allows us to evaluate angler preferences for striped bass fishing trips and measure the economic importance of keeping and releasing small, medium-sized, and trophy-sized striped bass. During survey pretesting and development, an experimental design was constructed to optimize the statistical stability of the parameter estimates in the ensuing behavioral model. The experimental design generated 18 sub-versions of the angler survey,

which differed only in the attributes of the CE questions. These questions presented participants with three options; two striped bass fishing trips, which differed in the number of fish caught, the fishing regulations, and cost of the trip, and a "no fish" option. Respondents were then asked to choose which option they "most-preferred" and which option they "next preferred." Responses to these questions were used to develop a behavioral model, explained in more detail below. During October 2016, the research team received 2015 saltwater license frames from the National Saltwater Angler Registry (NSAR); these frames were used to generate a survey sample. The data set of license frames consisted of roughly 1.5 million people across the 10 coastal states along the east coast (Maine to Virginia) that hold a recreational license, or are registered, to fish in saltwater during 2015. A proportionate stratified random sample of anglers was drawn from these license frames. In each state, surveys were sent in proportion to the number of estimated fishing trips that caught or targeted striped bass during 2015 – according to data from the Marine Recreation Information Program (MRIP). The total sample size drawn from the license frames was 3,200.

Implementation of the mail/web survey consisted of up to five contacts with potential respondents. A brief telephone survey (conducted to those who had valid a telephone number within the license database) was the first attempt to contact potential respondents. During the telephone interview, potential respondents were asked to provide demographic and fishing-related information, and whether they would be willing to participate in a follow-up survey. In future work, the demographic information collected during the telephone interview will be used to test for non-response bias (i.e., whether the group of anglers who subsequently completed a mail/web survey are statistically different from those who did not complete a survey) and if necessary, we will adjust our estimation strategy appropriately.

Respondents who agreed to participate in the follow-up survey and who had an email address were sent an email invitation and web link to the survey immediately after the telephone interview. Those who could not be reached via telephone were sent an email invitation with a web link to the survey. Those who did not have a telephone number were mailed an advance letter that described and provided a web-link to the survey, and contained a small striped bass magnet as an incentive to participate. About two weeks after these contacts, potential respondents who did not respond to the mail or web survey were sent a reminder email/postcard. About two weeks after the reminder email/postcard, respondents were mailed or email a second survey and cover letter. As of March, 22, 2017, the number of completed surveys was 864 with an overall response rate of 18.41%. Completed surveys are still being collected.

A partial data set of 406 completed surveys was received on March 2, 2017. After data cleaning and reformatting, the research team began preliminary analysis. We developed a behavioral model of angler preferences using 370 of the 406 completed surveys. Surveys responses were excluded from analysis if respondents' answers to Section B of the survey were deemed as "protest responses" (i.e., choosing the "no fish" option as their first choice in each question). We used a random utility model to determine factors that significantly influence recreational striped bass anglers' fishing decisions and to measure the relative importance of each of these factors. The model defines unobserved utility associated with a striped bass fishing trip to be a function of (1) the number of small, medium-sized, and trophy-sized striped bass that can be legally kept, (2) the number of small, medium-sized, and trophy-sized striped bass that must be

released due to binding regulations, (3) the number of other legal-sized fish caught on the trip, (4) the cost of the trip, and (5) the choice of not fishing for striped bass (the "opt-out" alternative).

We incorporated heterogeneous fishing preferences into our statistical model in two ways. First, we used a random parameters logit model and allowed the estimated "opt-out" parameter to be drawn from a normal distribution instead of being fixed. Second, we partitioned the full sample into two groups based on the respondents indicated primary mode of fishing. The first group included anglers who fish for striped bass primarily on private motorized boats, head/party boats, or charter boats. The second group included anglers who fish for striped bass primarily from shore or on a kayak.

Using the estimated parameters on the catch-related attributes and trip cost, we calculated the distribution of marginal willing-to-pay (WTP) associated with changes in size restrictions, and keep/release rules. The model is run separately for each group of anglers (boats vs. shore) to explore differences across groups.

HIGHLIGHTS

The preliminary results (early survey data) suggest that:

- *Releasing* small striped bass (as opposed to keeping them) is a driver of utility for anglers who fish primarily from shore.
- Shore anglers' marginal WTP for keeping a medium-sized striped bass (~$17.00) is slightly greater the marginal WTP for keeping a trophy-sized striped bass (~$16.00).
- Boat anglers' marginal WTP for keeping a trophy-sized striped bass (~$33.00) is about twice that of shore anglers' marginal WTP for keeping a trophy-sized striped bass.
- For boat anglers, the increase in WTP for the keeping fish is nearly proportional to the increase in fish size. Marginal WTP values for keeping a small, medium, and trophy sized striped bass are ~$11.00, ~$17.50, and ~$33.00, respectively.
- Boat anglers' marginal WTP for *releasing* a trophy-sized striped bass (~$12.00) is greater than the marginal WTP for *keeping* a small striped bass (~$11.00).

SOCIETAL BENEFITS

This research will provide managers of the Atlantic striped bass recreational fishery important economic information about angler preferences for slot size and catch/release regulations. This type of information was identified as a research priority in the 2013 Atlantic striped bass benchmark stock assessment, which indicated the need for the "[evaluation of] striped bass angler preferences for the size of harvested fish and trade-offs with bag limits". Our study will enable policymakers to balance socio-economic objectives of fisheries management with biological goals when considering potential regulations.

EDUCATION AND OUTREACH ACTIVITIES

Preliminary results of our study were presented at the North American Association of Fisheries Economists (NAAFE) conference in Las Paz, Mexico.

- Andrew Carr-Harris, Scott Steinback, Min-Yang Lee. "*Heterogeneous Angler Valuations for Keeping and Releasing Fish: A Shore Thing or A Boat-Load of Baloney?"* North American Association of Fisheries Economists (NAAFE) conference. Las Paz Mexico. March 21, 2017.

Developing Indices of Climate and Trophic Linkages of Euphausiids and Atlantic Herring in the Gulf of Maine Ecosystem

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Gareth Lawson, WHOI

NOAA Sponsor – Michael Jech, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Ecosystem Management***

Amount Funded: $ 85,822

PROJECT OVERVIEW, GOALS, AND MILESTONES

Atlantic herring (*Clupea harengus*) is a key prey species at the nexus of ecosystem function in the Northeast U.S. Shelf Large Marine Ecosystem (NES-LME), and supports a large commercial fishery. There is a growing body of evidence suggesting that euphausiids are also a critical component of the NES-LME ecosystem and provide an important forage base for numerous commercially important fishes, including Atlantic herring. Surprisingly little information is available, however, on the spatial and temporal patterns of euphausiid distribution, biomass, and trophic role in the Gulf of Maine/Georges Bank (GOM/GB) region.

The goal of this project is to examine climate- and environment-related drivers of euphausiid distribution and abundance, as well as their trophic importance to Atlantic herring, using a combination of existing data collected by the Northeast Fisheries Science Center (NEFSC). These include multi-frequency acoustic data from dedicated surveys, long-term bottom trawl and food habits data, and associated oceanographic data from surveys covering the entire pre-spawning concentration of Atlantic herring in the GOM/GB region.

Our approach involves a series of inter-related objectives, including to: 1) Develop a time-series of euphausiid abundance, distribution, and biomass using acoustic survey data, 2) Develop a suite of environmental and oceanographic indicators for euphausiid habitat, 3) Quantify the relationships among euphausiid abundance and consumption by herring and other predators, as well as with environmental and oceanographic indicators, and 4) Resolve our understanding of energy flow through lower trophic levels via ecosystem modeling incorporating the new indices of euphausiid biomass. Relative to our original objectives, the only significant change is that we have expanded the analysis of euphausiid consumption from herring alone to all euphausiid predators in the study region and time, using swept area abundance estimates from the NEFSC bottom trawl survey.

ACCOMPLISHMENTS

This project only began in July of 2016 but we are already making important progress on our four objectives.

Objective 1) Develop a euphausiid time-series using acoustic survey data: From 1999-2012 the NEFSC conducted an annual fall acoustic survey for Atlantic herring, designed to enumerate pre-spawning herring in pelagic habitats in the GOM/GB region. We have re-analyzed these data, applying, and in some instances extending, four multi-frequency methods available in the literature for discriminating euphausiids from other scatterers to extract estimates of euphausiid abundance and biomass (Figure 1). Net sample data available during some years has been used to parameterize target strength models and cross-validate acoustic biomass estimates. From this methodological exploration we are presently finalizing an optimal method and a most plausible time-series of euphausiid biomass. A manuscript based on this methodological work is in the planning stage.

Objective 2) Develop a suite of environmental and oceanographic indicators: Hydrographic data available at NEFSC will be used to derive a set of environmental descriptors. These indicators will be calculated for geographic and vertical regions identified as euphausiid habitat from the analysis of acoustic data. Relationships among oceanographic data and large-scale climate indices will also be explored. This component of the project has not yet begun and will await finalization of the acoustic methods of Objective 1.

Objective 3) Quantify the relationships among euphausiid distribution, abundance, and consumption by herring, as well as with environmental and oceanographic indicators: Stomach content and related data from the NEFSC food habits database have been used to directly assess consumption of euphausiids in the GOM/GB during fall (Figure 2), demonstrating that euphausiids are in some years key prey for higher consumers (in excess of 50% of diet in some instances), including herring. In the coming year, we will continue to synthesize the various datasets in order to 1) examine annual variability in herring diet composition, 2) quantify relationships among herring stock size and body condition, herring consumption of euphausiids, euphausiid abundance, and environmental/climate indices, and 3) assess the degree to which these prey support and/or limit the GOM/GB herring complex.

Objective 4) Resolve our understanding of energy flow through lower trophic levels via ecosystem modeling incorporating the new indices of euphausiid biomass: The resulting improved knowledge of euphausiid abundance and trophic interactions achieved via completion of objectives 1-3 will be used to improve parameterization of regional mass-balance ecosystem models currently under development at NEFSC. Two mass balance models will be run for the herring survey area: one using the current approach of a poorly resolved “micronekton” node and one that separates the euphausiids from other micronekton (i.e., amphipods, mysids, and other decapods) and incorporates the new data from the earlier phases of the project. This component of the work will begin in the project’s second year.

HIGHLIGHTS

- Multi-frequency methods for identifying euphausiids in acoustic data originally collected to assess herring abundance in the GOM/GB region have been assessed and extended, resulting in time-series of euphausiid abundance, biomass, and distribution. In addition to providing key information for the present herring-focused analyses, these methods can be used in the future to characterize euphausiids based on multi-frequency acoustic data collected during other non-target surveys (e.g., biannual bottom trawl surveys).
- A time-series of consumption of euphausiids by herring and other predators during fall in the study region has also been generated, demonstrating that euphausiid are key prey items in some years and for some species. Further exploration of patterns of variability in euphausiid consumption will be an important part of the project's second year.

SOCIETAL BENEFITS

Successful completion of the project will provide the basis for integrated scientific advice to managers by addressing a persistent gap in our understanding of the influence of climate, habitat factors, and species interactions on Atlantic herring bioenergetics and population dynamics. The work thus addresses the CINAR themes of Ecosystem Monitoring and Ecosystem Management, is directly aligned with the NEFSC Strategic Science Plan's theme of Science in Support of Ecosystem-Based Fisheries Management, and more generally is consistent with NOAA's Healthy Oceans goal of achieving marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

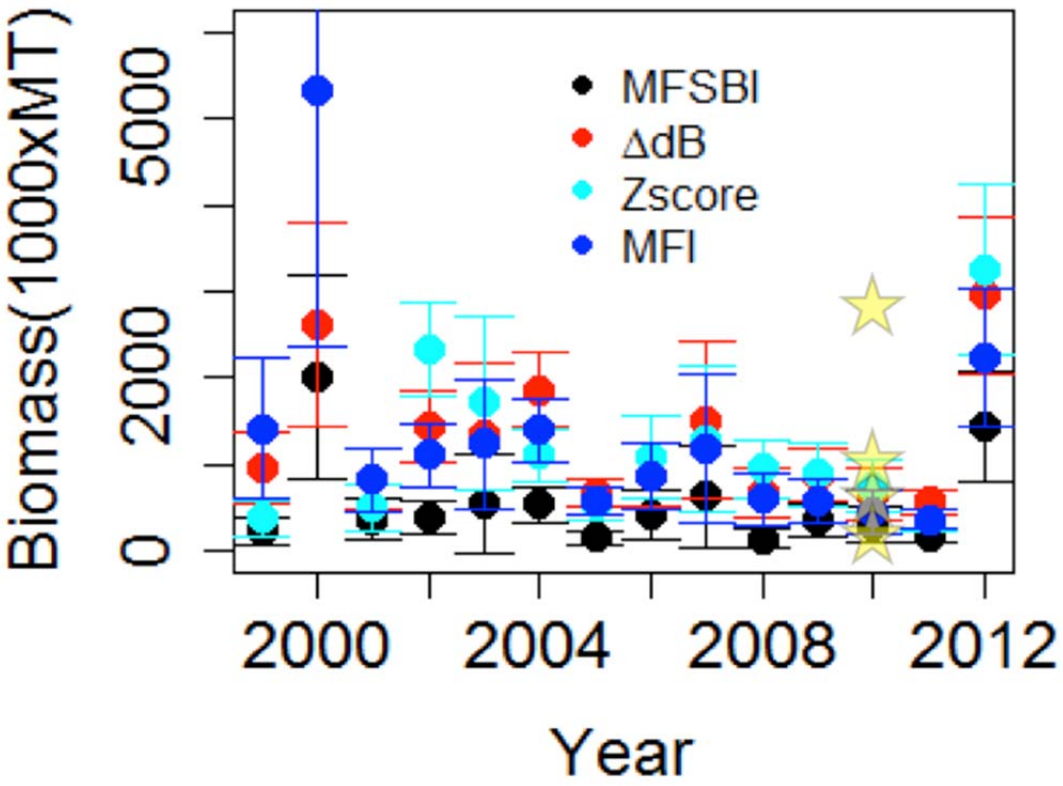


Figure 1. Euphausiid biomass (1000xMT) estimated from multi-frequency data collected during acoustic surveys of herring abundance, 1999-2012. Four different multi-frequency acoustic methods (colored circles) for discriminating euphausiids from other organisms were tested. Stars indicate biomass estimates based on net samples collected in 2010.

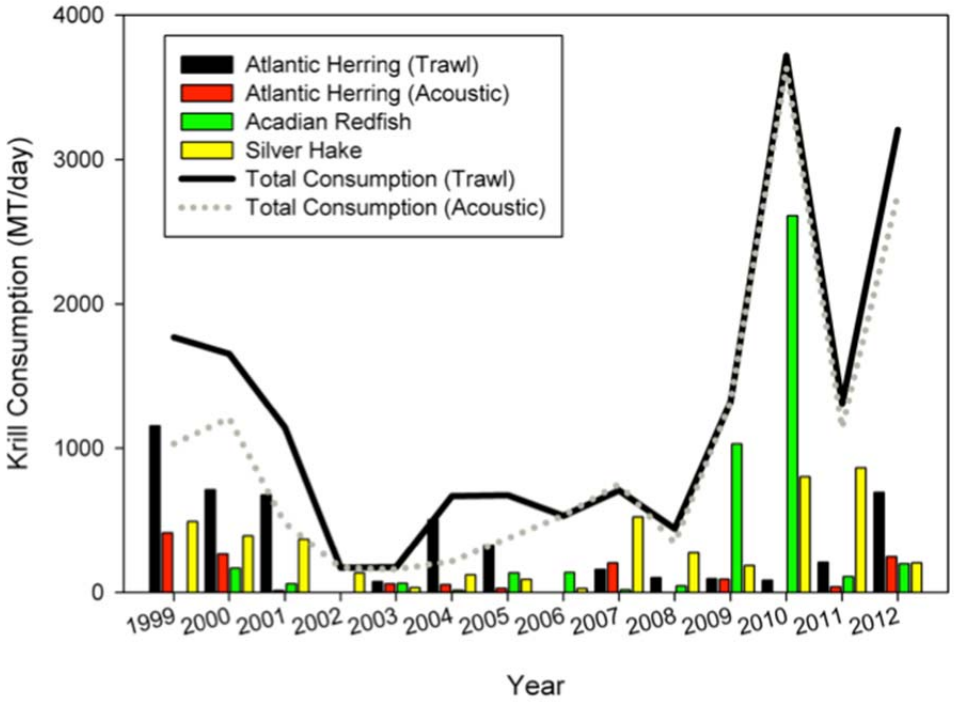


Figure 2. Consumption of euphausiids (MT/day) in the study region derived from stomach content data for three dominant predators. Herring consumption was calculated based both on bottom-trawl and acoustic survey estimates of herring abundance.

THEME IV. PROTECTION AND RESTORATION OF RESOURCES

Assessing Regional Sea-ice Predictability in the US Arctic: A Multi-model Approach

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Enrique Curchitser, Rutgers

NOAA Sponsor – Jessie Carman, OAR

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Protection and Restoration of Resources***

Amount Funded: $ 22,587

PROJECT OVERVIEW, GOALS, AND MILESTONES

In this project we implemented a high-resolution regional model for the Arctic and sub-Arctic regions. The model is based on the Regional Ocean Modeling System (ROMS) at nominal 10-km horizontal resolution, with enhanced resolution in the Chukchi, Beaufort, and Bering Seas. Figure 1 shows the implemented pan-Arctic grid bathymetry and corresponding resolution. The coupled ice-ocean model is being implemented first in a pure hindcast mode to test the model setup and parameters.

We have started analyzing sea ice predictability in the regional seas of the Arctic – Bering Sea, Chukchi Sea, and Beaufort Sea (Figure 2) using the NCAR CESM large ensemble runs output. Seasonal ice area persistency is examined through lagged autocorrelations. We compared the seasonal persistency in the regional seas to that of the Arctic. During the freezing season (Figure 3; November, January and March), ice area persistency in the regional seas is generally lower than that of the entire Arctic, but there are also regional variations. For example, the Bering Sea autocorrelations starting in January and March closely follow their Arctic counterparts until sea ice melts away at the end of spring (blue and black lines in Figure 3). Meanwhile, ice area in the Chukchi and Beaufort Seas shows a faster drop in their autocorrelations than ice area in the Arctic and Bering Sea. In comparison, in the spring and fall seasons (Figure 3, May and September), the Arctic and regional ice areas show similar magnitude of autocorrelation until a lag of four months. We will continue examining the mechanisms that contribute to such regional and seasonal differences in the ice area autocorrelation, and their implications on regional sea ice predictions.

ACCOMPLISHMENTS

Tasks completed include:

- Published results on diagnostic sea ice predictability

- Pan-Arctic domain coupled ocean-sea ice model constructed

PUBLICATIONS

Cheng, W., E. Blanchard-Wrigglesworth, C. M. Bitz, C. Ladd, and P. J. Stabeno (2016), Diagnostic sea ice predictability in the pan-Arctic and U.S. Arctic regional seas, Geophys. Res. Lett., 43, 11, 688–11,696, doi:10.1002/2016GL070735.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

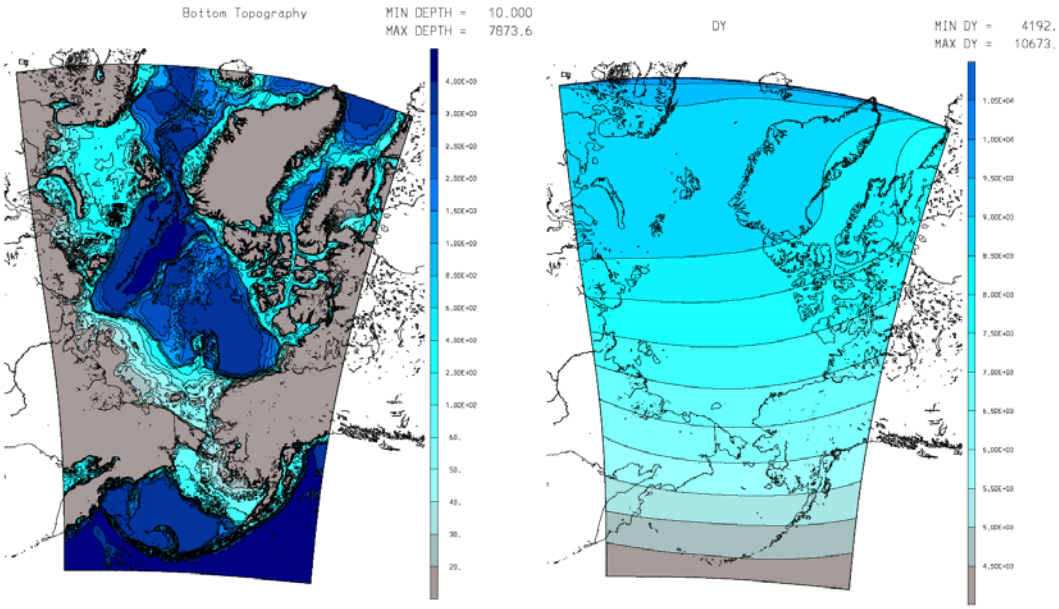


Figure 1. Model bathymetry (left) and resolution (right) for the Pan-Arctic grid. Resolution is enhanced in the oceans surrounding Alaska.

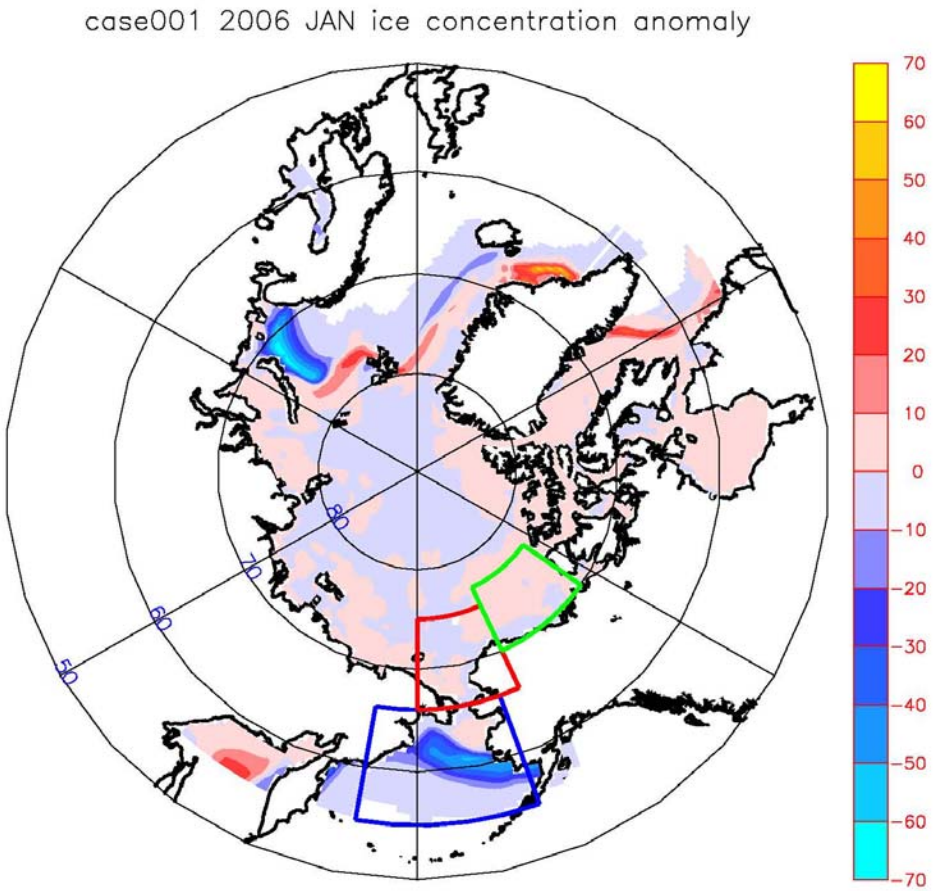


Figure 2. Blue, Red, and green boxes indicate the Bering, Chukchi, and Beaufort Sea domains respectively. Color shading shows ice area anomalies (percentage) in January 2006 of run member 001. The NCAR CESM large ensemble runs consist of 30 members for years 2006-2080 with monthly mean output data. Monthly anomalies for all members are obtained by removing the ensemble mean of each month from the monthly data.

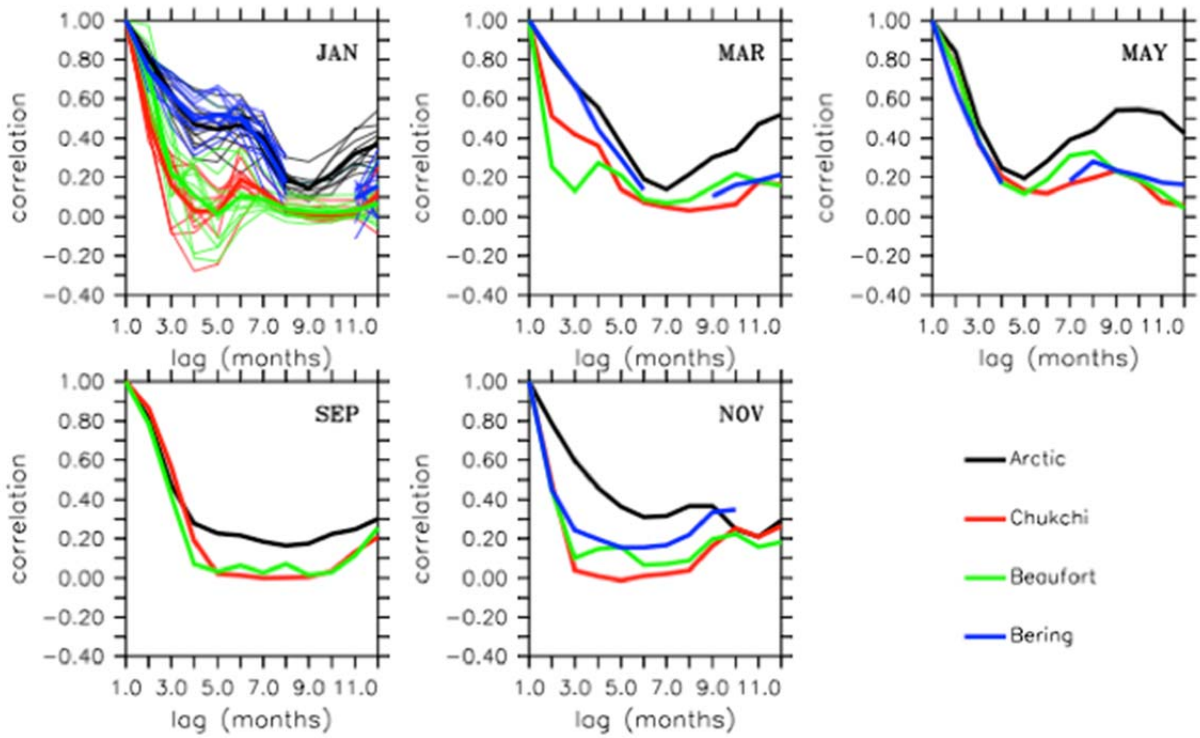


Figure 3. Autocorrelations of ice area averaged over the entire Arctic (north of 55°N) and the regional seas. The starting month of the calculation is marked on the panels, and the x-axis indicates the lag (in month) relative to the starting month. Colors correspond to different regions and the legend is shown on the bottom right. Thin lines in January plot correspond to the ensemble members and the thick lines correspond to the ensemble means. For clarity, individual ensemble member results are skipped in months other than January.

Resilience Planning for Water Dependent Uses

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Matthew Campo, Rutgers University

NOAA Sponsor – Darlene Finch, OAR

Related NOAA Strategic Plan Goal: ***Resilient Coastal Communities and Economics***

CINAR Theme: ***Protection and Restoration of Resources***

Amount Funded: $ 100,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project will produce a guide for coastal communities on how to locate, evaluate, and assemble publicly available data from federal, state, and local sources to establish a baseline set of geospatial (and related) data needed to inform local land use planning to improve the resiliency of water-dependent uses and their supporting infrastructure. The Project will produce both paper-based and web-based versions of a "Guide to Resilience Planning for Water-Dependent Uses (RPWDU)". It will also use ESRI's ArcGIS Online Story Map templates that will allow interactive mapping demonstrations of how to use these various data sources in preparing such a plan.

The research project provides an opportunity for NOAA to enhance the capabilities of water-dependent users that are resource constrained and share practices among all user groups to enhance and coordinate planning for a challenging environment. The research team has conducted two pilot workshops; one in a city in the larger Hampton Roads area that contains commercial terminals and other large marine terminal facilities (Chesapeake City, VA), and another in a smaller coastal waterfront community that relies on commercial fishing, recreational uses and other types of water dependent uses (Cape Charles, VA). The research team will use the findings from the workshops to modify the draft paper-based and web-based versions of the guidance, gathering additional feedback from internal NOAA professionals and other stakeholders. The final products will be added as resources to Digital Coast for reference throughout coastal regions of the United States.

ACCOMPLISHMENTS

Over the course of this grant period, the research team completed Milestone 1 and Milestone 2 of the project plan. Researchers worked to prepare an initial set of maps and analyses using ArcGIS Online Story Maps for the two study areas (Chesapeake City, VA and Cape Charles, VA). In order to prepare maps and analyses for the initial demonstration of the integrated guide, the researchers inventoried and collected data and resources from several federal, state and local

agencies associated with water-dependent uses. In addition, researchers developed a companion, paper-based user guide to provide additional detail for the acquisition, processing, and display of data using ESRI Story Map tools.

Upon completion of the data collection, the project team demonstrated the Story Map to local stakeholders in Chesapeake City, VA and Cape Charles, VA. The project team also worked with Virginia Department of Environmental Quality, the Hampton Roads and Accomack-Northampton Regional Planning District Commissions, and several NOAA departments (e.g. Fisheries, Office of Coastal Management, Education and Outreach, Digital Coast). Guide demonstrations were conducted as focus groups, which included two activities. First, the researchers conducted a formal walk-through of the draft ESRI Story Map. Following the walk-through, researchers facilitated a discussion among the focus group participants regarding the usability of the tool and the feasibility of conducting such an exercise in communities with different levels of technical capability and resources. Researchers then conducted an additional visioning activity for the participants, the purpose of which was to gather information on the suitable contexts for using the planning guide and tools.

Researchers are currently preparing the final summary of outcomes from the focus groups conducted in two coastal communities in Virginia. Following the development of the outcome summary, the research team will work with their NOAA partners to develop a final version of the integrated guide for delivery through NOAA Digital Coast, in addition to a series of communication and outreach events to encourage the use of the guide.

HIGHLIGHTS

- Developed draft versions of web-based and paper-based guide for "Resilience Planning for Water-Dependent Uses"
- Conducted two focus groups (Chesapeake City, VA and Cape Charles, VA) to engage local professional planners, recreational users, industrial operators and other stakeholders in waterfront planning discussions.

SOCIETAL BENEFITS

The results of this research will integrate federal, state and local data sources into a framework that will improve data accessibility and assist users in the application of those data in planning decisions. In doing so, the resulting guidance will allow water-dependent and working waterfront users to communicate a more comprehensive view of water-dependent users and the values of their activities within existing land use planning deliberations and decisions.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

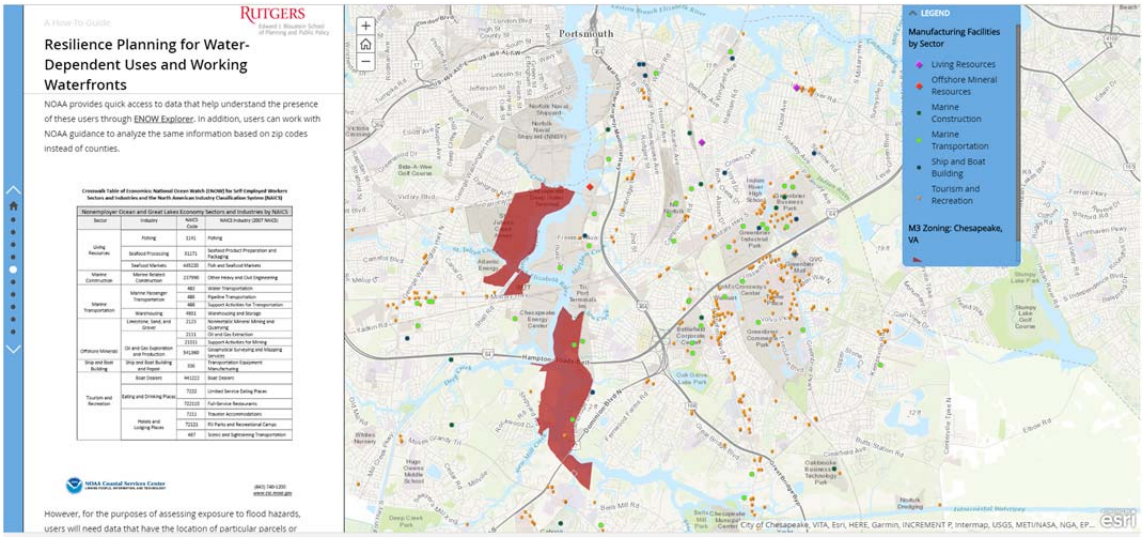


Figure 1. Rutgers researchers presented the "Guide to Resilience Planning for Water-Dependent Uses (RPWDU)" using ESRI Story Map web-based tools.

Impacts of a Changing Ecosystem on Atlantic Salmon Marine Productivity

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Kathy Mills, GMRI

NOAA Sponsor – Tim Sheehan, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Protection and Restoration of Resources***

Amount Funded: $ 285,305

PROJECT OVERVIEW, GOALS, AND MILESTONES

This study will evaluate the hypothesis that Atlantic salmon marine growth provides a mechanism that links changing ecosystem conditions to Atlantic salmon survival and productivity. Specifically, it will accomplish three main objectives:

(1) Document how patterns of marine growth and survival have changed over time for populations of Atlantic salmon.
(2) Evaluate how changing ecosystem characteristics affect Atlantic salmon marine growth and survival.
(3) Model how ecosystem changes are affecting energy flow to Atlantic salmon and the impacts of these changes to salmon growth, survival, and productivity.

Progress towards these objectives is underway as described below.

ACCOMPLISHMENTS

Major accomplishments this project year include: (1) running a session at the ICES Annual Science Conference to evaluate how changing ecosystem conditions are affecting fish populations, (2) finalizing the Penobscot River scale measurement dataset, and (3) hiring a postdoc to conduct analyses and modeling associated with this project.

Tim Sheehan and Kathy Mills co-convened a symposium (with Mark Payne, Denmark) for the 2016 ICES Annual Science Conference entitled "Ecosystem changes and impacts on diadromous and marine species productivity." Understanding how changes in the Northwest Atlantic ecosystem have affected Atlantic salmon and the mechanisms through which ecosystem factors influence salmon populations is a key focus of this CINAR project. This symposium enabled us to extend our understanding to other species and regions of the North Atlantic to learn how climate-ecosystem-fish population linkages are being studied and the findings that are accruing at this larger scale. A summary of the session was published by ICES and is included in the 'publications' section of this report.

Also during this year, we finalized the data set of Penobscot River scale measurements that will be used as a basis for growth analyses throughout this project. Circuli measurements from 1SW and 2SW Atlantic salmon adult returns were taken for several clusters of smolt years. Years 1978-1980, 1986-1988, and 1998-2000 were read as part of our initial plan to study growth during periods of high, medium, and low marine survival. We also added data from a more recent time period (2012-2015) when ocean temperatures have been exceptionally high and return rates have been very low. Analyses are progressing on this data set. Specifically, we have applied models to identify specific periods of the marine phase (i.e., minimum growth during the winter and maximum growth during the summer) and are using the individual increments to develop von Bertalanffy growth curves to estimate key parameters such as growth rate and asymptotic length.

A major accomplishment for this project has been the addition of a postdoc who will conduct analyses and lead the associated modeling efforts. Dr. Felix Massiot-Granier started in this position in January 2017. He is in the early stages of developing a bioenergetics model based on Dynamic Energy Budget (DEB) theory to estimate and predict growth and reproduction of an Atlantic salmon in a dynamic environment. This model can account for how changes in factors such as temperature, prey quality and prey abundance affect a fish from egg to adult stages. This type of model accounts for individual variability in environmental conditions that may be encountered and growth responses that may occur. These outputs can then be incorporated into population models, with the individual-level variability from the DEB model supporting uncertainty estimates at the population level.

HIGHLIGHTS

- ICES ASC session demonstrated environmental factors structure fish populations through a variety of mechanisms. Most studies have been at annual to decadal time scales and local to regional spatial scales, so larger scale analyses and syntheses would be valuable.

SOCIETAL BENEFITS

This project will broadly expand our scientific capacity to understand how marine ecosystem changes can affect the vital rates (e.g., growth, mortality, fecundity) of fish species—information that is essential for effectively assessing the population status and trajectories of fish populations that NMFS manages. In this case, our focus is Atlantic salmon (a protected species), so understanding factors that influence its population trajectory provides a basis for evaluating recovery potential of the species and for planning effective recovery strategies, particularly in the context of ongoing climate change in its marine habitat range.

EDUCATION AND OUTREACH ACTIVITIES

Mills, K. E., M. R. Payne, T. F. Sheehan, and A. J. Pershing. 2016. Impacts of climate and ecosystem change on fish and fisheries in the North Atlantic. ICES Annual Science Conference, Riga, Latvia. September 2016.

Mills, K. E., A. J. Pershing, and T. F. Sheehan. 2016. Climate and ecosystem influences on fish body size and growth in the Northwest Atlantic. ICES Annual Science Conference, Riga, Latvia. September 2016.

Sheehan, T.F., Renkawitz, M.D., Mills, K.E., Dixon, H.J., and Nygaard, R. 2016. Changing trophic structure and energy dynamics in the Northwest Atlantic influences Atlantic salmon abundance. ICES Annual Science Conference, Riga, Latvia. September 2016.

PUBLICATIONS

Mills, K., T. Sheehan, and M. Payne. 2016. Theme session D: Ecosystem changes and impacts on diadromous and marine species productivity. ICES Annual Science Conference 2016. (http://www.ices.dk/news-and-events/asc/ASC2016/Pages/Theme-Sessions.aspx)

Effects of Oil, Chemical Dispersant, and Dispersed Oil on the Functional Characteristics of Mysticete Whale Baleen: Proposal for a Study to be Conducted at the National Oil Spill Response Research & Renewable Energy Test Facility (OHMSETT)

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Michael Moore, WHOI

NOAA Sponsor – Teresa Rowles, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Protection and Restoration of Resources***

Amount Funded: $ 58,100

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Emergency Response Division of NOAA (NOAA/ERD) in collaboration with the North Slope Borough (AK) Department of Wildlife Management (NSB/DWM), the Office of Protected Resources of NOAA (NOAA/OPR), Woods Hole Oceanographic Institute (WHOI), and Hampden-Sydney College (HSC) undertook a research project to investigate the effects of oil, chemical dispersant, and dispersed oil on the functional characteristics of whale baleen. The work was performed in September and December, 2015, and January 2016 at the OHMSETT facility in Leonardo, NJ. Data analysis is ongoing.

ACCOMPLISHMENTS

Sept 28th – Oct. 1st 2015. The objectives of this first test period at the OHMSETT facility were to establish a testing protocol, generate preliminary data, and, if circumstances allowed, expose a subset of baleen to oil (Alaska North Crude). To secure baleen for movement through water, a lever arm fabricated at WHOI consisting of a baleen clamp, load cell, and pivot was installed on the tow tank bridge. The baleen clamp was mounted on a turntable that had different positions to allow baleen to be rotated. Drag was measured with 500 or 100lb Omega load cell (Figure 1.1) with data acquisition on a custom LabView GUI. Splaying of individual baleen plates was solved by tying the plates to each other with a series of monofilament clove hitches to hold the baleen spacing the same as it was spaced at the gum (Slide 1, Fig. 4). Bowhead and humpback whale baleen was tested. Load cells were then calibrated at WHOI using the same baleen clamp and known weights at the center of effort of each baleen sample.

December 7th – 11th 2015. Installed vibration dampers to resolve bridge load cell noise issue. Ran

a series of tow tests with bowhead and humpback baleen with clean water, oil (surface delivery and after painting on baleen bristles in air, or after elevating baleen through a surface slick). Fouling from the surface treatment was limited to minor sheen at the water line. Baleen hair clumped with the painting treatment. A single dispersant run was undertaken to test the deployment system.

Jan 4th – 8th 2016. Control runs with bowhead and humpback were followed by runs with fresh and weathered oil (Figure 1.2 to 1.5).

Data Analysis:

Load data were sampled at 10Hz or 1Hz continuously during each run at several velocities (Figure 2). After the speed change, the baleen rack required several seconds to 'settle down' to a steady state load at the new bridge velocity. In order to calculate median loads for each stage speed and each run, it was necessary first to discard data from these non-representative transitional phases (Figure 2). Due to the nature of the recording devices and the baleen drag behavior, load transition phases could not be directly mapped to changes in bridge speed. We used a semi-automatic screening process in the R statistical language to solve this problem. First, the segment neighborhoods approach to mean change-point estimation was applied to the load time series data using the "changepoint" package in R. The number of change-points was known because the number of bridge speed levels was controlled; however, the algorithm can fail to find all the correct change-points in the load data. Therefore we fit the change-point model specifying double the desired number of change-points, then discarded the extraneous ones. This analysis provided the central moments of the transitional phases (not counting the settling time).

To calculate the boundaries of when load data should be ignored, we examined 26 transitions and visually estimated the times when the bridge began and ended its speed change, and the length of the settling period thereafter. We used linear regression to estimate the time required to change bridge speed as a function of the level of change in bridge speed. Next, the subsequent settling time was, surprisingly, not related to speed, so we used the maximum value of 6 seconds. Having established these results from the training data, for the real data we used the regression model to predict a bridge speed change time, added and subtracted half this amount to the change point estimate, then subtracted 1.15 seconds (for the start of transition) and added 7.15 seconds (for end of transition and settling down), where these values reflect 1.96 standard deviations of the regression intercept and the 6 second settling period. Load data within such intervals was omitted (Figure 3), and median loads for each stage were calculated (Figure 3, see red line through data points) from the remaining data. To measure variability, we used the MAD, which is a robust estimator of the standard deviation.

Conclusions:

We continue to analyze data, and anticipate concluding the study in summer 2017.
Some preliminary results are shown in Figure 5 and in the anova table (below) for the response variable equaling the square root of median load.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.46577	0.12366	3.767	0.000262 ***
Plates #	0.07345	0.14957	0.491	0.624274
Orient(degrees)	-0.38618	0.07436	-5.193	8.92e-07 ***
Knots	2.39031	0.13118	18.222	< 2e-16 ***
Tied	-0.21395	0.07657	-2.794	0.006091 **
Plate:knots	-0.37331	0.16887	-2.211	0.029023 *

From the table, we note that drag increases with speed (knots), untied baleen has more drag than tied baleen, and orientation (90 vs. 54 degrees) is also significant, with 54° incurring more drag than 90°. There is no significant difference between 15 plates and 30 plates. This is evident in the plot because the black and red lines are nearly superimposed (Figure 5).

Currently, we are analyzing data of control runs and will soon compare to treatment runs that used fresh crude oil, weathered oil, dispersed oil, or dispersant alone. While we are not certain that the amount of oil that coated baleen was enough to cause a detectable change in drag, we visually noted that residues from treatments of the above were present on baleen, albeit in small, qualitative amount (Figure 6). Chemists from the Institute for Environmental Studies at LSU confirmed that fringe "hair" samples exposed to the above treatments retained variably measurable amounts of the treatments expressed a smicrograms of product vs. grams of "hair"/baleen. Lower temperature appeared to result in greater fouling.

HIGHLIGHTS

- Currently, we are analyzing data of control runs and will soon compare to treatment runs that used fresh crude oil, weathered oil, or dispersed oil.
- While we are not certain that the amount of oil that coated baleen was enough to detect change in drag, we visually noted that treatments of the above were present on baleen, albeit in small, qualitative amount (Figure 6).
- We have recently confirmed from a lab at LSU that fringe "hair" samples exposed to the above included micrograms of product vs. grams of "hair"/baleen.

SOCIETAL BENEFITS

Understanding of the extent to which fresh and weathered oil with and without dispersant fouls whale baleen, and the effect of environmental temperature, is important for planning and response to oil spills in large whale habitat.

EDUCATION AND OUTREACH ACTIVITIES

- Poster - Field Methods: Study of Oil and Dispersant on Mysticete Whale Baleen: 3rd Annual Alaska Oil Spill Technology Symposium (Fairbanks, AK) 22-24 March 2016 at

Pipeline Training Center http://dec.alaska.gov/spar/ppr/AOSTS_2016.htm presented by Todd Sformo (NSB-DWM); and

- Alaska Marine Science Symposium (Anchorage, AK) 23-27 January 2017 presented by Gary Shigenaka (NOAA Federal) http://amss.nprb.org/program-schedule/agenda/
- NOAA newsletter: http://response.restoration.noaa.gov/about/media/first-time-decades-scientists-examine-how-oil-spills-might-affect-baleen-whales.html
- "How do whales stow their baleen?" at the Society for Marine Mammalogy meeting in San Francisco in December, 2015, by Alex Werth

PUBLICATIONS

Werth, A. J., R. W. Harriss, M. V. Rosario, J. C. George and T. L. Sformo. 2016. Hydration affects the physical and mechanical properties of baleen tissue. Royal Society Open Science 3:160591.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

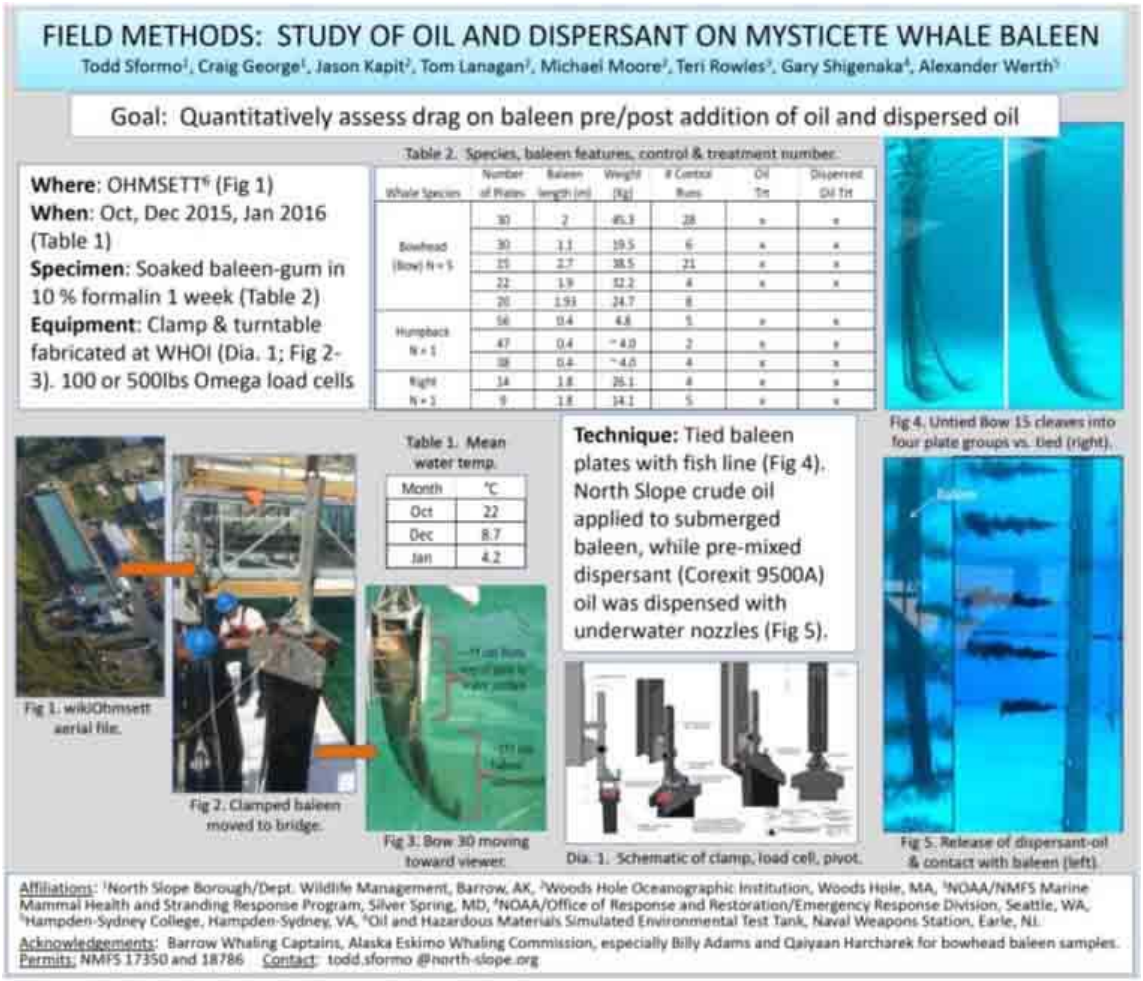


Figure 1. OHMSETT facilities, overall procedures for baleen clamping, water temperature, and dispersed oil application.

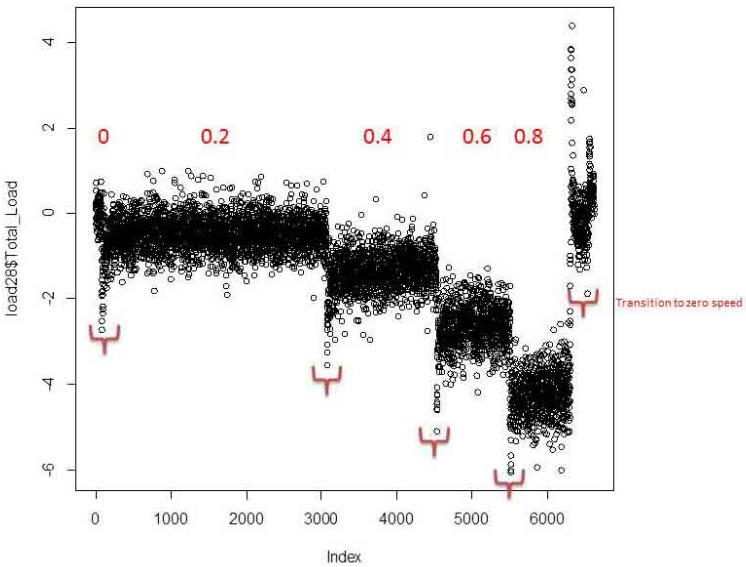


Figure 2. Raw data from baleen run #28 at 10Hz. Speeds (0, 0.2. 0.4, 0.6 and 0.8 knots) in red above data points. Note difficulty in observing initial zero speed. Note also transition speed changes denoted by a bracket. There is also a certain lag time before baleen 'settles' into its new speed. These transition and settling times are removed by changepoint.

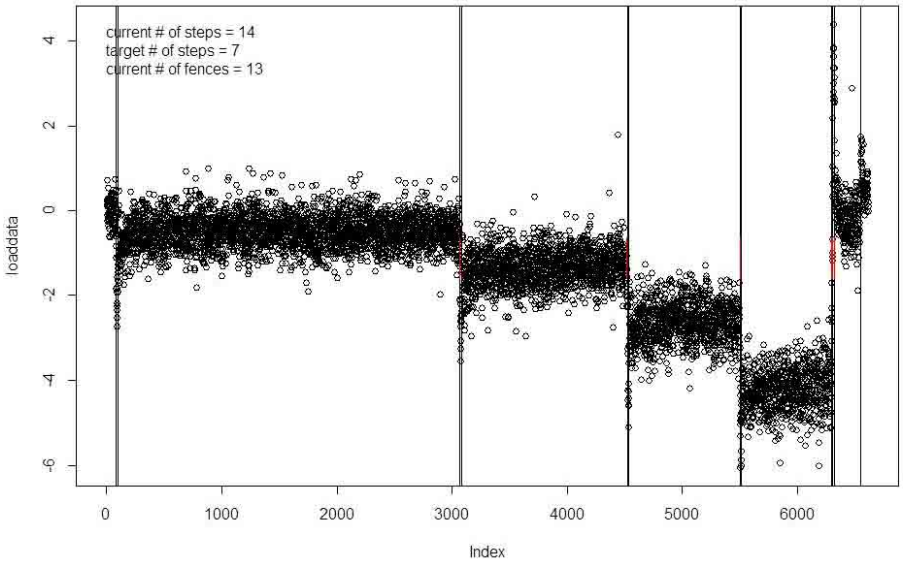


Figure 3. Boundaries established within the changepoint criteria. The next step is to evaluate the 'steps' and to reduce the step number to the target number. This allows for elimination of the transition speed data as the bridge changes speed.

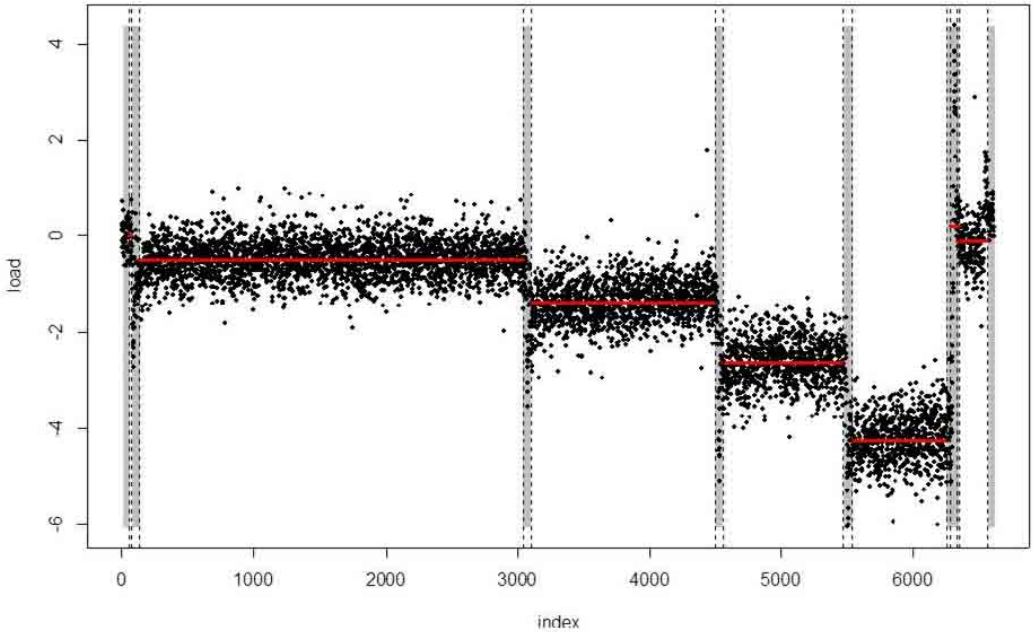


Figure 4. Eliminated data (within gray bars), while data points within red lines are used to calculate median drag and median absolute deviation.

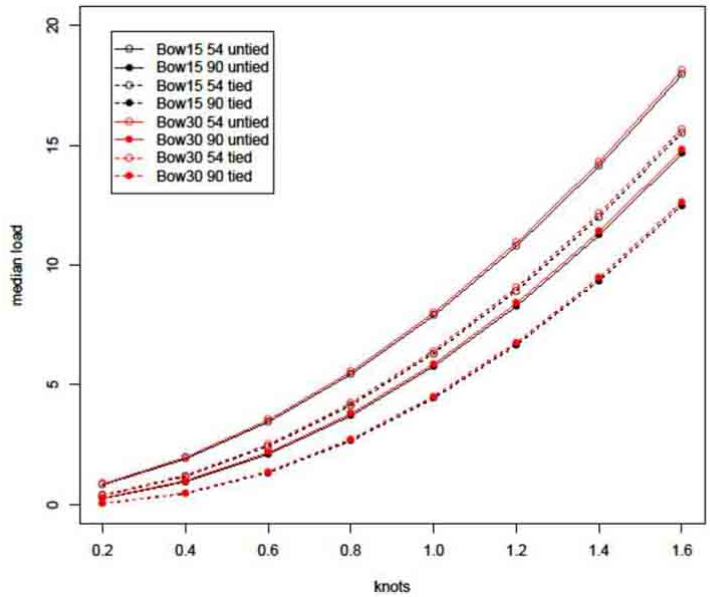


Figure 5. Relationship among two independent bowhead racks of baleen with 15 or 30 plates, tied or untied, and oriented 90 or 54 degrees to the OHMSETT bridge (see Figure 1.1 and 1.3).

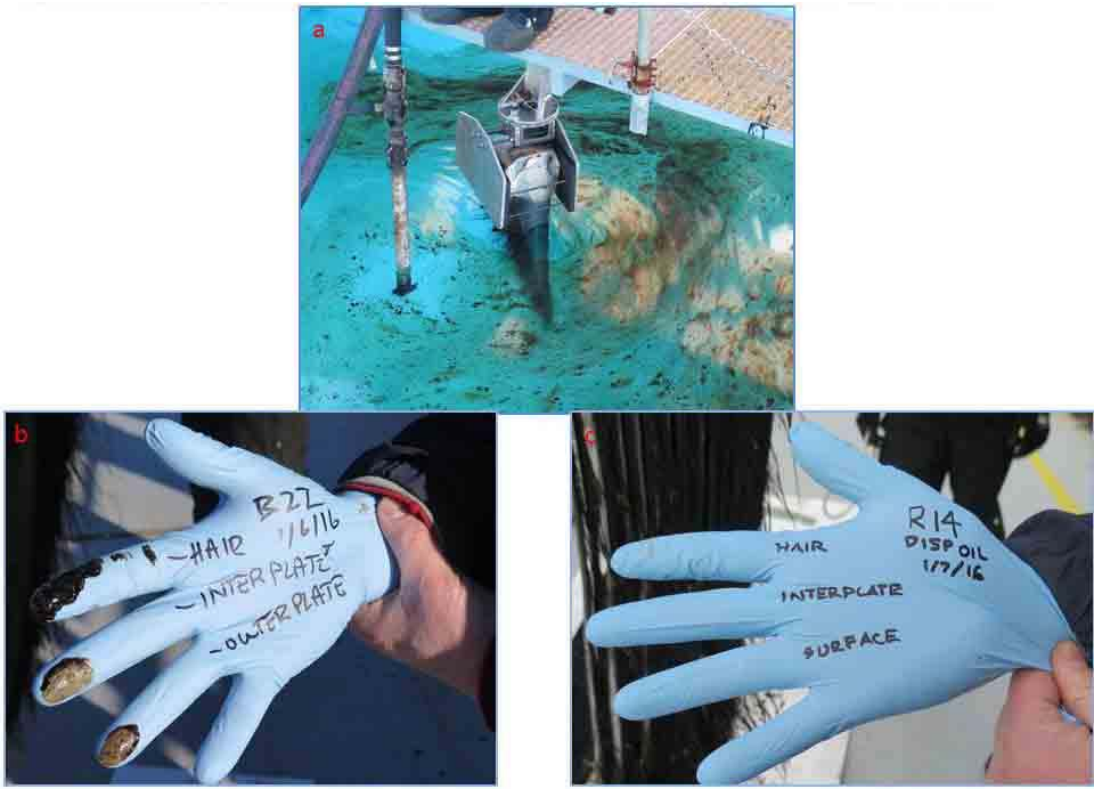


Figure 6. a. End of a surface oil baleen exposure. b and c. Qualitative test after exposure to b. product, and c. dispersed product, on baleen.

Developing a Bio-compatible Large Whale Tracking Tag

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Michael Moore, WHOI

NOAA Sponsor – Peter Corkeron, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Protection and Restoration of Resources***

Amount Funded: $ 48,692

PROJECT OVERVIEW, GOALS, AND MILESTONES

The overall long-term goal of this work is to use a systematic approach to improve satellite tag biocompatibility that in turn should improve tag service life. To this end, the aims of this particular work are directed toward developing a more biocompatible tag that ultimately will more closely match tissue properties, promote more stable integrative wound healing, and have a reduced tag footprint when deployed. More specifically, we are characterizing the properties of skin-blubber tissue of large whales and using these properties to aid in the rational design of an adhesive hydrogel and blubber only tag.

ACCOMPLISHMENTS

Aim 1: Characterize the skin-blubber tissue structure of large whale and changes in response to implantation trauma. The characteristics focused on during testing were the viscoelastic properties (time-dependent). The majority of natural tissues, such as whale blubber, exhibit viscoelastic properties due to their biological make-up, specifically the presence of certain concentrations of inelastic and elastic polypeptides, water content, and lipid content.

Activities/accomplishments: Incremental samples of blubber were prepared from the skin to the underlying connective tissue. This was done in order to generate a depth profile of tissue stiffness and time-dependent mechanical behavior. This information will be used to optimize hydrogel properties in Aim 2 and the blubber only tag design in Aim 3. Whale blubber samples were assessed for their complex modulus (G*), a measure of their viscoelastic (time-dependent) behavior that is composed of both the elastic (G') and viscous moduli (G") using parallel plate rotational rheometry. We verified that 1) blubber exhibits strain stiffening behavior; and 2) the stiffness showed a depth dependency. (Fig. 1) These results affected our choice of initial polymers for developing our adhesive hydrogel (Aim 2) and also will influence the ultimate architecture of blubber only tag, where we may be able to incorporate broad tissue properties differences with depth into tag stiffness and surface architecture modifications. Remaining challenges: We are currently gathering additional tissue samples to assess the location and

species dependent variations in the properties measured thus far.

Aim 2: Demonstrate the application of adhesive polymers and polymer sponges as a means to stabilize implanted tag in an ex vivo tissue model. Select and evaluate natural and synthetic curing adhesive polymers and polymer sponges to optimize interfacial binding and matching of mechanical, chemical, and physical tissue-material properties such as stiffness, hydrophilicity, and swelling behavior.

Activities/accomplishments: In order to create an integrating polymer that would exhibit strain stiffening behavior of natural tissue and also have good tissue adhesive properties, we exploited the tissue-cell adhesiveness and inducible gelation chemistry (i.e, tissue factor and thrombin activated) of fibrin based hydrogels and the marine mussel adhesive catechol amino acid, 3,4-di-hydroxy-phenylalanine (DOPA), that enables mussels to attach to both organic and inorganic surfaces in hydrophilic and salt micro-environments to create a composite adhesive hydrogel (Fig. 2) that 1) is able to gel reliably, 2) acts as a tissue-device (tracking tag) interface adhesive even under relatively harsh pH, salt content, and hydrophobic-hydrophilic tissue microenvironments, and 3) potentially can be used as a vehicle for local deliver of antimicrobials. Remaining challenges: We are currently optimizing the adhesive properties of the hydrogel and its deployment methods and will be doing prototype tag stabilization experiments.

HIGHLIGHTS

- Blubber exhibits strain stiffening behavior that showed a depth dependency. This information will enable suitable polymer choice to enhance tag retention.
- We are currently optimizing the adhesive properties of hydrogel and its deployment methods to enhance intra-dermal large whale tracking tag retention.

SOCIETAL BENEFITS

Detailed knowledge of the spatial temporal movement patterns of large whales is critical for their conservation and the ability of stakeholders such as defense and industrial entities to undertake their missions at sea in a sustainable manner. This project aims to minimize the animal welfare and health impacts of implantable tracking tags, while sustaining their efficacy.

EDUCATION AND OUTREACH ACTIVITIES

Capstone Engineering Senior Design Project (2016-2017). Design project title: Blubber-only Implantable Satellite Tag Anchoring System.

Conference proceedings:

Tyo A, Fisher H, Hubbard K, Lee B, Rajachar R. Novel Fibrin Poly-Dopamine Composite Hydrogel for Marine Applications. Society for Biomaterials 2017 (Podium presentation).

He W, Tyo A, Fisher H, Meng H, Lee BP, Rajachar RM. Development of a Novel Fibrin-

polydopamine Adhesive Hydrogel for Marine Mammal Tracking and Wound Healing Applications. The Adhesion Society Annual Meeting 2017 (Podium presentation and extended abstract)

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

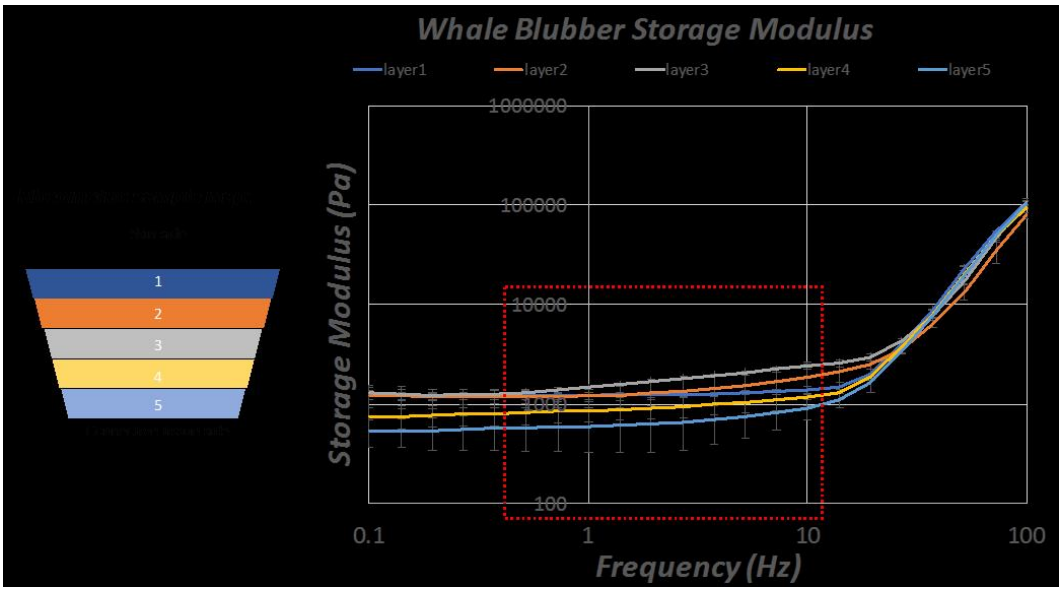


Figure 1. Blubber depth dependent variations in stiffness (storage modulus) and strain stiffening behavior (increasing storage modulus with frequency rate of applied load).

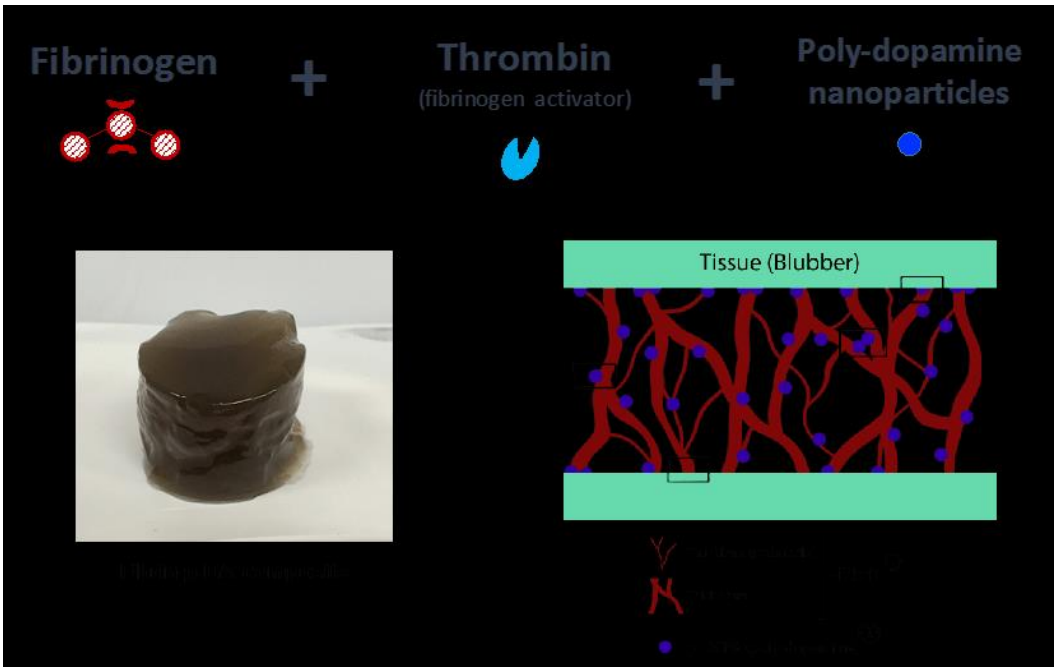


Figure 2. Schematic of the components of the composite adhesive hydrogel (top), actually gelled composite (lower left), and proposed tissue adhesive mechanisms (lower right).

THEME V. SUSTAINED OCEAN AND OBSERVATIONS AND CLIMATE

Global Ocean Observing Coordination Activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Champika Gallage, WMO

NOAA Sponsor – Steve Piotrowicz, OAR

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 518,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

1. Ocean Observations Coordination (OOPC and JCOMM OCG)

OOPC is a scientific expert group charged with making recommendations for a sustained global ocean observing system for climate in support of the goals of its sponsors (GCOS, GOOS and WCRP). This includes recommendations for phased implementation. The panel also aids in the development of strategies for evaluation and evolution of the system and of its recommendations, and supports global ocean observing activities by interested parties through liaison and advocacy for the agreed observing plans. The panel increasingly plays a role in connecting across the other expert panels for GCOS (Atmosphere, Terrestrial), and GOOS (Biogeochemistry, Biology and Ecosystems).

Mark Bourassa stepped down as co-chair of OOPC, and was replaced by John Wilkin, which also enables OOPC to strengthen connections into the coast, and complements the skills of the other Co-Chair, Bernadette Sloyan. The secretariat for OOPC is Katherine Hill, who is also providing oversight support for JCOMM OCG, and international coordination support for the TPOS 2020 Project.

A major deliverable in 2016 was the successful completion of the GCOS Implementation Plan (The Global Observing System for Climate: implementation needs), including two rounds of community review. OOPC Co-Chair Bernadette Sloyan worked with GOOS Biogeochemistry Chair, Toste Tanhua to lead the ocean component of the GCOS Implementation plan, supported by the OOPC secretariat. The Ocean chapter includes input from across the three panels of GOOS, and includes new ECVs (Ocean Surface Stress, Heat Fluxes, Nitrous Oxide, Marine Habitat properties), and a reframing of ocean carbon ECVs. The plan also focuses on what we need to deliver by ECV, and the implementation targets by network.

2. Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Observations Programme Support Centre (JCOMMOPS)

This project supports contributions to the World Meteorological Organization (WMO) global ocean observing coordination activities for 2016-2017 via the U.S. NOAA's Climate Program Office. These activities focus on developing international consensus on the requirements for ocean observations and technical support to ocean observing networks participating in the WMO-led Global Climate Observing System (GCOS) coordination activities which encompass, inter alia, the Global Ocean Observing System (GOOS). In investing in multilateral cooperation, the United States ensures that its substantial investment in global ocean observations is matched by other national investment in a system that is compatible and shares standardized data in real time. Specifically supported is technical coordination within JCOMMOPS, the Observations Programme Support Centre of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

JCOMMOPS occupies a unique place as the focal point for the practical co-ordination of the in-situ ocean observing system defined by JCOMM. Its roles include:

- To assist in the implementation and deployment of the observing networks through close interaction with program managers and platform operators;
- To assist in establishing, maintaining, and verifying mechanisms for the timely exchange of data and metadata, including the facilitation of quality control and archival functions; and
- To develop the tools needed to monitor the status of the observing system, its attendant data and metadata distribution, and to improve the overall effectiveness and development of the system.

JCOMMOPS serves the following groups and resources:

- Data Buoy Cooperation Panel - maintains a network of surface drifting buoys measuring temperature, pressure, and surface currents, tropical and coastal moorings, tsunameter buoys, polar buoys;
- OceanSITES - collecting high-quality data from long-term, high-frequency, and multidisciplinary observations at fixed locations in the open ocean;
- Ship Observations Team - maintains volunteer commercial ship observations of meteorological parameters, as well as underway measurements of surface and subsurface ocean variables, and
- Argo Information Center - technical support and coordination activity for the global network of 3800 Argo profiling floats, including deep and biogeochemical floats.

Support is also included for the GOOS component of GCOS via the Ocean Observations Panel for Climate (OOPC), which provides scientific oversight for open ocean GOOS, identifying the requirements for observations for climate and other societal benefit areas, and ensuring the outputs of the system are fit for purpose.

ACCOMPLISHMENTS

1. OOPC and JCOMM OCG

Accomplishments include:

- Completion of the GCOS Implementation Plan (The Global Observing System for

Climate: implementation needs), including 2 rounds of community review.

- Holding fortnightly calls with the co-chairs and maintains regular contact with OOPC members. The actions from the preceding meeting are tracked using an online spreadsheet.
- Formation of four vice chair positions (or task area leads) in JCOMM OCG.
- Consultant recruited to help with the day to day running of OCG, with guidance and oversight from the secretariat.
- Holding fortnightly calls with the chair/vice chair of JCOMM OCG, organizing quarterly calls with the membership of the JCOMM OCG to progress the work plan, and providing guidance and oversight to JCOMMOPS activities.
- Secretariat focus on strategic support to the Executive in the development of OCG activities; including shaping forward strategies, work plan priorities, and engaging new networks.
- Worked with the new Ocean Gliders programme to establish the steering committee and forward priorities including articulation of missions and targets. Currently task teams are working on developing missions for boundary currents, storms, mixing and convection (water formation), and polar regions. There is also a data management task team.
- Provides international support to the TPOS 2020 Project, which this year focused on connecting the project into the intergovernmental system as it plans for the transition of the observing system. TPOS 2020 is now a WIGOS Pre Operational Pilot, and will be delivered through a joint JCOMM/TPOS 2020 Cross Cutting Transition and Implementation Task Team.

2. JCOMMOPS

Data Buoy Cooperation Panel

Support was provided to the DBCP through a dedicated 0.7 FTE, Champika Gallage (Canada). Support was ended in September 2016 with her move to WMO. This position has remained vacant since September 2016 and WMO is in the process of recruiting a new incumbent. The Panel showed great satisfaction with its TC services.

Achievements:

- Moored buoy metadata is collected in a common format and available to the community.
- KPIs are finalized for coastal/national MB and reported monthly.
- Progress on Moored buoys (Tropical and Coastal/National MB) reporting data on the GTS in BUFR format.
- 100% of the drifting buoys are reporting data on the GTS in BUFR format.
- 60% of the drifters are providing Barometric Pressure data to the GTS.
- KPIs for all DBCP networks are finalized and are reported monthly.

OceanSITES

Support to OceanSITES was provided with a dedicated 0.3 FTE (Champika Gallage, Canada), to the Science Team, who is working to develop requirements for each of the several networks embedded with the OceanSITES programme (www.oceansites.org). The overall JCOMMOPS

infrastructure is providing integrated monitoring tools, including for OceanSITES. The TC has been establishing links with the community, checking the quality of the OceanSITES metadata and requirements to include these in the new Information System.

Achievements:
- Mission, goals, benefits, and governance documents are finalized and available on website.
- Publications list is compiled and available on website.
- Deep Ocean T/S observing network being implemented.

Argo

Support to the Argo programme is provided via a dedicated TC Mathieu Belbeoch (0.7 FTE) . The Argo Information Centre (AIC) maintains appropriate tools to facilitate the implementation planning and optimize the network distribution and data flow. In depth analysis and reports allows to discover weaknesses in the data flow for some national centers or highlight existing or upcoming gaps in the network.

Achievements:
- The yearly report to Argo Steering Team (AST) identify a major unbalance in the Argo implementation. Recommendations provided will improve the overall distribution of the Argo array; design reviewed (initial 3200 to global 3800).
- Density and coverage maps designed to track the spatial distribution of the network and guide implementation.
- Harmonized the vocabulary across JCOMMOPS metadata, Argo netCDF format and WIGOS/GTS code tables.
- The Exclusive Economic Zone warning system has been maintained operational and slightly improved.

Ships

The Ship Observation Team and the GO-SHIP Steering Team were served through a dedicated TC (0.7 FTE), Martin Kramp, who serves all integrated ship issues for the remaining 0.3 FTE. For SOT, the production of maps was maintained and various new maps developed, including statistics on participating countries, data quality, automatization and timeliness or masking schemes. Maps, monitoring tools, and performance indicators are available on the new SOT website.

Achievements:
- Collection of metadata for SOOP was exploited to produce a survey of 2016 implementation.
- Progress on fall rate studies of SOOP.
- Review of metadata requirements for platforms and observations.
- Initialization of SOOP platform registration at JCOMMOPS.
- New GO-SHIP classes (High Frequency, associated) led to more contributing countries and/or lines.
- Performance indicators and number of new monitoring tools are available for GO-SHIP through website.

- European joint AWS project validated: 400 new automated stations will be produced and installed shortly.
- "Third Party Class": More active ships without recruitment by a national weather agency.
- Maintains a master list for all ships used in the observing networks on JCOMMOPS database.
- The VOS metadata services (managed via E-SURFMAR website) were gradually migrated to JCOMMOPS.
- Major national R/V cruise plans are now available in the JCOMMOPS system.

JCOMMOPS

JCOMMOPS has benefited from the IT Support provided by the CLS Argo Office in Toulouse, France, according to the agreement between WMO and CLS Argo (Toulouse). This is partly funded ($34,000/year) through this agreement. IT services provided by JCOMMOPS are in accordance with the JCOMM Observations Coordination Group (OCG) requirements and guidance.

During the reporting period, all JCOMMOPS websites were finalized, and core services operationalized. Hundreds of harmonized performance indicators were designed and implemented – a major achievement for all networks. An integrated cruise plan database is now available online, representing a major achievement that has required many international interactions and technical developments.

The main challenge for the team is now to communicate with these powerful tools, and for the community to take ownership of them and use them for their day to day work (e.g., deployment planning).

The visibility of the Centre has been greatly elevated, which implies now further responsibilities, and to deliver services despite difficulties (such as staff turnover). JCOMMOPS has also started cooperating with European initiatives (such as AtlantOS), and will certainly cooperate closely with the TPOS project.

HIGHLIGHTS

1. Ocean Observations Coordination (OOPC and JCOMM OCG)

- Successful completion of the GCOS Implementation Plan (The Global Observing System for Climate: implementation needs), including two rounds of community review.
- The Ocean chapter of the GCOS Implementation Plan includes input from across the three panels of GOOS, and includes new Essential Climate Variables (ECVs; Ocean Surface Stress, Heat Fluxes, Nitrous Oxide, Marine Habitat properties), and a reframing of ocean carbon ECVs.
- Assess, review and prioritize requirements for Essential Ocean Variables (EOVs) and ECVs.
- Work with JCOMM OCG and regional bodies to coordinate observing networks.
- Review the status of and requirements for data and information management.
- Develop a process for ongoing evaluation of the observing system.

2. Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Observations Programme Support Centre (JCOMMOPS)

- Implementation/finalization of a new information and data management system.
- Development of an ambitious website with a theme for each JCOMMOPS-coordinated network, and also an integrated perspective. AtlantOS theme being developed (www.jcommops.org).
- Development of a cross-cutting Cruise Coordination and Information System.
- Operationalization of core services such as routine production of harmonized monthly maps.
- Development of harmonized Key Performance Indicators (KPI) for most of networks (267 thus far) with time series.
- Improved internal organization and efficiency through regular team meetings and work plan tracking.
- Development of a unique ID scheme for ships (in cooperation with ICES/BODC) and ship based platforms.
- Initial monitoring of GLOSS (sea level tide gauges) within JCOMMOPS.
- Migration of the E-SURFMAR ship database (Pub47) into JCOMMOPS IS.
- Production of a detailed yearly report for Argo, demonstrating the benefits of using design recommendations, targets, KPIs, etc. See http://www.argo.ucsd.edu/AIC_Rep_AST18.pdf.
- Initiated discussions with Gliders groups to start monitoring at JCOMMOPS.
- Initial submission of metadata to WIGOS/OSCAR.
- Contribution to "The Sea" book with a chapter focused on "The frontier of in situ open ocean observing system."
- Preparation of a yearly JCOMM Report Card, highlighting the benefits of an integrated observing system enabling a set of societal applications (to be released later this year).

SOCIETAL BENEFITS

1. Ocean Observations Coordination (OOPC and JCOMM OCG)

The Ocean Observations Panel for Climate is a scientific expert advisory group charged with making recommendations for a sustained global ocean observing system for climate in support of the goals of its sponsors. This includes recommendations for phased implementation. The Panel also aids in the development of strategies for evaluation and evolution of the system and of its recommendations, and supports global ocean observing activities by interested parties through liaison and advocacy for the agreed observing plans.

2. Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Observations Programme Support Centre (JCOMMOPS)

JCOMMOPS monitoring tools and services provides a clear vision of the system elements, critical to implementers and user community. It allows the optimization of resources available to implementers, of the data and data quality available to users. It also participates in democratizing the access to the information around these observing systems. It provides rigorous monitoring tools to track the progress and promote each observing system, and report on any perspective (network, cross-network, global, national, regional, etc.).

EDUCATION AND OUTREACH ACTIVITIES

1. Ocean Observations Coordination (OOPC and JCOMM OCG)

Webinars – The GOOS Project Office co-ordinates monthly webinar series as an opportunity to show and discuss activities or topics of interest to the GOOS and OOPC community, and to interact with the speakers directly. A number of Webinars have focused on OOPC and JCOMM OCG activities, including TPOS 2020, DOOS, and observing networks. See full list at www.goosocean.org/webinar.

Websites - A new GOOS website was launched in late 2016, and the OOPC web pages have been integrated into this website. More dynamic content will be added (such as ocean indices, and dynamic information on the status of the observing systems; see www.goosocean.org).

Specifications - A full list of Essential Ocean Variables (EOV) and their specifications were developed by GOOS panels. These are now available on the GOOS website at www.goosocean.org/eov. Network Specifications are also under development and will be added to the website, along with a list of the 'GOOS networks.'

OceanObs Conference - Planning the OceanObs'19 Conference has commenced, which will be held from the September 16-20, 2019. Currently the secretariat is assisting in identifying leadership for the program committee, and securing sponsorship from key agencies and programs. More details can be found at www.oceanobs19.net.

A summary of meetings attended by the OOPC secretariat can be found below. Meeting attendance is planned and prioritized in consultation with the OOPC chairs.

Dates	Meeting	Location
4-6 April 2016	JCOMM Observations Coordination Group	Esporles, Majorca
6-8 April 2016	OOPC Meeting	Esporles, Majorca
24-26 May 2016	GCOS IP Writing Team Meeting	Ispra, Italy
1-3 June 2016	GOOS Steering Committee	Sopot, Poland
14-16 Sept 2016	Cross Panel working meeting	Ostende, Belgium
3-7 Oct 2016	GCOS Steering Committee	Guayaquil, Ecuador
24 Oct 2016	TPOS 2020 SC 3	Lima, Peru
8-10 Feb 2017	Super EOV Workshop	Miami, USA
14-17 March 2017	OOPC-20	WHOI, Cape Cod, USA

2. Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology Observations Programme Support Centre (JCOMMOPS)

- Contribution to local/international marine observing and educational activities (i.e., SaferSeas, Brest International Maritime Festival), contributed to local articles promoting the networks; prepared posters, slogans, articles for COP21, in collaboration with UNESCO.
- Contribution to "The Sea" book with a chapter focused on "The frontier of in situ open ocean

observing system" (paper under revision).

- JCOMMOPS poster with all JCOMMOPS Ocean Observing Networks distributed to 200 global contacts.
- International meeting organization (i.e., 1st Ocean Observers Workshop, an educational workshop to bring together ocean scientists, educators, the sailing community and marine communicators to share experiences on ocean observing educational activities). 80 participants worldwide will attend the meeting.
- Host the next DBCP-33 session in Brest/Ifremer.
- Collaboration with civil society (i.e., Barcelona World Race: Floats away!).
- Contribution for brochures content and design (i.e., Argo brochure; JCOMM Report Card 2016).

PUBLICATIONS

Battaglia, A. S., Tanelli, S., Kobayashi, S., Zrnic, D.S., Hogan, R.J. 2010. 2010: Multiple-scattering in Radar Systems: a Review. J. Quantitative Spectroscopy and Radioactive Transfer 111:917-947

Dolman, A.J., Belward, A., Briggs, S., Dowell, M., Eggleston, S., Hill, K., Richter, C., Simmons, A. 2016. A Post Paris Look at Climate Observations. Nature Geoscience 9:646. doi:10.1038/ngeo2785

K.Hill. 2016. Report of the 7th Session of the JCOMM Observations Coordination Group. http://www.jcomm.info/index.php?option=com_oe&task=viewDoclistRecord&doclistID=111

K.Hill. 2016. Report of the 19th Session of the Ocean Observations Panel for Climate. https://library.wmo.int/opac/doc_num.php?explnum_id=3059

K.Hill. In Review. Report of the 20th Session of the Ocean Observations Panel for Climate.

2016. The Global Observing System for Climate: Implementation Needs 2016. http://www.wmo.int/pages/prog/gcos/

Ocean Acidification Coordination and Community Building: The 4th International Symposium on the Ocean in a High-CO2 World and the 3rd Global Ocean Acidification Observing Network Science Workshop

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Heather Benway, WHOI

NOAA Sponsor – Libby Jewett, OAP

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme*: Sustained Ocean Observations and Climate*

Amount Funded: $ 36,260

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Ocean Carbon and Biogeochemistry (OCB) Program (www.us-ocb.org) has served as a major coordinating body for ocean acidification (OA) research and communication efforts in the US, and in collaboration with international partners. For this project, the OCB Project Office utilized funds from the NOAA Ocean Acidification Program to provide and coordinate travel support for two international OA meetings that convened OA PIs from around the world to share new research results and discuss future priorities in ocean acidification research and monitoring. For both meetings, OCB facilitated travel arrangements and reimbursement for participants in need of travel support (as identified by the respective meeting organizing committees).

ACCOMPLISHMENTS

- OCB used NOAA funds to support the travel costs of three invited plenary speakers at the *4th International Symposium on the Ocean in a High CO2 World.*
- OCB used NOAA funds to support the travel costs of 14 participants to attend the *3rd Global Ocean Acidification Observing Network Science Workshop*, including ~2-3 participants from developing nations.

SOCIETAL BENEFITS

The travel support provided for the *3rd Global Ocean Acidification Observing Network Science Workshop*, particularly for participants from developing countries, helped develop ties for these scientists to the broader OA research community in an effort to build global OA observing capacity.

EDUCATION AND OUTREACH ACTIVITIES

- OCB at the *4th International Symposium on Oceans in a High CO_2 World Meeting.*
- Compiled ocean acidification outreach materials and resources for the meeting website and sent OCB brochures and relevant ocean acidification publications to the meeting for distribution (see http://www.highco2-iv.org/ocean-acidificationcarbon-cycle-outreach-materials).
- Prepared a poster "The US Ocean Carbon and Biogeochemistry (OCB) Program: Ocean Acidification Coordination, Training, and Outreach", which was presented by attending members of the OCB-OA subcommittee.

The Argo Project: Global Observations for Understanding and Prediction of Climate Variability

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Steven Jayne, WHOI

NOAA Sponsor – Stephen Piotrowicz, CPO

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 2,540,670

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Argo Program obtains systematic global observations of subsurface ocean temperature, salinity, and circulation. These key variables describe the physical state of the ocean, including its heat and fresh water content and their transport by ocean currents, and the contribution of changes in seawater temperature and salinity to sea surface height. Almost 4000 Argo floats presently provide over 130,000 ocean profiles each year.

ACCOMPLISHMENTS

WHOI continues to deploy floats in the Atlantic Basin with an emphasis on increasing coverage of the Intra-Americas seas. Newly deployed floats all use Iridium SBD communication, which shortens the time the float spends on the surface to about 15 minutes. The decreased time spent on the surface reduces the influence of surface currents and as a result, floats are less likely to drift into shallow waters and beach. So far, all the Iridium floats deployed in the Gulf of Mexico have stayed in this region: none have been swept out by the loop current and none have washed up on beaches. WHOI continues to develop metrics for assessing the status of Argo float coverage and to use as a guide for planning future deployments.

HIGHLIGHTS

WHOI prepared and deployed 61 Argo floats between April 1, 2016 and March 30, 2017, and currently operates a fleet of 343 active floats (see Figures 1 and 2).

SOCIETAL BENEFITS

Argo data are used in (i) basic oceanographic research, (ii) operational analyses of the ocean including initialization of ocean and ocean-atmosphere forecast models, (iii) national and international assessments of climate, and (iv) secondary and tertiary education.

PUBLICATIONS

Timmermans, M.-L., and S. R. Jayne, 2016: The Arctic Ocean spices up. *Journal of Physical Oceanography*, **46**, 1277–1284.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

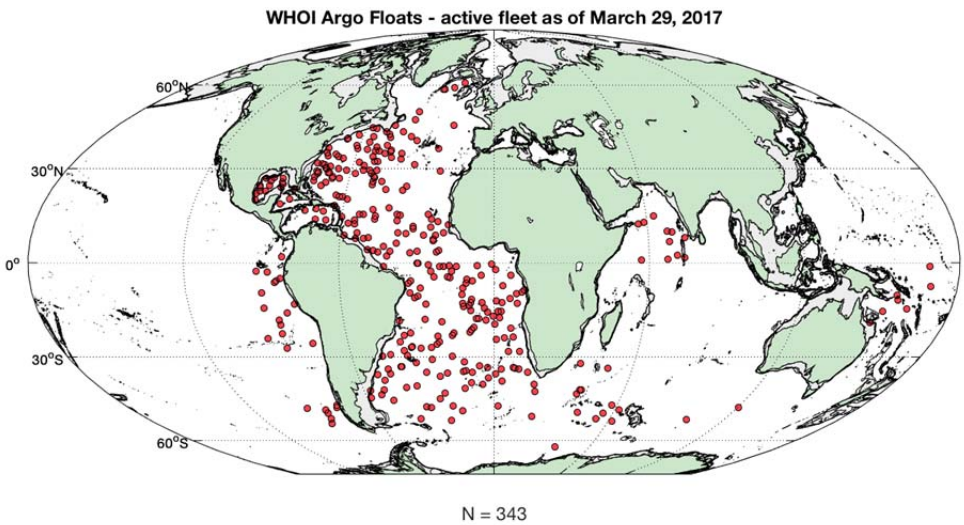


Figure 1. Map of WHOI Argo floats active on March 31, 2017.

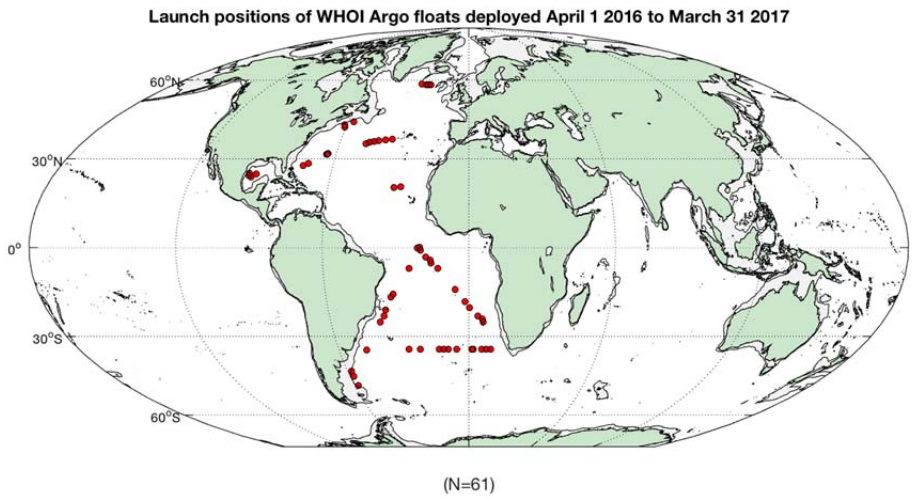


Figure 2. Deployment locations for WHOI Argo floats deployed between April 1, 2016 and March 31, 2017.

Tracking Changes in North American Marine Species Distributions

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Malin Pinsky, Rutgers University

NOAA Sponsor – Jonathan Hare, NMFS

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Migration***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 33,489

PROJECT OVERVIEW, GOALS, AND MILESTONES

This project proposed to:
(1) Acquire the latest bottom trawl survey data from the Eastern Bering Sea, Aleutian Islands, Gulf of Alaska, West Coast US, Northeast US, and Southeast US;
(2) Process these new data and integrate them into the fish distribution indicator website; and
(3) Update the software pipeline to streamline data acquisition from NMFS science centers where possible.

ACCOMPLISHMENTS

We acquired the latest scientific survey data from the Eastern Bering Sea, Aleutian Islands, Gulf of Alaska, West Coast US, Northeast US, and the Southeast US, and integrated these data into the visualization website, http://oceanadapt.rutgers.edu as of February 2017. We also re-designed our database backend to better deal with the small, annual changes in the format of the data that we receive from the Science Centers and other data providers. The new scripts and metadata are publicly available at https://github.com/mpinsky/OceanAdapt.

HIGHLIGHTS

- Data from OceanAdapt is now in use by a wide range of management agencies. These include the Atlantic States Marine Fisheries Commission, the South Atlantic Fisheries Management Council, the Mid-Atlantic Fisheries Management Council, and the Gulf of Mexico Fisheries Management Council. The data also contributed to the first climate-change vulnerability assessment by the National Marine Fisheries Service, and to the Mid-Atlantic Regional Ocean Action Plan.
- Data from OceanAdapt were incorporated into the latest EPA Climate Indicators publication (https://www.epa.gov/climate-indicators/climate-change-indicators-marine-species-distribution).

SOCIETAL BENEFITS

These data are helping fisheries managers and regional ocean planners in the US plan and adapt to climate change.

EDUCATION AND OUTREACH ACTIVITIES

- Jim Morley presented to the South Atlantic Fisheries Managment Council in June 2016.
- Jim Morley presented at the International Marine Conservation Congress (IMCC) in August 2016.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

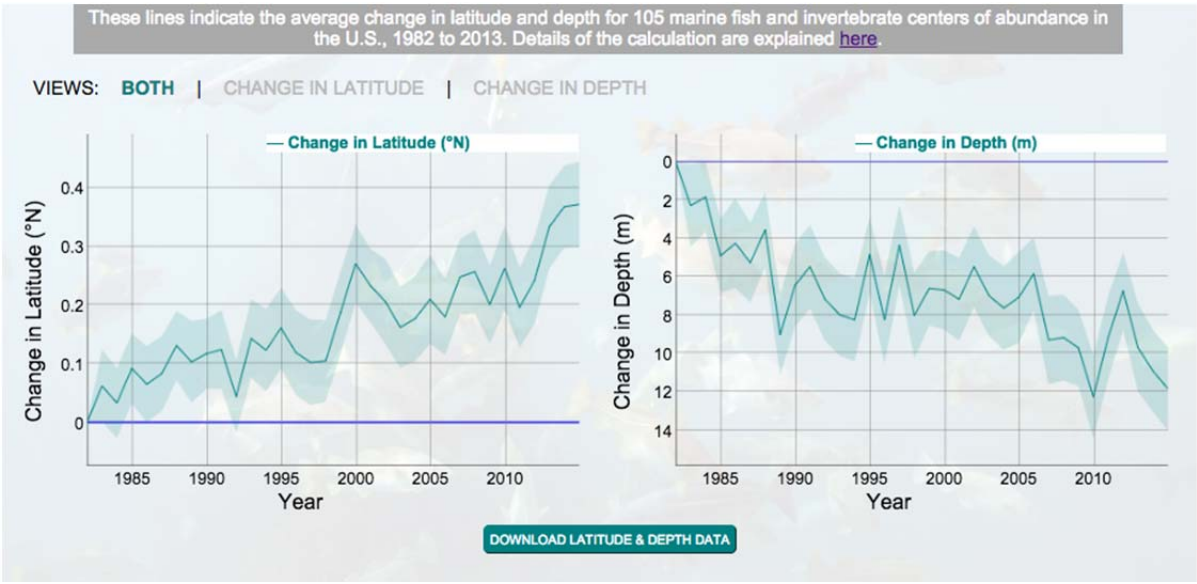


Figure 1. The latest update to the national marine species distribution indicator shows a strong northward and deeper shift for a wide range of marine fish and invertebrates in North America.

Ocean Climate Observations and Analyses (2016-2017)

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Robert Weller, WHOI

NOAA Sponsor – James Todd, OAR

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 2,368,370

PROJECT OVERVIEW, GOALS, AND MILESTONES

To provide sustained, climate-quality observing of the trade wind region, we have developed surface moorings with the capability of making sustained, accurate observations at the sea surface and in the water column, and have chosen and occupied three key trade wind sites. These surface moorings are known as Ocean Reference Stations (ORS). The three sites are the Stratus ORS, the NTAS (Northwest Tropical Atlantic Station) ORS, and the WHOTS (WHOI Hawaii Ocean Timeseries Site) ORS. Together, the three sites form a comprehensive array by sampling distinct branches of the trade wind regime while focusing on specific regional processes.

In FY2016 we carried out a cruise to each of the three ORS as described above. NTAS was serviced by the RV *Endeavor* in January–February 2017. Stratus was serviced by the Chilean Navy vessel *Cabo de Hornos* during a June 2016 cruise. WHOTS was recovered and redeployed in June 2016 on the NOAA Ship *Hi'ialakai*. Stratus and NTAS involved charter funding and preparation of the associated supplemental proposals for those funds.

Each cruise resulted in the collection of the internally recorded data from the instrumentation on the buoy and on the mooring line, and of supporting data sets from the ships, such as meteorological data for comparison with the buoy meteorological data. From the deployment of a new buoy onward, the surface meteorological data are available in near-real time, with hourly averages telemetered via satellite. The WHOI ORS data are not placed on the global telecommunication system (GTS); instead, they are used as independent data for model validation by users such as ECMWF (European Centre for Medium Range Weather Forecasts) and NCEP (National Centers for Environmental Prediction), and for quantification of error in fields, such as the surface fluxes, by investigators working in coordination with the CLIVAR Global Synthesis and Observations Panel (GSOP).

Through the year, we have in parallel to the field deployments worked on the analyses and publication. Among the highlights are: 1) continuing analyses of the Stratus ORS significant trends in wind speed, wind stress, latent heat flux, and het heat flux (Weller, 2015) in the first ten

years of observations and looking toward potential change in these trends as the PDO (Pacific Decadal Oscillation) index changes sign; 2) following up on links between NTAS ORS upper ocean temperature structure and Atlantic storm activity and working with University of New Hampshire colleagues on salinity anomalies at NTAS; and 3) continuing work with our colleagues at the University of Hawaii on covariability in local and regional surface freshwater fluxes and the WHOTS upper ocean thermohaline structure. These findings highlighted the particular value of the three ORS data sets. To make the ORS data more readily available to modelers and others, in 2015 we added a Reference Data Sets page to our web site (http://uop.whoi.edu/ReferenceDataSets/index.html) and are providing merged, quality controlled time series with the longest possible continuous time series we can construct, with an initial focus on the surface meteorological and air-sea flux time series.

ACCOMPLISHMENTS

The basic deliverables from the ORS are the high quality data, supported by the documentation of the methods. The directly observed data collected by the Stratus ORS fall into three main categories: 1) Surface meteorology and air-sea fluxes. The surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming long wave radiation, and rain rate are measured at a once per minute rate. Logged at the same time are buoy bridle temperature and salinity; 2) Surface oceanographic data; 3) Ocean observations of temperature, salinity, velocity, and dissolved oxygen along the mooring line. The surface meteorology, surface temperature, and surface current are used with the bulk forumulae to compute the following fourth product: 4) Air-sea fluxes of heat, freshwater, and momentum. In addition, all three ORS obtain: 5) Deep temperature and salinity from additional sensors approximately 36 m above the sea floor; Stratus and NTAS ORS obtain: 6) Surface wave data using a NOAA National Data Buoy Center wave package; Stratus and WHOTS ORS obtain: 7) pCO_2 observations using NOAA Pacific Marine Environmental Laboratory (PMEL) instrumentation; and Stratus carries: 8) Dissolved oxygen using sensors deployed both under this project and by Dr. Lothar Stramma from Geomar in Kiel, Germany.

The surface moorings are a very effective methodology. The WHOTS mooring has been on station 100% of the desired time. The Stratus and NTAS moorings have each provided 94% of the planned station time. Close to a complete (99.6%) record of surface meteorology has been delivered by the three ORS. In spite of biofouling, fishing gear entanglement, and other challenges 89% of the ocean sensor data sought while on station have been recovered; and, with redundancy in ocean instrumentation on the moorings, the result has been very effective observation of the variability and structure of the upper ocean.

The ORS addresses the following ocean observing system program deliverables:

- **Sea surface temperature (SST) and surface currents.** The ORS surface buoys have been instrumented to provide improved sea surface temperature observations. Because they sample surface and near-surface ocean temperature and because they have collocated, high-quality air-sea fluxes, ORS data are sought by investigators working on climate dynamics, air-sea interaction, diurnal warm layer dynamics, and remote sensing of SST.
- **Ocean heat content and transport.** The ORS are equipped with temperature, salinity, and

velocity sensors concentrated from about 1000 m to the surface and also the deep sensors close to the bottom. As a result, the temporal evolution of the mixed layer and its heat storage can be tracked as well as the heat content of the upper ocean.

- **Air-Sea Exchanges of Heat, Momentum and Freshwater.** The ORS are equipped to make state of the art, sustained air-sea flux observations, providing the air-sea exchanges of heat, freshwater, and momentum. The Stratus surface meteorological and air-sea flux data, uniquely, are both high quality and withheld from real-time assimilation into weather and climate models.
- **Ocean Carbon Uptake and Content.** Collaboration with NOAA PMEL provides pCO_2 observations from Stratus and WHOTS.

HIGHLIGHTS

- Weller (2015) reported finding long-term trends in surface meteorology and air-sea fluxes at the Stratus ORS. Using the first ten years of Stratus data, statistically significant trends were found in wind speed, wind stress, latent heat flux, and het heat flux. Increases in wind speed, wind stress, and latent heat flux over nine years were 0.8 m s-1, 0.022 N m-2, and 20 W m-2 or 13, 29, and 20% of the respective nine-year means. The decrease in the annual mean net heat flux was 39 W m-2or 104% of the mean. Bringing the latest Stratus data into the recovery now shows that the increase in the trade winds has stopped and that they are weakening.
- WHOTS, like the other ORS, records local air-sea forcing (exchanges of heat, freshwater and momentum) as well as local ocean variability. We have now extended the surface meteorological and air-sea flux time series to July 2016. The trends toward clearer skies continues, reflected in large net shortwave radiation and thus in larger net air-sea heat flux.
- At the NTAS ORS we have moved forward defining the local climatology and examined the linkages between anomalous conditions there (SST, surface heat fluxes, and meteorology) and storm activity. Warm SST and humid marine atmospheric boundary layer conditions with higher sea level pressures coincide with years of more storm activity.

SOCIETAL BENEFITS

The ORS long-term observing effort is particularly significant in two areas: 1) It provides benchmarks to validate and improve climate models in a region important to global climate but presently not well-modeled, and 2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean, including the SST and heat content. The ability of society to prepare for and mitigate weather and climate variability and impacts depends heavily on the realism of models, and the withheld, high quality time series from the ORS are a key asset in the effort to improve models and build an improved understanding of the earth system.

EDUCATION AND OUTREACH ACTIVITIES

- Whenever possible, cruises to the Stratus and WHOTS ORS have involved NOAA Teachers at Sea and undergraduate and graduate students.
- ORS staff have written two chapters in a new text book in preparation: 1) Weller, R. A., Observing surface meteorology and air-sea fluxes. In: Observing the oceans in real time – Instruments, Measurement and Experience. R. Venkatsen, editor, Springer. Submitted. 2) Bigorre, S. and N. Galbraith, Sensor performance and data quality control. In: Observing the oceans in real time – Instruments, Measurement and Experience. R. Venkatsen, editor, Springer. Submitted.
- "Circulation, eddies, oxygen and nutrient changes in the eastern tropical Pacific Ocean", presentation at the European Geophysical Union annual meeting, April 2016.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

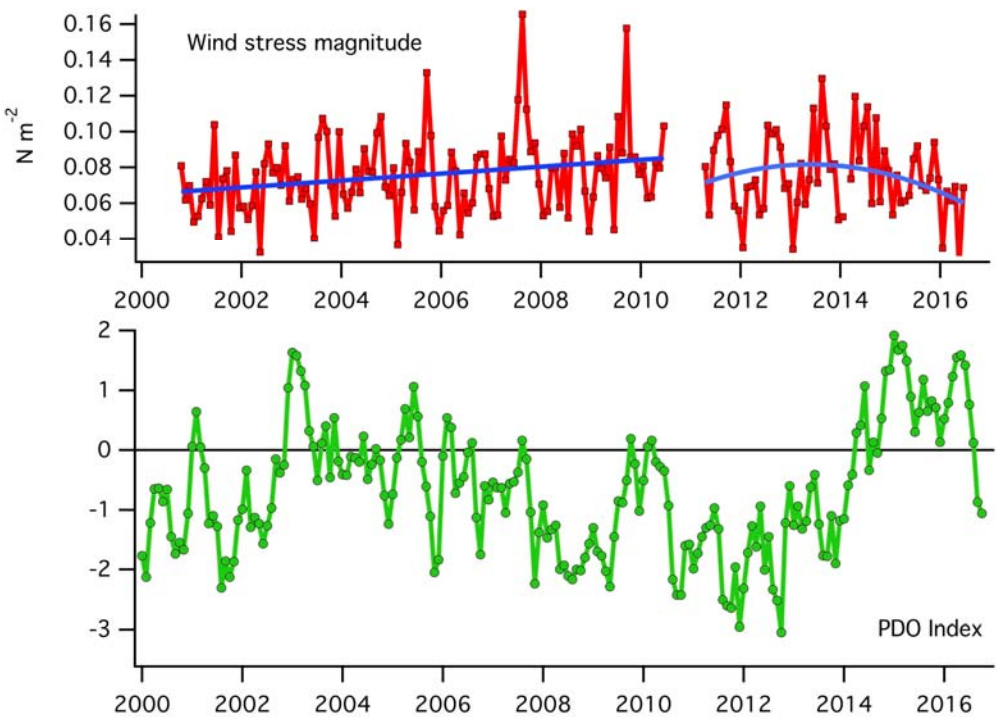


Figure 1. Monthly values of the ORS Stratus wind stress magnitude (upper, red) and of the Mantua PDO Index (lower, green). The 2000 to 2010 wind stress data has a least squares fit of a line (upper, blue) illustrating the significant increases in wind stress over that period. A cubic polynomial fit to the 2011 to 2016 wind stress data illustrates the present trend toward weaker wind stress.

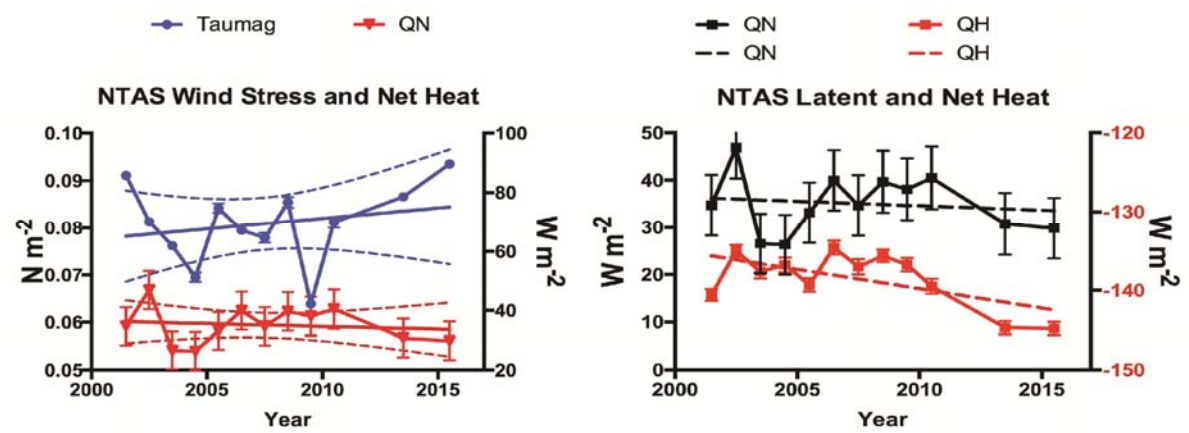


Figure 2. (Left) Annual means and linear fits for NTAS wind stress magnitude (blue) and net heat flux (red). These trends are not statistically significant, and the dashed lines show the envelope of possible slopes. 95% confidence intervals are shown as well. (Right) Annual means and linear fits to net heat flux (black) and latent heat flux (red). The negative slope of latent heat flux is statistically significant, with a slope of -0.49 W m^{-2} yr^{-1}.

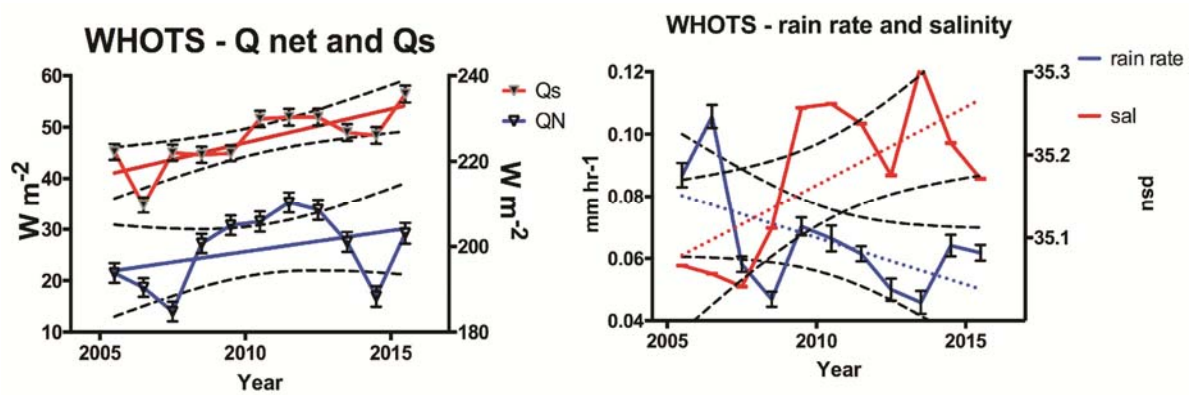


Figure 3. (left) Annual means of WHOTS net heat flux (blue) with a linear fit with a slope of 0.8 W m^{-2} yr^{-1}, and net shortwave radiation (red) with linear fit with a slope of 1.6 W m^{-2} yr^{-1}. 95% confidence intervals are shown on the mean values, and the dashed lines show the envelope of possible slopes. The slope for net shortwave is significantly non-zero at 95%. (right) Annual means of precipitation rate (blue) with a linear fit with a slope of -0.003 mm hr^{-1} yr^{-1}, and surface salinity (red) with linear fit with a slope of 0.019 psu yr^{-1}. The slope for salinity is significantly non-zero at 95%.

Supplement to: Ocean Climate Observations and Analyses – ORS Buoy Logger Iridium Upgrade

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Robert Weller, WHOI

NOAA Sponsor – Diane Stanitski, OAR

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 489,292

PROJECT OVERVIEW, GOALS, AND MILESTONES

To provide sustained, climate-quality observing of the trade wind region, we have developed surface moorings with the capability of making sustained, accurate observations at the sea surface and in the water column, and have chosen and occupied three key trade wind sites. These surface moorings are known as Ocean Reference Stations (ORS). The three sites are the Stratus ORS, the NTAS (Northwest Tropical Atlantic Station) ORS, and the WHOTS (WHOI Hawaii Ocean Timeseries Site) ORS. Together, the three sites form a comprehensive array by sampling distinct branches of the trade wind regime while focusing on specific regional processes.

To date, data telemetry from the ORS has relied on using Service ARGOS. This is a satellite data link with relatively low bandwidth, and we have had to use multiple transmitters on each buoy. Even so we have been able only to forward hourly-averaged data from the buoy. NOAA has now negotiated a favorable rate for usage of the higher bandwidth Iridium satellite data communication system and is asking users to convert from Service Argos to Iridium for telemetry of data from platforms at sea. This proposal covers the cost of purchasing Iridium hardware, interfacing to the ORS buoy data loggers, programming the loggers for Iridium telemetry, and initial testing.

ACCOMPLISHMENTS

Iridium telemetry will be phased in on the three ORS in turn as the buoy hardware comes back to WHOI for refurbishment during the annual deployment cycle. The first deployment of the new Iridium hardware will be on the WHOTS ORS to be deployed in July 2017. We have thus completed an initial design, acquisition, and test in order to equip the WHOTS buoy with one Iridium system while still maintaining one older Service Argos system.

HIGHLIGHTS

- Conversion of the Ocean Reference Stations from use of low bandwidth Service Argos data telemetry systems to higher bandwidth Iridium data telemetry systems is on track with the initial deployment planned for July 2017.

SOCIETAL BENEFITS

The ORS long-term observing effort is particularly significant in two areas: 1) It provides benchmarks to validate and improve climate models in a region important to global climate but presently not well-modeled, and 2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean, including the SST and heat content. The ability of society to prepare for and mitigate weather and climate variability and impacts depends heavily on the realism of models, and the withheld, high quality time series from the ORS are a key asset in the effort to improve models and build an improved understanding of the earth system.

Ocean Reference Stations Supplement: 2016 NTAS Ship Charter

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Robert Weller, WHOI

NOAA Sponsor – Diane Stanitski, OAR

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 545,575

PROJECT OVERVIEW, GOALS, AND MILESTONES

To provide sustained, climate-quality observing of the trade wind region, we have developed surface moorings with the capability of making sustained, accurate observations at the sea surface and in the water column, and have chosen and occupied three key trade wind sites. These surface moorings are known as Ocean Reference Stations (ORS). The three sites are the Stratus ORS, the NTAS (Northwest Tropical Atlantic Station) ORS, and the WHOTS (WHOI Hawaii Ocean Timeseries Site) ORS. Together, the three sites form a comprehensive array by sampling distinct branches of the trade wind regime while focusing on specific regional processes. Among the goals of the ORS project is to provide continuous time series for validation, verification, and calibration of models and remote sensing methods. This requires servicing of the ORS (recovery of a previously deployed mooring and deployment of a refurbished mooring at the same location) at intervals of 12-14 months. Supplemental funds were used to ensure timely servicing of the NTAS ORS in 2016.

ACCOMPLISHMENTS

The basic deliverables from the ORS are the high quality data, supported by the documentation of the methods. The directly observed data fall into three main categories: 1) Surface meteorology and air-sea fluxes. The surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming long wave radiation, and rain rate are measured at a once per minute rate. Logged at the same time are buoy bridle temperature and salinity; 2) Surface oceanographic data; and 3) Ocean observations of temperature, salinity, velocity, and dissolved oxygen along the mooring line. The surface meteorology, surface temperature, and surface current are used with the bulk forumulae to compute the following fourth product: 4) Air-sea fluxes of heat, freshwater, and momentum. In addition, all three ORS obtain: 5) Deep temperature and salinity from additional sensors approximately 36 m above the sea floor; and Stratus and NTAS ORS obtain: 6) Surface wave data using a NOAA National Data Buoy Center wave package.

The supplemental funds allowed a mooring service cruise for the NTAS ORS to be conducted so that the ORS deliverables were obtained. In January-February 2016 the University of Rhode Island UNOLS vessel R/V *Endeavor* was used to recover the mooring deployed the previous year (NTAS-14) deploy a refurbished mooring (NTAS-15).

The NTAS ORS addresses the following ocean observing system program deliverables:

- **Sea surface temperature (SST) and surface currents.** The NTAS surface buoy has been instrumented to provide improved sea surface temperature observations. Because they sample surface and near-surface ocean temperature and because they have collocated, high-quality air-sea fluxes, Stratus ORS data are sought by investigators working on climate dynamics, air-sea interaction, diurnal warm layer dynamics, and remote sensing of SST.
- **Ocean heat content and transport.** The NTAS ORS is equipped with temperature, salinity, and velocity sensors from about 150 m to the surface. As a result, the temporal evolution of the mixed layer and its heat storage can be tracked as well as the heat content of the upper ocean.
- **Air-Sea Exchanges of Heat, Momentum and Freshwater.** The NTAS ORS is equipped to make state of the art, sustained air-sea flux observations, providing the air-sea exchanges of heat, freshwater, and momentum. The NTAS surface meteorological and air-sea flux data, uniquely, are both high quality and withheld from real-time assimilation into weather and climate models.

HIGHLIGHTS

A unique, high quality long time series data set is being provided the NTAS ORS, deployed since March 2001 in the Northwest Tropical Atlantic. This is a region of high scientific interest and challenge, as evidenced by biases found there in ocean and climate models and by it being a region of little change in sea surface temperature or even cooling in a world where SST is generally warming. The uniqueness of the NTAS ORS time series stems from their being withheld and independent of the models, their high quality, their provision of coincident surface forcing and ocean variability, and their high vertical and temporal resolution in the upper ocean.

SOCIETAL BENEFITS

The NTAS ORS long-term observing effort is particularly significant in two areas: 1) Providing benchmarks to validate and improve climate models in a region important to global climate but presently not well-modeled; and 2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean, including the SST and heat content. The ability of society to prepare for and mitigate weather and climate variability and impacts depends heavily on the realism of models, and the withheld, high quality time series from the ORS are a key asset in the effort to improve models and build an improved understanding of the ocean's role in the earth system.

EDUCATION AND OUTREACH ACTIVITIES

The PIs routinely presents research results at national and international scientific meetings. Whenever possible, ORS cruises involve NOAA Teachers at Sea, undergraduate, and graduate students.

PUBLICATIONS

Pisareva, M.N., Pickart, R.S., Iken, K., Ershova, E.A., Grebmeier, J.M., Cooper, L.W., Bluhm, B.A., Nobre, C., Hopcroft, H.R., Hu, Haoguo, Wang, J., Ashjian, C.J., Kosobokova, K.N., Whitledge, T.E. 2015. The relationship between patterns of benthic fauna and zooplankton in the Chukchi Sea and Physical Forcing. Oceanography 28(3): 69-83. doi:10.5670/oceanog.2015.58.

Accessing and Visualizing Satellite Data for Use by Fisheries Managers in the Northeast

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Riley Young Morse, GMRI

NOAA Sponsor – Ellen Mecray, NCEI

Related NOAA Strategic Plan Goal: ***Climate Adaptation and Mitigation***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 27,027

PROJECT OVERVIEW, GOALS, AND MILESTONES

Note: The funding for year three of this award did not become available until February 2017; thus, we have limited progress to report for the April 1, 2016-March 30, 2017 reporting period, although work is underway at the time of this report. Additionally, NCEI was in the process of relocating data services during the March-May 2017 time period, which prevented us from working with NCEI data during that time period.

At the completion of the first two years of this project, we have met our initial goals of: 1) data access and integration; 2) spatial averaging; 3) building reference levels (climatologies); and 4) developing interactive presentations of data and integrating into the dashboard (User Interface). As we move into year three, we are working to continuously improve upon our initial goals, and have been implementing recommendations from the initial rollout and engagement with our stakeholder group. For data access, the focus has been on moving beyond temperature (OISST) and adding new data types based on recommendations from the stakeholder efforts. On spatial averaging, we have further refined our technique to map data from different datasets to a common grid to permit accurate comparisons. We are now working on temporal averaging; specifically the development of data products with a decadal and seasonal focus.

For both products, we have long-term data sets as well as forecasts. Through this and our other efforts (e.g., "*Building tools for applying climate science to fisheries management*"), we continue to engage with fishery stakeholders to ensure that the tools we develop are intuitive and useful. Major activities are organized under the following goals and objectives:

1) Data Acquisition and Integration
    a) Access/Understand/Document structure and accessibility of data through NCEI/CWC/CDR
    b) Develop web services and scripts to access and subset data by temporal/spatial boundaries
    c) Develop standards-based web services to access data and update on the fly

d) Pilot in NE with an eye toward reuse/extensibility

2) Spatial Averaging
   a) Subset global data set for the NES LME and sub-regions
   b) Develop aggregations of data to produce averages at each region for the available data parameters
3) Build Reference Level (i.e. climatology) for the data
   a) Develop climatologies for sub-regions from the 30 year time series
4) User interface: Seasonal and Decadal Visualizations
   a) Integrate current data and climatologies into dashboard

ACCOMPLISHMENTS

1) Data acquisition and Integration
   - Years 1 and 2: We developed scripts that were used to query the data services at CDR - OISST THREDDS through NetCDF Subset Services (NCSS) to return the full time series for grid points within our target bounding box (Northeast Shelf Large Marine Ecosystem). These new data sets were output as JSON for further use in development of reference/climatology.
   - Year 3: We are continuing to use and improve scripts developed during the first two years to acquire new data sets for the project (to include chlorophyll, precipitation, fisheries landings, etc.)

2) Spatial averaging
   - Years 1 and 2: To make more relevant comparisons between the data, we used specific regions within the boundaries of the NES LME that more closely match the stock oceanographic regions of Ecological Production Units (EPUs) (Figure 1) and management areas for stock boundaries in the Gulf of Maine, Georges Bank, and Southern New England used by fisheries managers. Four EPUs have been defined for the NES LME. With the boundaries selected, we then average the values within that region.
   - Year 3: We are continuing to develop data products for OISST as well as new data using the spatial averaging techniques. Based on stakeholder input, we will apply the spatial averaging approach to develop temporal averages for seasonal/decadal views of the data.

3) Build reference level/climatology of data
   - Years 1 and 2: Used the OISST 30 year period (1/1/1982-12/31/11) and applied a suite of statistics to the time series to build high/low means, averages, and standard deviations at each grid point for each day of the year. The background climatology is overlaid with current conditions (monthly/daily). The climatology is fixed, but the current data are dynamically updated on a daily basis. The OISST anomalies are also calculated for the sub-region.
   - Year 3: apply techniques to additional datasets for both spatial (sub-region) and temporal (seasonal/decadal) aggregations.

HIGHLIGHTS

- Developed automated processes to aggregate and calculate spatial averages from data subsets that map to bounding boxes fisheries management areas.
- Calculated climatology statistics and higher resolution anomalies for subset data.
- Modified scripts to automate the process of accessing latest data from SST and SST Anomaly time series from OISST services to append to visualizations.
- Launched dashboard in beta mode with OISST data for end-user testing: http://dashboard.gmri.org (see Figure 2).
- Received additional funding from NOAA COCA to continue development of the Fisheries and Climate Data Dashboard for the next two years.

SOCIETAL BENEFITS

This project contributes to the CINAR theme of sustained ocean observations and climate, and to improved integration and availability of ocean observations from global to local scales. Additionally, this project contributes to the NOAA research goal of understanding climate variability and change to enhance society's ability to plan and respond.

EDUCATION AND OUTREACH ACTIVITIES

- PI Young Morse presented the dashboard/data project at the 2016 NOAA CPASW (Climate Prediction Applications Science Workshop) in Burlington, VT (March 2016).
- PI Young Morse presented at the 2016 American Geophysical Union Annual Meeting. The subject of the talk was the development of the fisheries dashboard where the data products developed through this effort are housed. The technical processes developed for accessing, sub-setting, and aggregating the OISST data sets were discussed.
- PI Young Morse was invited to attend three meetings of regional and federal fisheries managers in Northeast and Mid-Atlantic to promote the dashboard and build the end-user network during the winter/spring of 2016-2017.
- PI Young Morse and Co-I Ellen Mecray will be presenting during a panel discussion at the upcoming AMS Climate (Asheville, NC) June 25-29th, 2017.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

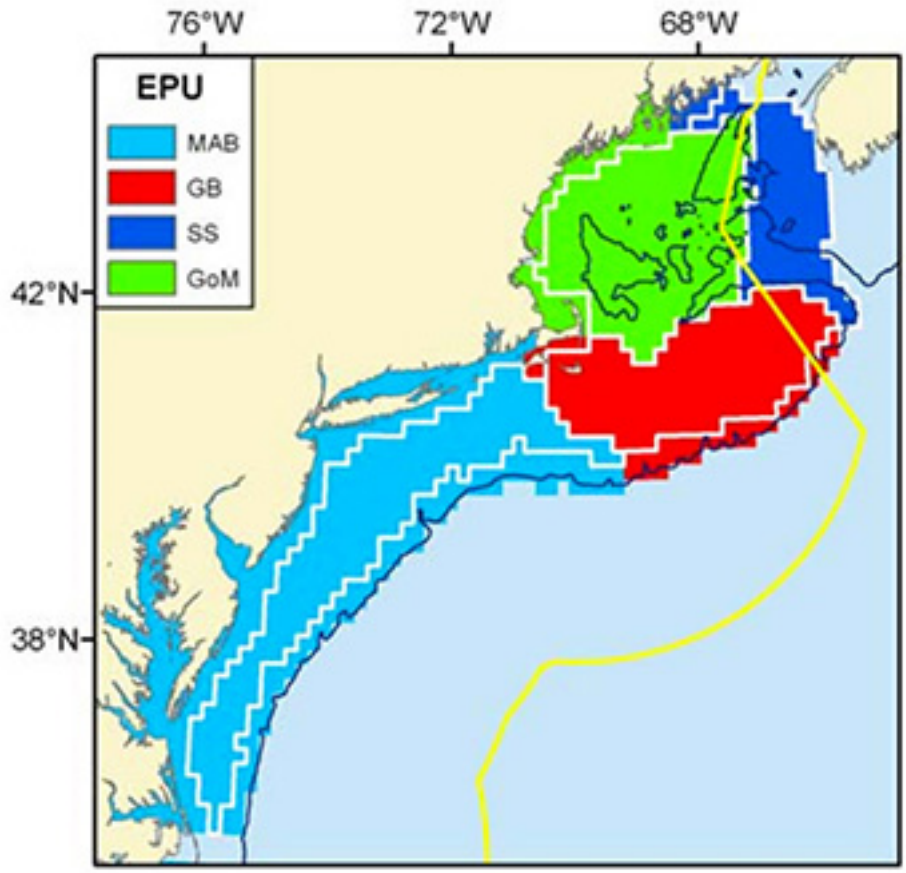


Figure 1. Map of the four Ecological Production Units (EPUs) as defined for the NES LME for MAB = Mid Atlantic Bight, GOM = Gulf of Maine, GB = Georges Bank, SS = Scotian Shelf. (http://www.nefsc.noaa.gov/publications/crd/crd1207/crd1207.pdf).

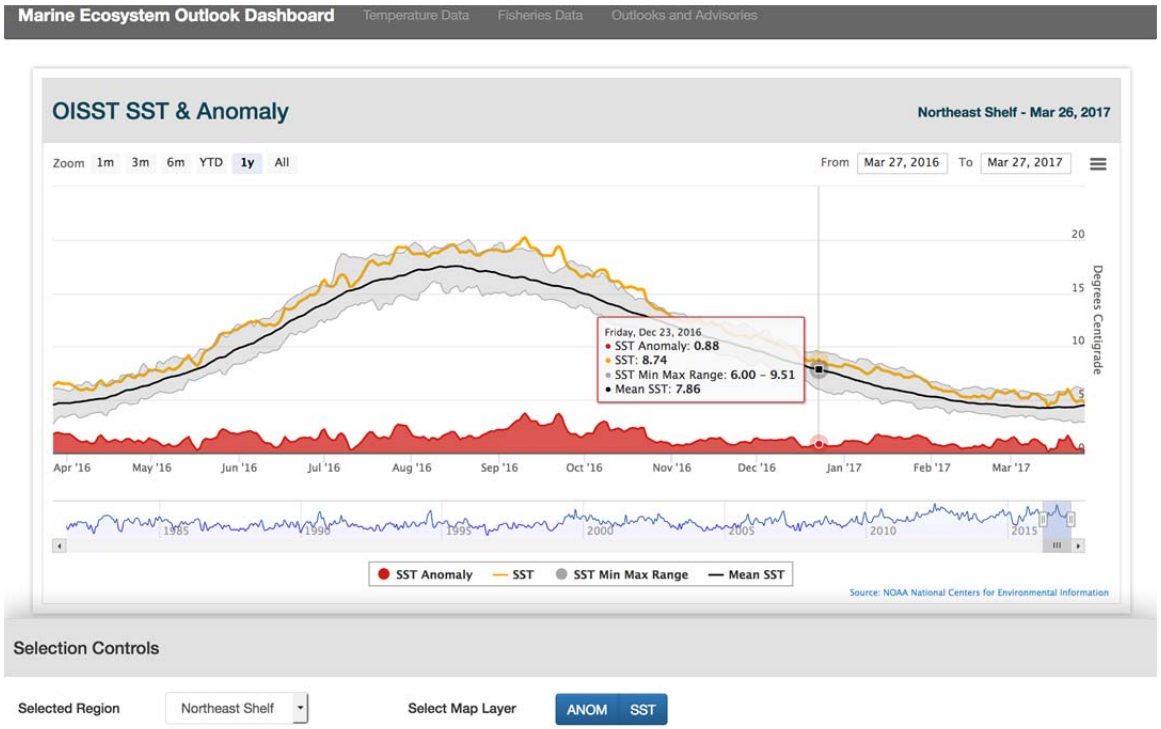


Figure 2. Image of the climatology data visualization in the Dashboard.

50 Year Global Ocean Surface Heat Flux Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Lisan Yu, WHOI

NOAA Sponsor – David Legler, OAR

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Sustained Ocean Observations and Climate***

Amount Funded: $ 180,526

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Objectively Analyzed air-sea Fluxes (OAFlux) is a research and data development project focusing on global air-sea heat, moisture, and momentum fluxes. The project is committed to produce high-quality, long-term, global ocean surface forcing datasets from the late 1950s to the present to serve the needs of the ocean and climate communities on the characterization, attribution, modeling, and understanding of variability and long-term change in the atmosphere and the oceans.

The OAFlux project was established on the basis that quality global flux fields can be obtained only when data errors are properly treated. This is due to the fact that global air-sea flux fields are commonly constructed from flux bulk parameterizations that require surface meteorological observables (e.g., wind speed, temperature, humidity, cloud cover, etc.) as inputs. However, no surface meteorological observables are free from errors/biases regardless of whether they are ship-based measurements or space-born satellite retrievals. To take into account data errors, the OAFlux project developed an objective synthesis to include error information in the formulation and to improve the flux estimates through synthesizing measurements/estimates from various sources. The error information of input data is determined from air-sea measurements from surface moorings. The OAFlux established a validation database consisting of more than 130 flux buoys from the ocean climate observing system, including the tropical moored array network in all three tropical oceans (i.e., the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network [TAO/TRITON] in the Pacific, the Prediction and *Research* Moored Array in the Atlantic [*PIRATA*], and the *Research* Moored Array for African–Asian–Australian Monsoon Analysis and Prediction [RAMA] in the Indian Ocean), and the OceanSITES Ocean Reference Stations deployed and maintained by the Woods Hole Oceanographic Institution (WHOI) and by the National Oceanography and Atmospheric Administration (NOAA) Pacific Marine Environmental laboratory (PMEL).

The OAFlux project distributes freely online (http://oaflux.whoi.edu/) the global 1° resolution, daily/monthly analysis (1958-to the present) of ocean evaporation, air-sea latent and sensible heat fluxes, and related surface meteorological variables. In past five years, the project has been

under extensive development of a high-resolution (0.25°), satellite-based, global analysis of air-sea fluxes starting from July 1987 onward. Three new sets of flux products are obtained: (1) near-surface air and humidity (ta and qa), (2) ocean evaporation, latent and sensible heat fluxes, and (3) ocean surface vector winds (this work is supported by NASA). The products will be disseminated online in the coming months after the evaluation study.

The OAFlux project demonstrates the important role of integrating air-sea measurements from the global ocean climate observing system in constraining the global flux products. At the same time, the OAFlux global products broaden, strengthen, and enrich the use of in situ flux measurements. The buoy-validated, completely global, gridded, and temporally homogeneous products of several-decades long can help the ocean and climate diagnostic and modeling studies in many ways that the irregularly spaced and sparse buoy time series cannot do. The OAFlux user base has been growing rapidly. Since the access counter was installed on 01 May 2013, the project home page has been accessed 13,645 times and the data download page 12,465 times. The OAFlux products have been cited in 747 papers since their online dissemination in 2008. A new recent trend shows that OAFlux has emerged as a leading source of verification and validation for climate models and data assimilation models.

The OAFlux global products of 50-years continue to provide new insights into the fundamental changes in the global climate under warm conditions. The evidence yielded from the OAFlux products leads to a wide recognition on the intensification of ocean evaporation since the late 1970s, providing observational support for the Intergovernmental Panel on Climate Change (ICPP) 5th assessment report (AR5) on the acceleration of the global hydrological cycle in the past warm decades. The OAFlux products lead to the finding of the important role of the strengthening ocean surface wind speed in increasing ocean evaporation, providing a thought-provoking addition to the theory based on the Clausius-Clapeyron equation. The OAFlux datasets lead to the identification of the non-negligible contribution of high-latitude sensible heat flux (i.e. the thermal exchange at the air-sea interface due to air-sea temperature differences) to the global energy balance. The OAFlux global products have demonstrated in many ways their value in stimulating advances in our understanding of the role of the ocean in the global energy budget, the global hydrological cycle, and the change and variability of the Earth's climate.

ACCOMPLISHMENTS

Technical accomplishments

In FY2016, efforts were made to address the Climate Observation Division's priorities by delivering two lines of research: (1) a continuous global analysis of air-sea turbulent heat and moisture fluxes from 1958 to the present, and (2) a new suite of satellite-derived, high-resolution OAFlux analysis (called OAFlux-HR) of all ocean-surface turbulent fluxes (heat, moisture, and momentum) for the satellite period from 1988 to the present.

The OAFlux-HR products establish a critical step toward building a complete ocean-surface forcing data set of the heat, freshwater, and momentum fluxes. We now have the turbulent latent and sensible heat fluxes, the moisture (evaporation) flux, and the momentum flux. Only two

atmospheric flux components, that is, radiation (shortwave and longwave) and precipitation at the ocean surface, are needed to complete the full suite of ocean forcing data sets. Collaborative efforts with leading surface radiation and precipitation groups have been developed, including the NASA Fast Longwave and Shortwave Radiative Fluxes (FLASHFlux) project, the NASA Clouds and the Earth's Radiant Energy System (CERES) project, and the NASA Global Precipitation Climatology Project (GPCP).

Scientific achievements

Two research themes were addressed.

1. Assessment of the global ocean water cycle in atmospheric reanalysis, satellite, and ocean salinity: We conducted an assessment of the uncertainty in ocean-surface (OS) freshwater budgets and variability using evaporation (E) and precipitation (P) from 10 atmospheric reanalyses, two combined satellite-based E-P products, and two observation-based salinity products. Three issues were examined: the uncertainty level in the OS freshwater budget in atmospheric reanalyses, the uncertainty structure and association with the global ocean wet/dry zones, and the potential of salinity in ascribing the uncertainty in E-P. The products agree on the global mean pattern but differ considerably in magnitude. The OS freshwater budgets are 129±10 (8%) cm yr-1 for E, 118±11 (9%) cm yr-1 for P, and 11±4 (36%) cm yr-1 for E-P, where the mean and error represent the ensemble mean and one standard deviation of the ensemble spread. The E-P uncertainty exceeds the uncertainty in E and P by a factor of four or more. The large uncertainty is attributed to P in the tropical wet zone. Most reanalyses tend to produce a wider tropical rain band when compared to satellite products, with the exception of two recent reanalyses that implement an observation-based correction for the model-generated P over land. The disparity in the width and the extent of seasonal migrations of the tropical wet zone causes large spread in P, implying that the tropical moist physics and the realism of tropical rainfall remain a key challenge. Satellite salinity appears feasible to evaluate the fidelity of E-P variability in three tropical areas, where the uncertainty diagnosis has a global indication. The study was published in Journal of Climate (Yu et al. 2017).

2. Assessment of the energy budget at the ocean surface: We conducted assessment analyses on the uncertainty of the energy budget at the ocean surface in reanalysis and satellite products. One study focused on the surface energy budget in semi-enclosed seas such as the Mediterranean Sea. In the context of the energy and water budget balance, the semi-enclosed Mediterranean Sea is a constrained basin, ideal to be used as a test basin for validating the surface flux estimates against the heat and water budgets computed from the hydrographic observations. We used historic hydrological observations and estimated the heat content changes and advective heat flux based on the heat budget equation. We examined nine flux climatologies against the heat budget derived from ocean observations and found that the surface energy in the products was contaminated by the errors and uncertainties. Seven products (NCEP 1, NCEP 2, CFSR, ERA-Interim, MERRA, NOCSv2.0 and OAFlux+ISCCP) showed higher estimates of Qnet spanning from 6 Wm-2 to 27 Wm-2, while two products had lower estimates at -6 Wm-2 (JRA-55) and -14 Wm-2 (CORE.2). Together with our previous warm pool work, we found that the CFSR, MERRA, NOCSv2.0, and OAFlux+ISCCP showed higher Qnet not only in the western Pacific warm pool but also in the Mediterranean Sea, whilst the CORE.2 indicated lower quantification

in both regions. NCEP 1, 2 and ERA-Interim showed lower estimate over the warm pool but higher quantification in the Mediterranean Sea. The study was published in JGR-Oceans (Song and Yu 2017).

HIGHLIGHTS

- The nearly 60-year time series of global ocean evaporation, turbulent latent and sensible heat fluxes (1958 onward) provides a continuous depiction of the multi-decadal change of ocean surface forcing functions.
- The newly completed high-resolution flux products over the past 30-year satellite era represent major improvements in resolving air-sea interaction on meso and frontal scales, and quantifying decadal trends and variability over the global ocean

SOCIETAL BENEFITS

OAFlux project deliverables help to identify and assess changes in forcing functions driving ocean conditions and atmospheric conditions and contribute to elucidate oceanic influences on the global water cycle.

EDUCATION AND OUTREACH ACTIVITIES

The PI routinely presents research results at national and international scientific meetings. She serves on the NOAA Ocean Observing System Team of Experts and has led the analysis of global ocean surface flux for the NOAA State of Climate annual assessment report since 2005. She serves on the CLIVAR Global Synthesis and Observations Panel, and is a member of the NASA Sea Surface Temperature Science Team, NASA Ocean Surface Salinity Science Team, and NASA Ocean Vector Wind Science Team. She is a co-Chair of the CLIVAR Global Synthesis and Observations Panel (GSOP), a member of Science Advisory Group on European Space Agency SMOS mission Pi-MEP, a member of the CLIAVR Earth Energy Imbalance (EEI) core working group, and a member of the Tropical Pacific Observing System (TPOS) 2020 Back Bone Task Team.

PUBLICATIONS

Yu, L., R. F. Adler, G. J. Huffman, X. Jin, S. Kato, N. G. Loeb, P. W. Stackhouse, R. A. Weller, and A. C. Wilber, 2016: Global ocean heat, freshwater, and momentum fluxes. In *The State of Climate in 2015*, *Bull. Amer. Meteor. Soc.*, 97(8), S74-S78.

Boutin, J., Y. Chao, W.E. Asher, T. Delcroix, R. Drucker, K. Drushka, N. Kolodziejczyk, T. Lee, N. Reul, G. Reverdin, J. Schanze, A. Soloviev, L. Yu*, J. Anderson, L. Brucker, E. Dinnat, A.S. Garcia, W.L. Jones, C. Maes, T. Meissner, W. Tang, N. Vinogradova, B. Ward, 2016: Satellite and in situ salinity: Understanding near-surface stratification and sub-footprint variability. *Bull. America Meteor. Soc.* 97, 1391–1407, doi: 10.1175/BAMS-D-15-00032.1.

Yu, L., X. Jin, S.A. Josey, T. Lee, A. Kumar, C. Wen, and X. Yan, 2017: The global ocean water

cycle in atmospheric reanalysis, satellite, and ocean salinity. *J. Climate*, doi: http://dx.doi.org/10.1175/JCLI-D-16-0479.1.

Song, X., and L. Yu, 2017: Airs Sea heat flux climatologies in the Mediterranean Sea: Surface energy balance and its consistency with ocean heat storage. *J. Geophys. Res.*, Special issue on dense water formations in the North Western Mediterranean: from the physical forcings to the biogeochemical consequences. J. Geophys. Res. Oceans, 112, doi: 10.1002/2016JC012254.

Wen, C., Y. Xue, A. Kumar, D. Behringer, and L. Yu, 2017: How do uncertainties in NCEP R2 and CFSR surface fluxes impact tropical ocean simulations? *Climate Dynamics*, doi:10.1007/s00382-016-3516-6.

THEME VI. EDUCATION AND OUTREACH

Research and Education in Quantitative Fisheries and Ecosystem Science

NOAA Cooperative Agreement No. NA14OAR4320158
April 1, 2016-March 31, 2017

CINAR Investigator: Donald Anderson, WHOI

NOAA Sponsor: Bill Karp, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

Amount Funded: $ 460,000

PROJECT OVERVIEW, GOALS, AND MILESTONES

Both NOAA and the NEFSC have a need for skilled personnel and new technologies to assist in stock assessment and quantitative fisheries science. In the Northeast region, there has been considerable controversy within the fishing community and fisheries management councils as well as with NOAA and its scientists because of disagreements concerning the existing size of fish stocks, the acceptable harvesting levels, and the best ways to determine these important parameters. A significant additional complication is the congressionally mandated need to manage fisheries in the context of the complex ecosystem interactions that are involved. As a result, Integrated Ecosystem Assessments and Ecosystem Approaches to Management are now being developed for the Northeast Continental Shelf Ecosystem. These new responsibilities, added to the need for traditional assessment surveys for individual fish stocks, has led to heavy pressure on dwindling budgets for monitoring and assessment activities in the region. Compounding these challenges is a current and projected shortage of trained fisheries scientists throughout NMFS. With NOAA funding, CINAR has recently initiated a research and education program to address both of these shortfalls through the enhancement of teaching and advising activities in a graduate fisheries program, and the development and implementation of new technologies that can improve and enhance assessment and management capabilities in the region. The program is a partnership between the Woods Hole Oceanographic Institution (WHOI) with its strong research, instrumentation, and modeling capabilities, and the University of Massachusetts School for Marine Science and Technology (SMAST) which has an established graduate program in Fisheries Science and longstanding involvement with fisheries stock assessment, management, and socio-economic research.

ACCOMPLISHMENTS

This program was initiated in 2012. The first CINAR Fellows were appointed in early 2013, and in fall 2015 a second competition was held. Progress reports on their activities during 2016-2017 are given in the attached Appendix, and are summarized below.

SMAST Faculty. Assistant professor Dr. Gavin Fay joined the Department of Fisheries Oceanography in the fall 2014 semester. Dr. Fay is using marine ecosystem models to evaluate the performance of ecosystem-based fisheries management strategies for the northeast U.S. continental shelf. As he develops his research program at SMAST, he is expected to use interdisciplinary multi-model approaches to extend the scope of applications for fisheries and ecosystem assessment.

CINAR Fellows. In fall 2015, a second competition for three new CINAR fellows in Quantitative Fisheries and Ecosystem Science was held. We received a remarkably strong set of 12 applications from WHOI scientists in response to CINAR's call for applications. These files were reviewed and ranked by a committee of WHOI scientists, the WHOI Director of Research, NEFSC representatives, SMAST representatives, and the CINAR Director. With this funding and additional funds provided by both the NEFSC and WHOI, three new CINAR fellows were appointed: Scott Gallager, Associate Scientist, Biology Department, Joel Llopiz, Assistant Scientist, Biology Department, and Heidi Sosik, Senior Scientist, Biology Department. Their proposed research projects are summarized below, and reports on their activities are included in the Appendix that follows.

Scott Gallager, Associate Scientist, Biology Department. Dr. Gallager plans to continue his collaborations with NOAA NEFC by transitioning instrumentation and technologies for fisheries science into operational fisheries management. Specifically, HabCam (HABitat mapping Camera) is routinely used in NOAA's annual sea scallop survey and now provides on of the most critical numbers on scallop biomass for this survey. His fellowship plans are to develop software tools to extract additional information from HabCam imagery, and thus expand its applicability to stock assessments.

Joel Llopiz, Assistant Scientist, Biology Department. Dr. Llopiz's research objectives as a CINAR fellow will center around three themes. First, he will taxonomically expand our knowledge of the larval fish feeding dynamics of commercially important fishes in the Northeast US Shelf Large Marine Ecosystem (NES LME), including further examining the potential for stock assessment-relative indices of zooplankton composition and abundance. Second, he will continue refining the 'Diadrocam' (a high-resolution camera system for quantifying migrating juvenile diadromous fishes) and its image analysis capabilities so that it can be used for broad-scale implementation in riverine systems throughout the Northeast US. Finally, he will continue work with colleagues in the NEFSC's Food Web Dynamics Program our analyses on NEFSC feeding data and examine them in concert with results from our NSF forage fish project. Through these activities, Dr. Llopiz will strengthen and expand his collaborations with the NEFSC, and initiate research- and education-related interactions with SMAST faculty and students.

Heidi Sosik, Senior Scientist, Biology Department As a CINAR Fellow, Heidi will focus on impacts of lower trophic levels on Northeast US shelf ecosystem status, productivity, and expected responses to climate change. She will partner with NOAA scientists and collaborators from other CINAR institution to evaluate and refine indices of phytoplankton community status that are needed for such products as Ecosystem Status Reports and food web models that predict sustainable fisheries yield. Specific activities include advancing use of new imaging technologies for spatial (ship) and temporal (coastal observatory) characterization of patterns of change in

plankton and combining in situ observations with state-of-the-art ocean color remote sensing to improve local-to-regional scale plankton retrievals.

SOCIETAL BENEFITS

The need for trained personnel and new technologies in fisheries science is significant and increasing. Dwindling fish stocks and associated economic impacts plus intense political pressures all dictate that immediate steps be taken to enhance the scientific basis of assessment and management of resources and to educate future personnel in quantitative aspects of fisheries science. In response, we are developing a research and education program to provide teaching and advising activities, and to develop and implement new technologies that can improve and enhance fisheries assessment and management capabilities in the US Northeast coastal region.

Please see individual reports (immediately following in Appendix A) for highlights, education and outreach, activities, and publications.

CINAR Fellow: Scott Gallager, WHOI

PROJECT OVERVIEW, GOALS, AND MILESTONES

There are three Objectives in this Fellowship program:

Objective 1: ***Quantification of demersal fish using HabCamV4***. HabCamV4 images may be used directly to quantify the distribution and absolute abundance of skates, flounders (particularly Yellowtail [YT] Flounder), and gadids (cod and Haddock). However, there are two issues that need to be addressed: First, fish are relatively rare in our images since the sample volume is small so as many images as possible (all 2 million per day) need to be annotated to make this approach effective, clearly an impractical manual task. I am developing an automated fish detector primarily using stereo segmentation and classification using machine vision and learning tools (Fig. 1) and build this capability into the standard processing workflow. Starting in 2016 and continuing into 2017, we have been running stereo rectification and point cloud production as part of the standard HabCam image processing workflow. We have now produced more than 20 million point clouds that are a full 3D representation of the seafloor from Delaware to Georges Bank. The fish detector is running as part of this workflow and pulls out both round fish and flatfish from the 3D images. These images are then being hand checked by myself and Jonathan Duquette, a NOAA stock assessment scientist.

The next step is to ground truth all of the 3D images and then look for sequential images where fish are darting out of the way of the vehicle. I am quantifying species-specific fish avoidance behaviors by viewing sequential, overlapping images of swimming fish. Another important use of optical imagery is the inter-calibration between bottom trawls, scallop dredges, and HabCamV4. If a "calibration" can be produced using HabCamV4 observations as ground truth, ground fish data from bottom trawls and scallop dredges could be used quantitatively, an asset highly desirable by the NEFSC. This work is in progress.

Objective 2: Quantifying the impact of swimming in early life history stages of sea scallop on post-settlement distribution. One of the major discoveries we made in the past two years is that juvenile scallops (1-2 year old) have a tendency to be swimming up in the water column. This discovery could not have been possible without the stereo imaging capability of HabCamV4 that allows us to measure (within 1 mm) their altitude off the seafloor and angle of attack (Gallager et al. in draft). Upwards of 150 small scallops per image (1 image ~ 0.75 m2) have been observed along the Northeast Shelf Large Marine Ecosystem (NES LME), which can go on for tens of kilometers.

My working hypothesis is that these very densely packed juvenile scallops swim into the benthic boundary layer as a mechanism for post-settlement dispersal. To test this idea, my colleague Prof. Changsheng Chen (SMAST) and I have initiated a project to model the potential transport of these scallops using FVCOM in both hindcast mode (to see where scallops could have been transported from) and in forecast mode (to predict where we expect these scallops to end up after swimming bouts of defined time periods).

Chen and I recently wrote a proposal to NOAA's scallop Research Set-Aside (RSA) program, and were funded specifically to continue this important study on swimming scallops. Understanding the impact of post-settlement swimming bouts in juvenile scallops has critical importance to management of the adult populations in rotational closure areas.

Objective 3: Habitat and ecosystem resiliency. The stereo imagery, side scan acoustics, environmental sensors (T,S,P,Chlorophyll, turbidity, O2) and plankton classifications (CPICS) on HabCamV4 make it a valuable source of information for both pelagic and benthic habitat. We now routinely and automatically classify substrate and build a stereo point cloud from every image (Gallager et al, in draft). Seafloor rugosity is extracted from the side scan and stereo images providing multi-scale (mm to hundreds of km) information on available surface structure and complexity. All of the information is then added to Habitat Suitability (HS) models and combined with point observations of demersal and ground fish. The result is a predictive model of species-specific fish habitat with measures of accuracy through bootstrapping (Gallager, 2013).

I used some of the fellowship funding to write a successful proposal to the scallop RSA program that specifically addresses habitat resiliency in the Closed Area II HAPC (Habitat Areas of Particular Concern). We are now deeply entrenched in processing 40TB of data to characterized habitat in this area. The next phase of the fellowship is to write a manuscript on the use of HIS modeling to predict stock recruitment as a function of climate change.

ACCOMPLISHMENTS

- I have developed an automated fish detector primarily using stereo segmentation and classification using machine vision and learning tools.
- I am the process of building this capability into the HabCam standard processing workflow.
- In collaboration with NOAA scientists, I am in the process of quantifying species-specific fish avoidance behaviors by viewing sequential, overlapping images of swimming fish.
- I am working on a manuscript that provides inter-calibration between bottom trawls, scallop dredges, and HabCam imaging. If a "calibration" can be produced using HabCamV4 observations as ground truth, ground fish data from bottom trawls and scallop dredges could be used quantitatively, an asset highly desirable by the NEFSC.
- I was funded along with Dr. Chen at UMass Dartmouth SMAST to model the potential transport of juvenile scallops using FVCOM.
- We now routinely and automatically classify substrate and build a stereo point cloud from every image (Gallager et al, in draft). Seafloor rugosity is extracted from the side scan and stereo images providing multi-scale (mm to hundreds of km) information on available surface structure and complexity.
- The basic question the New England Fishery Management Council (NEFMC) needs to answer is "at what spatial and temporal scale can scallop dredging be allowed without significantly impacting ecosystem function?" CLAII HAPC is an important habitat for juvenile gadids and other ground fish. I will address gear impacts on habitat for these

sensitive juveniles using existing survey dredge locations relative to their surroundings.

HIGHLIGHTS

- I have developed an automated fish detector primarily using stereo segmentation and classification using machine vision and learning tools.
- I am the process of building this capability into the HabCam standard processing workflow.
- In collaboration with NOAA scientists, I am in the process of quantifying species-specific fish avoidance behaviors by viewing sequential, overlapping images of swimming fish.
- I am working on a manuscript that provides inter-calibration between bottom trawls, scallop dredges, and HabCam imaging. If a "calibration" can be produced using HabCamV4 observations as ground truth, ground fish data from bottom trawls and scallop dredges could be used quantitatively, an asset highly desirable by the NEFSC.
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SOCIETAL BENEFITS

The basic question the NEFMC needs to answer is "at what spatial and temporal scale can scallop dredging be allowed without significantly impacting ecosystem function?" CLAII HAPC is an important habitat for juvenile gadids and other ground fish. I will address gear impacts on habitat for these sensitive juveniles using existing survey dredge locations relative to their surroundings. This work is in progress.

EDUCATION AND OUTREACH ACTIVITIES

- Several presentationas/seminars at the NEFSC
- One to two NOAA PEP students derive benefit from participating in my lab's research every summer
- I am co-chairing a session at the American Fisheries Society (AFS) meeting in Orlando in August 2017 entitled "Integration of Technologies for Next Generation Marine Observation Systems and Fisheries Independent Surveys"
- I will also present at the AFS meeting on the following subject: "Habitat Classification and Mapping Across Wide Spatial Scales Using Optical and Acoustic Sensor Fusion: The Towed and Autonomous HabCam Vehicles."

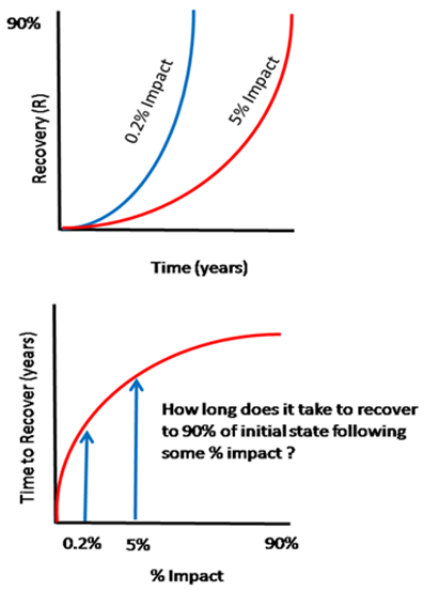
PUBLICATIONS

Kaplan, K, D Hart, K Hopkins, SM Gallager, AD York, R Taylor, P Sullivan. The distribution of the invasive tunicate *Didemnum vexillum* in Atlantic sea scallop *Placopecten magellanicus*

habitat on fishing grounds and closed areas of Georges Bank. ICES in press.

Kaplan, K, D Hart, K Hopkins, SM Gallager, AD York, R Taylor, P Sullivan. The invasive tunicate *Didemnum vexillum* limits Atlantic sea scallop *Placopecten magellanicus* habitat on fishing grounds and closed areas of Georges Bank. ICES In Press.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS



A. **Ecosystem Recovery versus Time at two impact levels:**

0.2% and 5%. Note the quadratic increase in R because R is a function of area. Shown are the curves for one habitat type. Each habitat will have its own family of curves.

B. Time to Recover versus % Impact at the experimental impact intensities for one type of habitat. The outward end of the curve may be simulated once we have established three points (0, 0.2 and 5% Impact).

Figure 1. Shelf-wide survey using HabCamV4 for stock assessment of scallops and habitat characterization. Ground fish are also being characterized during the survey.

CINAR Fellow: Joel Llopiz, WHOI

PROJECT OVERVIEW, GOALS, AND MILESTONES

My research interests and activities focus on fish ecology, with particular emphases on fish early-life stages and fish-zooplankton tropic interactions. The support received as a CINAR Fellow has been invaluable for me as an early-career scientist. Most importantly, it has given a remarkable ability to explore areas of research that have led to, and will lead to in the future, concrete projects and collaborations, as well as the ability to participate in activities such as cruises of opportunity, workshops, and more in-depth mentoring. Specifically, my activities have been related to research, proposal and collaboration development, service and outreach, and mentoring at the undergraduate, graduate, and postdoc level. The research activities specifically supported by my fellowship have included larval and adult sand lance on Stellwagen Bank (with NOAA collaborators), investigating the ecology of bluefin tuna larvae from the Slope Sea (with NOAA collaborators), deployment of a video monitoring system to examine juvenile river herring emigration dynamics, and participating on a cruise aboard the *Neil Armstrong* with WHOI and NOAA collaborators to examine biophysical interactions of zooplankton and fish. These and other activities are detailed below.

ACCOMPLISHMENTS

Research activities supported specifically by this fellowship have focused on river herring, sand lance, and bluefin tuna, all of which are ecologically and/or commercially important species in NE region. In the fall of 2016, I deployed a prototype camera system in the Monument River (which connects the Cape Cod Canal to Great Herring Pond) as a step toward the ambitious goal of counting every juvenile river herring heading to sea. A “pie-in-the-sky” piece of the puzzle when evaluating spawning habitat quality for anadromous fishes, such as river herring, would be quantifying the number of juveniles leaving a freshwater system and relating that number to the number of spawning adults that entered the system (yielding a per-adult value of juvenile productivity). This camera system is a major step toward reaching this goal. The system was deployed for three months (though not the entire emigration period of July-Dec), and successfully recorded almost the entire time. This year the system will be deployed in June to capture the beginning of the emigration period and continued work will be devoted to the automation of identifying, tracking, and enumerating juvenile herring in the video footage.

The other major research activity is a collaboration with NOAA’s Stellwagen National Marine Sanctuary (led by Dave Wiley there) and is focused on the ecology of sand lance—an important forage fish for a high diversity of upper trophic level consumers on Stellwagen Bank, including birds, whales, cod, and bluefin tuna. My graduate students and I participated in three cruises for this work. Our part of the work is focused on understanding the feeding dynamics of adult sand lance and the availability of their zooplankton prey, in addition to understanding the dynamics of larval sand lance on Stellwagen. This collaboration led to being a co-PI on a large proposal submitted to BOEM that is likely to be funded this year.

Finally, a collaboration with David Richardson (NOAA) and the Oceanography Branch at the NEFSC began in earnest this past year, focused on the larval ecology of bluefin tuna in the recently-discovered Slope Sea region offshore of the NE US. My lab has been involved in beginning to understand the growth and feeding success of bluefin larvae in this region, and this work will form a major portion of the thesis of my graduate student Christina Hernandez. Christina led the writing of a successful internal WHOI proposal to participate on a June 2017 NOAA cruise to the Slope Sea, where she will participate in the sampling and mapping of larval bluefin distributions and will lead efforts to release a dozen drifters in patches of bluefin larvae to understand the physical mechanisms associated with retention of larvae in the Slope Sea. This work is a collaboration with Jim Manning (NOAA), and Chrissy has also been involved with outreach activities at local schools to share this work with middle- and high-school students.

Educational activities have been numerous since receiving a CINAR Fellowship. I advise two graduate (Ph.D.) students—a first-year (Justin Suca—Hollings Scholar alumnus) and a second-year (Christina Hernandez). Justin has largely been working on an NSF project focused on the settlement dynamics of coral reef fish larvae in St. John, USVI, with the specific goal of elucidating the role of coral reef soundscapes in attracting settling larvae. He also been involved with the sand lance research on Stellwagen Bank, as well as ongoing projects we have on river herring. Chrissy's dissertation is centered on fish migrations and life history strategies, with a specific focus on Atlantic bluefin tuna and anadromous herrings. This work will have prominent theoretical and mathematical components, and Chrissy (an aspiring NOAA scientist) is expecting to make a significant contribution to stock-assessment-relevant information for bluefin tuna, as well as some exciting yet management-relevant results on the evolution of anadromy in herrings. Also advised this past year was Andrew Jones, a CINAR-funded Postdoctoral Scholar. Andy has since started a job at the NEFSC, but at WHOI was working on river herring ecology and examining the levels of individual-level diet specialization exhibited by fishes on the NE US shelf. This work capitalized on the NEFSC's Food Web Dynamics Program's extensive diet database and was a collaboration with Brian Smith (NEFSC). Finally, during the last year, my fellowship has helped me host and mentor four undergraduates, one guest Ph.D. student, and two high school students.

Other activities included the development of several proposals focused on the NE region. One of particular note was for the recent NSF new LTER site RFP. This effort was led by Heidi Sosik, and we were thrilled to hear that our project will be funded. The work is focused on the NE US shelf, and represents a major collaboration with NOAA scientists. I will lead the forage fish and zooplankton components of the work. Related to service, I am currently serving a two-year term as the chair of the Regional Association for Research on the Gulf of Maine, an activity that has been exceptionally impactful for getting to know many of the region's researchers, and would only be possible with CINAR Fellow support. Finally, I gave a seminar at UMass Dartmouth as part of SMAST's Fisheries Oceanography seminar series, and have given a number of talks to local organizations (e.g., Herring River Association, Cape Cod Charterboat Captain Association) and school-age children.

HIGHLIGHTS

- Deployment of a prototype camera system for three months in the Monument River to examine how many, and with what seasonal and diel frequency, juvenile river herring emigrate from their freshwater nursery habitats to sea.
- Participated in a large collaboration led by NOAA's Stellwagen National Marine Sanctuary to examine sand lance ecology and what drives their spatial and temporal variability in abundance.
- Began a collaboration with NEFSC to study the growth, feeding, and dispersal of bluefin tuna larvae in the Slope Sea.
- Participated on a one-week science verification cruise on the R/V *Neil Armstrong* with WHOI and NOAA scientists.
- Helped develop a successful NSF LTER proposal focused on the NE US shelf ecosystem. This project begins this in fall 2017 and relies heavily on collaborations with NOAA scientists and data.

EDUCATION AND OUTREACH ACTIVITIES

- Advised two graduate students, each involved in research focused on fish of ecological and commercial importance in the NE region.
- Advised CINAR-funded postdoc Andy Jones who led a collaboration with NEFSC's Food Web Dynamics Program.
- Hosted and mentored four undergraduates, each working on fish ecology for species within the NE region.
- Hosted two high-school students who were involved in our lab's fish research.
- Chair of the Regional Association for Research on the Gulf of Maine (RARGOM)
- Convener for RARGOM Annual Science Meeting.
- Gave a department seminar at UMass Dartmouth's SMAST.
- Stellwagen Bank Ecosystem Modeling invited workshop participant.
- Shared lab's research with the general public and school-age students through several presentations and lab tours.

PUBLICATIONS

Suca JJ and JK Llopiz (In revision) Trophic ecology of barrelfish in the oceanic waters near Miami, Florida. Bulletin of Marine Science.

DeVanna Fussell KM, REH Smith, ME Fraker, L Boegman, KT Frank, TJ Miller, JT Tyson, KK Arend, D Boisclair, OP Jensen, JK Llopiz, CJ May, RG Najjar, LG Rudstam, CT Taggart, YR Rao, SA Ludsin (2016) A perspective on needed research, modeling, and management approaches that can enhance Great Lakes fisheries management under changing conditions. Journal of Great Lakes Research 42: 743-752.

CINAR Fellow: Heidi Sosik, WHOI

PROJECT OVERVIEW, GOALS, AND MILESTONES

This CINAR Fellowship is focused on impacts of lower trophic levels on Northeast US shelf ecosystem status, productivity, and expected responses to climate change. The objectives include partnering with NOAA scientists and collaborators from other CINAR institution to evaluate and refine indices of phytoplankton community status that are needed for such products as Ecosystem Status Reports and food web models that predict sustainable fisheries yield. Specific activities include advancing use of new imaging technologies for spatial (ship) and temporal (coastal observatory) characterization of patterns of change in plankton and combining in situ observations with state-of-the-art ocean color remote sensing to improve local-to-regional scale plankton retrievals.

ACCOMPLISHMENTS

My CINAR Fellowship activities can be organized into four general areas: (1) continuing plankton observations at the Martha's Vineyard Coastal Observatory (MVCO) and, through collaboration with NMFS scientists, on ecosystem monitoring surveys over the Northeast US Shelf (NES); (2) analyzing and publishing results from on-going observations of plankton in the region; (3) providing leadership to catalyze new efforts for observation and study of NES ecosystems; and (4) engaging in related education, outreach, and strategic planning for the research community. Here, I provide a brief summary of key outputs in each of these areas.

Due to our efforts to promote time series continuity, the MVCO phytoplankton records now extend longer than a decade for complete characterization of communities from pico- to microplankton (picoplankton observations extend 14 years; microplankton commenced in summer 2006). Furthermore, we are now (since 2013) conducting approximately quarterly regional-scale surveys of nano- and microplankton as measured by Imaging FlowCytobot (IFCB). We recently (Feb 2017) completed our thirteenth deployment of IFCB on NOAA-sponsored NES survey cruises (EcoMon, CYST, and AMAPPS programs). On these cruises, we configure IFCB to sample automatically from the ship's underway flowing seawater (Fig. 1) and train NOAA personnel to perform routine instrument checks, thus enabling high volume data collection (e.g., Fig. 2) without need for WHOI technicians to attend the cruises.

In 2016, key peer-reviewed publications included reports on a 13-year study of picophytoplankton dynamics at MVCO (Hunter-Cevera et al. 2016) and on new approaches to investigate microzooplankton (Brownlee et al. 2016). The picoplankton study showed that warming conditions are leading to earlier spring blooms in the dominant taxa (Fig. 3). By coupling these observations with trait-based matrix population models (Sosik et al. 2003; Hunter-Cevera et al. 2014), we showed that this bloom shift results from enhanced growth rates (linked to alleviation of physiological temperature limitation) and also that loss rates (grazing or lysis) have shifted in tandem with the autotroph rates. The microzoooplankton paper documented new automated observational approaches that incorporate live-cell staining into IFCB analysis. In this work, we reported results from NOAA-EcoMon cruises that helped to support hypotheses

about variability in feeding strategy and prevalence of mixotrophy in ciliates (Brownlee et al. 2016).

During the past year, I led a successful multi-institution proposal to establish the Northeast US Shelf as a new site in the NSF-supported Long-Term Ecological Research (LTER) network. The NES-LTER project will commence in fall 2017 with funding for an initial 5 years ($5.6M) and with follow up 6-year renewal cycles pending successful outcomes. Notably, the NES-LTER project includes collaboration with NEFSC (contacts Jon Hare, Dave Richardson, Kevin Friedland, Kim Hyde) to expand the suite of observations made routinely on EcoMon surveys including continued IFCB operations and incorporation of gas tracer-based productivity measurements. The goal of the NES-LTER research is to understand and predict how planktonic food webs change through space and time, and how those changes impact the productivity of higher trophic levels. The strategy will combine observations that provide regional-scale context (EcoMon surveys), process cruises along a high gradient cross-shelf transect, high-frequency time series at inner- and outer-shelf locations (MVCO and NSF Ocean Observatories Initiative Pioneer Array), coupled biological-physical food web models, and targeted population models (Fig. 4). The long-term research plan is guided by an overarching science question: *How is climate change impacting the pelagic NES ecosystem and, in particular, affecting the relationship between compositional (e.g., species diversity and size structure) and aggregate (e.g., rates of primary production, and transfer of energy to important forage fish species) variability?*

Education and outreach activities include numerous conference proceedings related to the research described above, community-level and political engagement (e.g., presentations to local volunteers; ecosystem-science focused briefings to visiting dignitaries, etc.), and participation in graduate education (e.g., advisee Emily Brownlee defended her PhD dissertation; guest lecture in SMAST course on quantitative fishery and ecosystem science). In addition, I have participated in a variety of national and international activities promoting strategic investments in marine ecosystem studies (e.g., ICES Working Group on Phytoplankton and Microbial Ecology; ACT-sponsored HAB workshop; OCB Working Group on Phytoplankton Taxonomy and OCB Ocean Time Series committee, etc.) See list below for additional details.

HIGHLIGHTS

- Completed 13th successful Imaging FlowCytobot deployment on NOAA surveys of the Northeast US shelf, continuous underway operation has produced ~10 million plankton images in 143 days at sea (surveys during 2013-2017).
- Led successful proposal to establish the Northeast US Shelf as a new site in the NSF-supported Long-Term Ecological Research (LTER) network; the NES-LTER project includes partnership with NEFSC to continue (and expand) observations on EcoMon surveys and to share data and findings; additional academic partners include UMassD/SMAST, URI, and Wellesley.
- Published 13-year study documenting temperature impacts on picophytoplankton biomass and division rate on the New England Shelf, including trend toward earlier spring blooms (Hunter-Cevera et al. 2016, Science).

- Joined ICES Working Group on Phytoplankton and Microbial Ecology, and continued participation in numerous other strategic planning activities (see outreach list for details).

EDUCATION AND OUTREACH ACTIVITIES

See spreadsheet for presentation details.

- Meeting and discussion with President of the General Assembly of the United Nations (Peter Thomson) on ocean ecosystem status and observing, 6 Apr 2017
- Steering committee lead for OCB Working Group on Phytoplankton Taxonomy, to establish data standards and practices for taxon-resolved phytoplankton observations; http://www.us-ocb.org/phytoplankton-taxonomy-working-group/
- Member OCB Ocean Time-Series Committee; http://www.us-ocb.org/about/ocean-time-series-committee/
- Steering group for 2016 ASM-AGU joint colloquium on microbes and climate change; co-authored resulting report: http://www.asm.org/index.php/colloquium-reports/item/4479-microbes-and-climate-change
- Invited participant in Alliance For Coastal Technologies (ACT) Technical Workshop on "Sensors for monitoring of harmful algae, cyanobacteria and their toxins – Current Status and Integration into Observing Systems"; Moss Landing, CA 30 Jan-1 Feb 2017
- Presented at 2017 Annual Meeting of the Society for Integrative and Comparative Biology, 1 Jan 2017
- Briefed visitors from Canadian Consulate on ocean ecosystem observing strategies, 1 Dec 2016
- Presented at Ocean Optics Conference, 26 Oct 2016
- Lecture entitled "From Phytoplankton to Fisheries Management: Observations and Models" as part of graduate course at University of Massachusetts, Dartmouth (SMAST) "Quantitative Workshops in Fishery and Ecosystem Science", 14 Oct 2016
- Briefed Canadian Minister of Science (Kirsty Duncan) on ocean ecosystem observing strategies, 30 Sep 2016
- Member of NASA Working Group on Satellite Monitoring of Global Marine Biodiversity; attended WG Meeting, Santa Barbara, CA 6-8 Jun 2016
- Presented to NOAA Science Advisory Board Ecosystem Science and Management Working Group (ESMWG) meeting, 11 May 2016
- Presented at NASA Ocean Color Team Meeting, 5 May 2016
- Presented at Ocean Outlook Conference, 8 Apr 2016
- Presented at ICES Working Group on Phytoplankton and Microbial Ecology Annual Meeting, 6 Apr 2016
- Selected News Releases
    - http://www.whoi.edu/news-release/heidi-sosik-science-paper
    - http://www.whoi.edu/news-release/NES-LTER

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. Research Associate Emily Peacock on board the NOAA ship Henry B. Bigelow configuring Imaging FlowCytobot (IFCB) for unattended continuous operation imaging plankton in surface waters during a Northeast US Shelf survey.

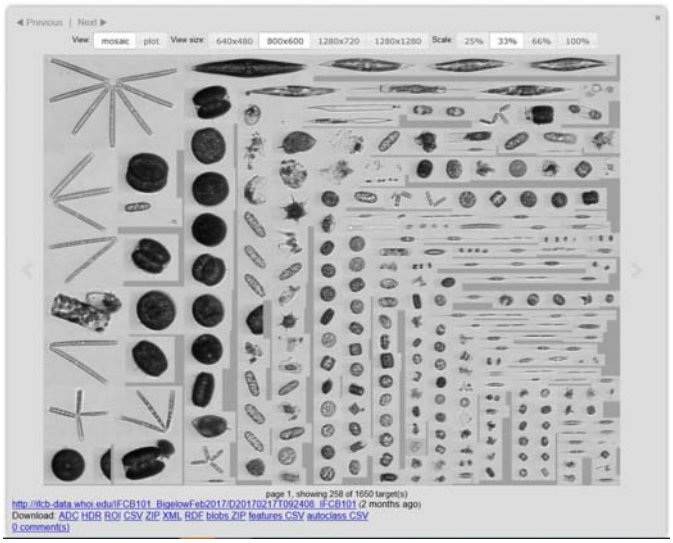


Figure 2. Example results from the IFCB Dashboard, which provides access via web services to all the plankton images (and associated data products) acquired on NOAA surveys across the Northeast US Shelf. See http://ifcb-data.whoi.edu/IFCB101_BigelowFeb2017 for the most recent cruise completed.

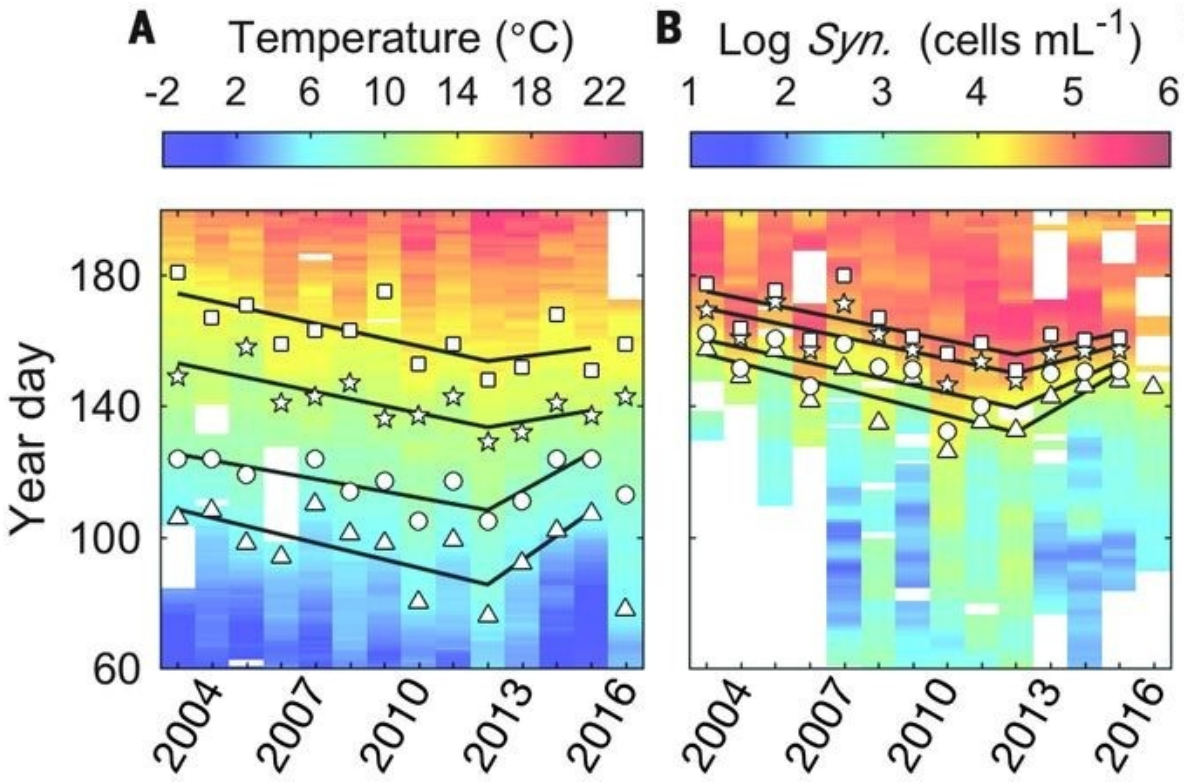


Figure 3. Multiyear trends showing spring temperature changes and the *Synechococcus* bloom shifts from 2003 to 2016 at MVCO. *Synechococcus* dominates the picophytoplankton in this system. The data are shown by day of the year (vertical axis), with values denoted by color. (A) Temperature. Markers indicate the day in each year when water temperature first exceeds 6° (triangles), 9° (circles), 12° (stars), or 15°C (squares). (B) *Synechococcus* cell concentration. Markers indicate the day in each year when cell concentration exceeds 8×10^3 (triangles), 1.6×10^4 (circles), 4.8×10^4 (stars), or 9.6×10^4 (squares) cells ml^{-1}. Parallel lines reflect insensitivity to the choice of threshold and a shift in only the timing, not in the shape, of the spring bloom trajectory. From Hunter-Cevera et al. (2016).

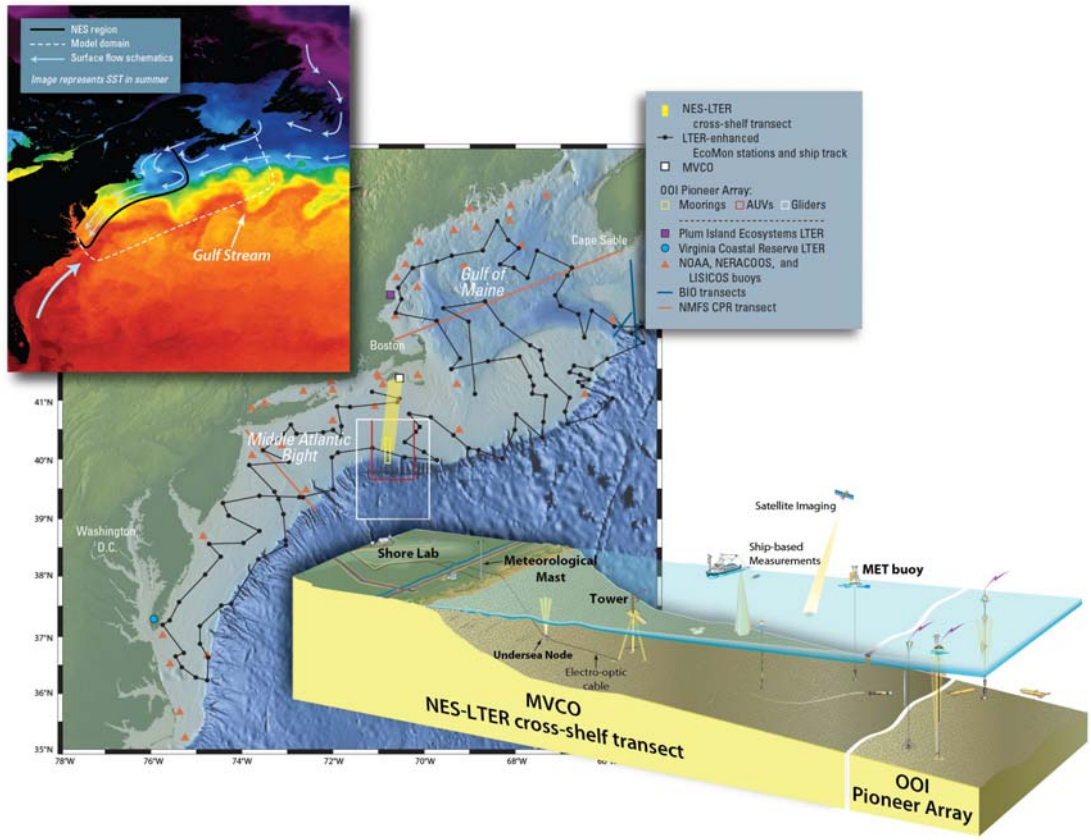


Figure 4. Overview of observational plans for the new NES-LTER program, which will begin in September 2017 with funding from NSF and in partnership with NMFS/NEFSC. The greatest focus of the proposed NES-LTER is on a cross-shelf transect from MVCO to the OOI Pioneer Array (foreground). However, quarterly EcoMon surveys (central map shows example cruise track) and biannual trawl surveys by NOAA colleagues, along with LTER-specific enhancements to these cruises, will provide select information at broad spatial scales and a greater contextual understanding of changes occurring in the NES ecosystem. Additional observations will come from regional observing system components (e.g., NOAA buoys). The proposed multi-scale modeling effort will address the impacts of high latitude processes and basin-scale forcing in this highly advective system by encompassing a domain that extends beyond NES boundaries (top left, with characteristic SST distribution). Slopeward extent of the OOI infrastructure is not depicted in the transect.

SMAST Faculty, Gavin Fay

PROJECT OVERVIEW, GOALS, AND MILESTONES

- Develop capability for graduate student education and training for the next generation of stock assessment scientists, ecosystem scientists, and economists, as part of NOAA Fisheries' Quantitative Ecology and Socioeconomics Training (QUEST) program.
- Fund new hire of full-time faculty position at the University of Massachusetts Dartmouth's School for Marine Science and Technology (SMAST) in line with NOAA QUEST goals.
- Support graduate students with research relevance to the QUEST program.

ACCOMPLISHMENTS

This grant provided Dr. Gavin Fay, tenure-track assistant professor of Fisheries Oceanography at SMAST, with 95% of his salary support during academic year 2016-2017. Graduate student Amanda Hart was partially supported by this grant (stipend and graduate/tuition fees); Amanda began the MS program in Marine Science at SMAST in September 2016. Amanda is applying quantitative modeling tools in her thesis research, which will focus on "Testing ecosystem-based management strategies for Georges Bank". Amanda is collaborating with the New England Fishery Management Council's Ecosystem-Based Fisheries Management Plan Development Team and ecosystem assessment scientists at NOAA Northeast Fisheries Science Center. Amanda will present her preliminary work on applying ecosystem-based management strategy evaluation at the American Fisheries Society Annual Meeting in Tampa in August 2017.

Classroom activities:

Dr. Fay taught the following four classes during the 2016-2017 academic year:
- MAR530 Ecosystem Based Fisheries Management (solo taught 3 unit course)
- MAR536 Biological Statistics II, co-taught with Prof. Cadrin (team-taught 1 unit courses)
- MAR580 Quantitative Workshop in Fishery and Ecosystem Science (solo taught 1 unit course, both fall and spring semesters)
- MAR595 Bayesian Statistics and Hierarchical Modeling for Ecology (solo taught 3 unit course)

MAR 530 and MAR 536 were revised and planned to develop a more integrated curriculum in quantitative fisheries and ecosystem science. MAR 580 was a new course, and comprised a series of in-depth seminars with participation by federal and state agency scientists, aimed at fostering student interactions and collaborations with agency partners. MAR 595 was a new course, offered as independent study to SMAST Ph.D. students. This course was successful and will be integrated into the curriculum as a formal course in future offerings. Brief description of these courses is provided below.

MAR 580-03: Advanced Population Modeling
This course provides instruction, demonstration, and exercises in advanced population modeling, as applied to fishery resources. A wide range of stock assessment methods will be developed through statistical programming to fit increasingly complex models to fishery data through estimation of parameters and their variance. Programming software, including Automatic Differentiation (AD) Model Builder, will be used for class assignments. The course is designed to train students to "have the ability to conduct high-quality scientific research in stock assessment, fishery population dynamics and related fields" (U.S. Dept. Commerce and U.S. Dept. Education 2008 NOAA Tech. Mem. NMFS-F/SPO-91). Although a course with this title had been taught in the past, this was a newly designed course covering a wider range of statistical modeling methods.

MAR 530: Ecosystem-Based Fisheries Management
Discussion and lectures highlighting the theory, challenges, and approaches for implementing Ecosystem-based Fisheries Management (EBFM). The course examines the history and background of fisheries management, leading to why more holistic approaches are being considered. A series of operational methods being used to implement EBFM, emphasizing technical efforts and models, are reviewed. The role of institutional structures and societal considerations in decision-making are explored to identify situations where EBFM can be successful. The course emphasizes current literature and case studies as main learning elements.

MAR 536: Biological Statistics II
Student-led learning in statistical analysis of ecological data. This course provides guided learning in advanced statistical analysis, as applied to ecological research and other fields of marine science. Advanced concepts in probability, hypothesis testing, and estimation will be presented by students, including analyses of example data sets and problems. Students will be required to learn selected methods independently, present topics to the class that are relevant to their graduate research, and complete a class project. A computer lab, focused on introductory and intermediate programming and analysis using R, will be held for the first half of the semester.

MAR 580 Quantitative workshops in Fishery & Ecosystem Science
To continue to improve and develop collaborations and interactions between UMassD researchers and scientists at regional governmental science agencies, in fall 2016 I instigated a seminar series focused on quantitative approaches, primarily in fisheries management. I have run this series for both Fall 2016 and Spring 2017 semesters, and plan it to continue every semester. This course consists of twice-monthly seminars on active quantitative research in pressing topics for management of living marine resources, with regional, national, and international scope. We broadcast the workshops via webinar, with participants and presenters including scientists at NOAA Fisheries Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries (DMF), and Rhode Island Department of Environmental Management, in addition to UMass Dartmouth students and research staff. This series has been successful in engaging students with regional agency scientists on quantitative topics.

MAR 595 Bayesian Statistics and Hierarchical Modeling for Ecology
Today's quantitative ecologists require skills in probability and model building. Application of

Bayesian statistical methods has become an indispensable tool for ecological research. This course introduces students to Bayesian statistics and hierarchical modeling with an emphasis on a mathematical statistics. Students worked through an excellent recent textbook on this topic with additional supplementary reading from the literature. A set of problems in the textbook were worked through using multiple methods, including writing out properly factored statistical expressions representing the Bayesian models, as well as implementation of models using current state-of-the art algorithms and software.

Dr. Fay also co-chaired an International Council for the Exploration of the Sea (ICES) student review group with Prof. Cadrin (May 2017). Students provided peer review of ICES stock assessments to maintain quantitative skills in population modeling and become familiar with operational stock assessment process.

Dr. Fay developed and submitted seven grant proposals, and acted as PI on another for a graduate fellowship. Two of these were funded. Four are currently pending, and two were unsuccessful. Newly funded grants include:

- Miller, T.J., G. Fay, K. Curti. Development and evaluation of a state-space multispecies fisheries assessment model. NOAA Stock Assessment Analytical Methods. $193,303. ($18,603 to UMass Dartmouth)
- Fay, G., R. Wildermuth. Performance evaluation of qualitative and Bayesian network social-ecological models for use in Integrated Ecosystem Assessment. MIT Sea Grant Population and Ecosystem Dynamics Graduate Fellowship. $33,650.

Pending proposals include:

- Georgianna, D., S. Inglis, G. Fay, K. St. Martin, M-Y. Lee. Developing strategies to reduce the effects of gray meat disease on the Atlantic sea scallop fishery. NOAA Saltonstall Kennedy. $248,825.
- Nye, J., G. Fay, S. Gaichas. Projecting the ecosystem-level effects of climate change on the Northeast US Continental shelf: a multimodel approach. NOAA Climate Program Office. $1,485,297.
- Kerr, L., S. Cadrin, G. Fay, S. Gaichas, A. Pershing. Development of robust management strategies for northeast groundfish fisheries in a changing climate. NOAA Climate Program Office. $1,122,745.
- Fay, G. Productivity and Ecology of Sand Habitats. NOAA Office of National Marine Sanctuaries. $210,000.

HIGHLIGHTS

- Five peer-reviewed publications published or in revision, and two technical reports.
- Eleven conference presentations at national, international, and regional meetings by Dr. Fay and his research group.
- Three courses and one seminar taught in topics relevant to NOAA QUEST program priorities.
- Support for proposal development has resulted in two newly funded grants to help Dr. Fay continue to establish his research program at UMass Dartmouth.

- Partial support for one M.S. student at University of Massachusetts Dartmouth.

SOCIETAL BENEFITS

Research supported has direct application to improving the stock assessment and management of commercially important fish species. Dr. Fay serves on the New England Fishery Management Council's Ecosystem-based Fisheries Management Plan Development Team, is a member of the ICES Working Group on Northwest Atlantic Regional Sea, and served on the 2015-2016 NOAA Fisheries Black Sea Bass Stock Assessment Technical Committee. Dr. Fay acted as an external independent reviewer for the New England Fishery Management Council 2017 Atlantic herring Management Strategy Evaluation. 2017, and the 2016 ICES inter-benchmark workshop on NSSK haddock, and was an external reference for the NOAA Northeast Fisheries Science Center Committee on Scientific Standing and Promotion. The project supported graduate education and a faculty position at the University of Massachusetts Dartmouth who is training future NOAA stock and ecosystem assessment scientists.

EDUCATION AND OUTREACH ACTIVITIES

In addition to the aforementioned teaching activities, Fay was either the presenter or major advisor of student presenters for the following conference abstracts:

- Weston, A.E., C.R. McGilliard, and G. Fay. 2017. Identifying robust model selection tools for including environmental links to recruitment in North Pacific groundfish stock assessments. Southern New England Chapter of the American Fisheries Society 50th Anniversary Meeting. Mystic, CT. USA.
- Winton, M.V., G. Fay, H. Haas, M. Arendt, S. Barco, M. James, C. Sasso, R, Smolowitz. 2017. Estimating loggerhead sea turtle densities from satellite telemetry data using geostatistical mixed models. Southern New England Chapter of the American Fisheries Society 50th Anniversary Meeting. Mystic, CT. USA.
- Winton, M.V., G. Fay, H. Haas, M. Arendt, S. Barco, M. James, C. Sasso, R, Smolowitz. 2017. Estimating loggerhead sea turtle densities from satellite telemetry data using geostatistical mixed models. National Protected Species Assessment Workshop: Novel methods for abundance and trends assessment and data poor bycatch estimation for protected species. Seattle, WA. USA.
- Fay, G., S.K. Gaichas, G.S. DePiper, R.J. Gamble, and J.S. Link. 2016. Ecosystem-based fisheries management procedures for the Northeast US: coupling ecological and economic models to quantify societal and ecological tradeoffs. Understanding marine socio-ecological systems: including the human dimension in Integrated Ecosystem Assessments. ICES Symposium. Brest. France.
- Schilpp, L.L., T.J. Miller, and G. Fay. 2016. Size-at-age trends in Northwest Atlantic ground fish and implications for stock assessment. International Marine Conservation Congress. St. Johns. Canada.
- Schilpp, L.L., T.J. Miller, and G. Fay. 2016. Size-at-age trends in Northwest Atlantic ground fish and implications for stock assessment. Regional Association for Research on the Gulf of Maine (RARGOM) Annual Science Meeting. Portsmouth, NH. USA.

- Weston, A.E., C.R. McGilliard and G. Fay*. 2016. Identifying robust model selection tools for including environmental links to recruitment in North Pacific groundfish stock assessments. PICES Annual Science Meeting. San Diego, CA. USA.
- Weston, A.E., G. Fay, and C.R. McGilliard. 2016. Identifying robust approaches for projecting North Pacific groundfish population dynamics using multiple models for linkages between environment and recruitment. ICES Annual Science Conference. Riga. Latvia.
- Wildermuth, R.W., G. Fay, and S.K. Gaichas. 2016. Structural uncertainty and data-limited ecosystem based management of the Georges Bank social-ecological system. International Marine Conservation Congress. St. Johns. Canada.
- Wildermuth, R.W., G. Fay, and S.K. Gaichas. 2016. Structural uncertainty and data-limited ecosystem based management of the Georges Bank social-ecological system. Regional Association for Research on the Gulf of Maine (RARGOM) Annual Science Meeting. Portsmouth, NH. USA.
- Winton, M.V., G. Skomal, J. Chisholm, and G. Fay. 2016. Investigating the seasonal residency and habitat use of white sharks in the coastal waters off Cape Cod, Massachusetts, using passive acoustic telemetry. Regional Association for Research on the Gulf of Maine Annual Science Meeting. Portsmouth, NH. USA.

Dr. Fay also gave the following invited seminars during 2016-2017:

- Fay, G. 2016. Testing management performance of ecosystem indicators using a multi-model approach. Massachusetts Division of Marine Fisheries, New Bedford MA. July 2016.
- Fay, G. 2016. Testing management performance of ecosystem indicators using a multi-model approach. CSIRO. Hobart, Australia. September 2016.
- Fay, G. 2017. Operationalizing Ecosystem Based Fisheries Management in the Northwest Atlantic. Stony Brook University School of Ocean, Marine, & Atmospheric Sciences. March 2017.

PUBLICATIONS

Samhouri, J.F., K.S. Andrews, G. Fay, C.J. Harvey, E.L. Hazen, S.M. Hennessey, K. Holsman, M.E. Hunsicker, S.I. Large, K.N. Marshall, A.C. Stier, J.C. Tam, S.G. Zador. Defining ecosystem thresholds for human activities and environmental pressures in the California Current. Ecosphere. doi: 10.1002/ecs2.1860

Fay, G., J.S. Link, J.A. Hare. 2017. Assessing the effects of ocean acidification in the Northeast US using an end-to-end marine ecosystem model. Ecological Modelling 347: 1-10.

DePiper, G., S. Gaichas, S. Lucey, P.P. da Silva, M.R. Anderson, H. Breeze, A. Bundy, P.M. Clay, G. Fay, R. Gamble, R.S. Gregory, P. Fratantoni, C.L.L. Johnson, M. Koen-Alonso, K. Kleisner, J. Olson, C.T. Perretti, P. Pepin, F. Phelan, V. Saba, L.A. Smith, J. Tam, N. Templeman, R.P. Wildermuth. 2017. Operationalizing Integrated Ecosystem Assessments within a Multidisciplinary Team: Lessons Learned from a Worked Example. ICES Journal of Marine Science. doi: 10.1093/icesjms/fsx038

Gaichas, S.K., M. Fogarty, G. DePiper, G. Fay, R. Gamble, S. Lucey, L. Smith. 2017.

Combining stock, multispecies, and ecosystem level fishery objectives within an operational management procedure: simulations to start the conversation. ICES Journal of Marine Science 74: 552-565.

Technical Reports

Fay, G. and S. Cadrin. 2016. Simulation testing assessment models for black sea bass. SAW62 Black Sea Bass Model Meeting Working Paper, BSB WP A1 Appendix A6. 26p. Stock Assessment of Black Sea Bass for 2016 draft report, NOAA Fisheries Northeast Fisheries Science Center.

Fay, G., J. McNamee, and S. Cadrin. 2016. Stock Synthesis Application to Black Sea Bass. SAW62 Black Sea Bass Model Meeting Working Paper, BSB WP A1 Appendix A9. 59p. Stock Assessment of Black Sea Bass for 2016 draft report, NOAA Fisheries Northeast Fisheries Science Center.

U.S. National Office for Harmful Algal Blooms

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Donald Anderson - WHOI

NOAA Sponsor – Quay Dortch – NOS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Education and Outreach***

Amount Funded: $ 233,100

PROJECT OVERVIEW, GOALS, AND MILESTONES

The U.S. National Office for Harmful Algal Blooms (HAB) serves as a "clearinghouse" for information related to national and international activities on HAB issues. One of its primary roles is to assist in the development of an integrated, national HAB research agenda based on technical evaluations of current research efforts, workshop activities, and ongoing Federal and state agency efforts to prevent, control and mitigate HABs. Further, the National Office serves as a focal point for HAB research and information by organizing and providing for scientific community access to the latest research developments, workshop reports, research strategies, and related data and information. **The primary objective of the Office is to facilitate an open exchange of scientific information and advance the state of knowledge and research efforts.** The National Office coordinates the interests of, and fosters collaboration among, the many stakeholders in HAB research and mitigation: Federal agencies with responsibilities to address HAB issues, the academic research community, and regional and local resource managers. The National Office also facilitates coordination and information exchange between the U.S. and international HAB research and mitigation efforts, and when requested, with the U.S. Congress.

ACCOMPLISHMENTS

Communication and Outreach:

<u>GAO Report on Harmful Algal Blooms</u>: The National Office contributed a considerable amount of written information and figures to the US Government Accountability Office (GAO) for their recently published report entitled "Information on Federal Agencies' Expenditures and Coordination Related to Harmful Algae, GAO-17-119." In response to GAO requests, the National Office provided written detailed descriptions and information about the U.S. HAB Symposium, the National HAB Committee, and the U.S. National Office for HABs, including the many communications and outreach activities and resources provided by the office. In addition, the National Office prepared a generalized summary map depicting occurrences of Harmful Algal Blooms (HAB) and their toxins in the United States (2006-2015) that was used in

the background/introductory materials, and also reviewed and suggested revisions to sections describing HAB syndromes.

National HAB Web Site: The *Harmful Algae* Web Site (www.whoi.edu/redtide) serves as a critical resource for the U.S. HAB community. The site is among the top three WHOI sites visited each month, with between 6,500 to 7,500 visits per month. In addition to maintaining the Web Site, conference announcements, funding opportunities, reports, etc. of interest to the HAB community are routinely posted and circulated through our numerous listservers.

Harmful Algae Facebook Page: In addition to maintaining the *Harmful Algae* Web Site, we maintain the Harmful Algae Facebook Page: (https://www.facebook.com/pages/Harmful-Algae/210160985681846). This site is updated on a near daily basis with news reports and other announcements related to HAB events and research. This is a very popular method for disseminating information to the HAB community, the general public, and Congressional staff. It is viewed up to 12,000 times every month, and at times, more than 5000 people per day see content associated with the site according to Facebook statistics from April 2016 to March 2017.

Information requests: The National Office deals with many direct requests for information that are elicited by the site. These include frequent requests for photographs or other media products, referrals to experts in particular regions or disciplines, inquiries from students doing reports, and journalist inquiries. Another important type of interaction is with victims of HAB poisonings who are seeking help in the form of information and referrals to appropriate physicians. In many of these cases, direct personal interactions are needed, requiring considerable time commitments, but also providing a necessary and valuable service to the public.

International Council for the Exploration of the Seas (ICES) Working Group on HAB Dynamics:

Each year we collect information on HAB events in the U.S. as the ICES *National Coordinating Center for Exchange of Information on Harmful Algal Blooms.* This involves interacting with colleagues around the U.S. to compile reports of all national HAB events each year. We are responsible for the entry of these data into the Harmful Algal Event Database (HAEDAT) maintained by the ICES Science and Communications Center in Vigo, Spain. Presentations on these bloom reports are also given at annual working group meetings of the ICES Working Group on Harmful Algal Bloom Dynamics (WGHABD). National and international bloom reports are provided to all U.S. network participants, as well as to other interested parties. This is the only compilation of U.S. HAB incidents. Decadal maps for all U.S. HAB events are usually updated annually for ICES as well as posting on the Harmful Algae Web site (see http://www.whoi.edu/redtide/page.do?pid=14898&tid=542&cid=47893&c=3 for an example). In addition, PI Anderson presented a summary of U.S. events for 2016 at the 2017 WGHABD meeting held in Helsinki, Finland.

The Intergovernmental Panel on Harmful Algal Blooms (IPHAB)

PI Anderson that attended the 13th Intergovernmental Panel on Harmful Algal Blooms (IPHAB) at the headquarters of the Intergovernmental Oceanographic Commission (IOC) in Paris. Serving

as a scientific advisor in support of NOAA participation (A. Lewitus, NCCOS), Dr. Anderson participated in discussions of many IPHAB activities and also presented a report from the Task Team on Harmful Algal Blooms and Desalination which he chairs. A major activity of that task team that required considerable time during the last year was the preparation of chapters and editing of *Harmful algal blooms (HABs) and Desalination: A guide to impacts, monitoring, and management*). The book contains 11 chapters, 5 appendices, and about 550 pages of text. All chapters but two have been copy edited and finalized for publication, and those should be completed within the next two months. Other tasks include indexing and final layout. The IOC will publish the Manual, and distribute it through the *IOC Manuals and Guides* series. Publication is expected before the end of 2017. PI Anderson was asked to remain as chair of the Task team and to begin exploring options for the second international conference on HAB's and desalination.

Event Response Program

The National Office administers a Rapid Response Program for HAB Events in the U.S. in cooperation with CSCOR administrators. This involves advertising the availability of funds to the HAB community as well as accepting requests for funds and administering their dispersal. The National Office works with NOAA Program Managers who decide who receives funds and how much will be needed in each case. Additionally, we make arrangements and process travel, vessel charters, analyses, and other expenses associated with these rapid response activities. This was a very active year for major HAB events, and event response projects were funded across the country, and are summarized below.

2016 *Pseudo-nitzschia* bloom. During the past year this office was involved in the event response to a significant *Pseudo-nitzschia* bloom in the Gulf of Maine region. In late September, high cell densities and domoic acid (DA) toxicity levels above quarantine (up to 200 ppm) were detected in eastern Maine, and the bloom extended from Canada down to Penobscot Bay. Concurrently, a *Pseudo-nitzschia* bloom was present in coastal waters of southern MA and RI. Event response funding from NOAA was allocated to WHOI as well as Bigelow to carry out sample collection, and to cover the costs of toxin testing (HPLC) by Bigelow. To improve networking and communications among the resource managers in the region seeking to understand and respond to the bloom, the National Office facilitated discussions and coordination through group email correspondence and a series of conference calls that were coordinated and led by PI Anderson. Call participants exchanged information about monitoring results and closures, discussed and interpreted data collected by researchers and state managers, and coordinated event response activities. This event was also notable for the interest generated from the press, and highlighted the fact that as this is still an emerging issue in the region, state programs don't regularly test shellfish for DA. Why this occurred in 2016 and not during other years is unknown. Prior to the outbreak there were prevailing easterly and northeasterly winds, which may have been a contributing factor, bringing offshore populations to shore. These conference calls were re-initiated for a short period in March 2017 due to reports of high *Pseudo-nitzschia* cell densities in southern New England (MA and RI). Based on positive feedback from the participating managers and scientists, we are considering formalizing this ad hoc regional communication and information sharing through the establishment of a Northeast HAB Network. This will provide a dedicated forum for correspondence through the establishment of

communications and data exchange, as well as a framework for coordinating monitoring activities.

During the past year the National Office also worked with scientists and managers on the following unexpected or unique HAB events and/or targeted projects: an *Aureoumbra* "brown tide" HAB event in the Indian River Lagoon, FL, which caused one of the largest fish kills ever recorded in the Lagoon; mitigation of a microcystin-impacted freshwater pond on Padre Island, TX that provides important habitat for migratory birds; an examination of strategies for minimizing mortality of oysters during blooms of *C. polykrikoides* and *A. monilatum* in the York River, VA; monitoring and analysis during toxin-producing cyanobacteria blooms (*Microcystis*) in the St. Lucie Estuary, FL. At the time of this writing, event response funds were approved to assess impacts of DA to marine birds and benthic organisms in southern CA, and to determine DA concentrations in offshore waters.

It is impossible to predict what the next year will bring in terms of HAB events, but the Office will be ready to assist NOAA CSCOR with administering the Rapid Response Program.

Scientific Meetings

The National Office often assists with the formulation of scientific agendas, arranging for financial and administrative support, and providing expert representation for national and international HAB workshops, symposia, and conferences. The National Office also assists in selection and disbursement of funds for student travel to national and international conferences, workshops, and training courses. During the project year, meetings we were involved with include the *17th International Conference on Harmful Algae* (Brazil) and planning for the upcoming *9th Symposium on Harmful Algae in the U.S.* (Maryland).

U.S. HAB symposia. Richlen currently serves on the Steering Committees for the *9th Symposium on Harmful Algae in the U.S.,* to be held November, 2017 in Baltimore, MD. She is working closely with the organizers to communicate updates and announcements to the U.S. HAB community, and will also solicit and process travel awards for students and managers for the symposium.

International HAB Conferences. Anderson served on the Steering Committee for the *18th International Conference on Harmful Algae,* which was held in Florianópolis, Brazil in October 2016. The National Office handled travel reimbursements for students receiving support to attend the meeting.

National HAB Committee (NHC)

The National HAB Committee was formed in 2005, and is charged with overseeing coordination and implementation of the revised U.S. National Plan. The National Office provides support to the NHC. Each year we request nominations for the election of new members from the community and handle the subsequent election and notifications, and as appropriate, nominations and voting for Committee Chair(s). We initiated and continue to maintain and update the NHC Web Site and listserver, which facilitates communication by this group. Richlen provides administrative support to this group, and both she and Anderson serve as *ex officio* members. Richlen also serves on the Travel Awards subcommittee. The National Office

arranges and leads conference calls for the group as well as in-person meetings.

HIGHLIGHTS

- Preparation of written materials and figures for GAO report on Federal activities related to HABs.
- Coordination among state and regional managers during the 2016-2017 *Pseudo-nitzschia* bloom in New England waters.
- Preparation and presentation of data on bloom reports in the U.S. in 2016 for the ICES Working Group on Harmful Algal Bloom Dynamics.
- Participation in the 13th International Panel on Harmful Algal Blooms and coordination and editing of *Harmful algal blooms (HABs) and Desalination: A guide to impacts, monitoring, and management*.
- Participating on the steering committee for the *9th Symposium on Harmful Algae in the U.S.* (Baltimore, MD); soliciting and processing travel award applications for students and managers.
- Soliciting and selecting travel awards for students and managers for the *17th International Conference on Harmful Algae* (Brazil).

SOCIETAL BENEFITS

All of the activity under this project relates to HABs, a serious and growing threat to the nation's fisheries, coastal ecosystems, and human coastal communities.

EDUCATION AND OUTREACH ACTIVITIES

- Anderson, D.M., U.S. Summary of HAB Events – 2016, ICES WGHABD, Helsinki, Finland, April, 2017
- Anderson, D.M., IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB-XIII), Paris, France, 2017)
- Harmful Algae website: http://www.whoi.edu/redtide
- Harmful Algae Facebook webpage: https://www.facebook.com/Harmful-Algae-210160985681846/
- National HAB Committee Web Site: www.whoi.edu/nationalhab/
- Northeast PSP website: http://www.whoi.edu/northeastpsp/

In addition to the aforementioned activities, PI Anderson is frequently contacted by journalists about HAB issues (estimated 5 or 6 over the past year alone). Anderson also often receives requests for guidance and referrals from congressional staff.

2016 AUV Sentry Nizinski Cruise

2016 ROV Jason R/V Sikuliaq Cruise

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Andrew Bowen, WHOI

NOAA Sponsor – Martha Nizinski (NMFS) and Thomas Peltzer (OAR)

Related NOAA Strategic Plan Goal: ***Healthy Oceans / Climate Adaptation and Migration***

CINAR Theme: ***Education and Outreach / Ecosystem Management***

Amount Funded: $ 300,933

PROJECT OVERVIEW, GOALS, AND MILESTONES

2016 AUV Sentry Nizinski Cruise: Provide Sentry AUV for 15 days (8/22/16-9/05/16) in support of Dr. Martha Nizinski's investigation of deep-sea coral habitats in canyons and slope areas off of Virginia, North Carolina, and South Carolina on NOAA R/V *Pisces*.

2016 ROV Jason R/V Sikuliaq Cruise: Provide Jason AUV for one day to recover samples during Brian Ittig and David Butterfield's cruise (7/08/16-8/15/16) on R/V Sikuliaq.

ACCOMPLISHMENTS

Vehicle operations were successful on both cruises.

SOCIETAL BENEFITS

The impact on society derived from these oceanographic expeditions can be extensive, and includes technological advances to be achieved in sensing and imaging the deep ocean and seafloor, knowledge to be gained from historical climate records stored in the deep sea, and the effect of an open house tour of the manned and unmanned submersibles on a group of high school students. The general public, and the U.S. and international scientific communities all benefit from the work done with the vehicles operated by the National Deep Submergence Facility (NDSF).

EDUCATION AND OUTREACH ACTIVITIES

Over the past several years an increased awareness of our collective responsibility to bring this science into the public forum has resulted in new avenues for sharing these scientific findings.

Previous expeditions and engineering trials utilizing NDSF assets include the University of Washington's REVEL program, the *Jason* Project, and the NOAA Vents Program. Our vehicle operations and associated science programs have reached the public through a variety of television and internet outlets, including programs on National Geographic Explorer, National Geographic Channel, Discovery Channel, PBS, the History Channel, the National Geographic Society and NOAA's Ocean Explorer web sites. The cruise website concept has been effective in reaching the classroom with near real-time images and two-way communications between the scientists and students in schools across the country. Several cruises in 2017 are planning to use this tool. Past examples of websites of this nature are:
http://science.whoi.edu/DiveDiscover/
http://www.ridge2000.org/SEAS/

Several 2017 cruises will involve collaborative efforts involving the international community. The joining of scientific minds without regard for ethnicity or political background strengthens these expeditions and brings the world closer together.

Marine Resources Education Program (MREP): Northeast Region, Fostering Trust and Shared Information in Fisheries Science and Management

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Alexa Dayton, GMRI

NOAA Sponsor – John Hoey, NEFSC

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme*: Education and Outreach*

Amount Funded: $ 203,479

PROJECT OVERVIEW, GOALS, AND MILESTONES

For the period May 1, 2015 to April 30, 2016 the MREP Implementation Team proposed to carry out four initiatives:

- Deliver one MREP Science 100 module and one MREP Management 100 module in a Mid-Atlantic location;
- Deliver a MREP workshop, covering both science and management, tailored to the needs of recreational fishermen;
- Deliver a MREP 200 module, focused on the trawl survey and fisheries data collection methods, to be offered to MREP graduates; and
- Perform active outreach in building a fishing community network to support MREP training and recruiting throughout the Northeast and Mid-Atlantic regions, and seek opportunities to expand the program training reach to more fishermen at less cost.

We further proposed that program delivery will be evaluated along established protocols, with continuing development of instruments to track program relevance. Testimonials and other feedback have been captured both in writing and with photography.

ACCOMPLISHMENTS

We delivered the following workshops as outlined in our proposed scope of work:

- February 23-25, 2016 – MREP for Recreational Anglers in Norfolk, VA (three days).
- October 29-31, 2016 – MREP Ecosystems 200 at the NOAA/NEFSC Howard Lab at Sandy Hook, NJ and in Long Branch, NJ (two days).
- January 3-5, 2017 – MREP Science 100 in Atlantic City, NJ (three days).
- January 17-19, 2017 – MREP Management 100 in Atlantic City, NJ (three days).

Atlantic City, NJ was chosen as the venue for the MREP Science and Management 100 modules in an effort to engage Mid-Atlantic fishermen while remaining accessible to those fishermen in New England. A general 3000-piece mailing went out to commercial and highly-migratory permit holders in the New England and Mid-Atlantic regions, followed by direct one-on-one

recruiting through key partners in the regions (Jeff Kaelin, Peter Hughes). The result was an average of 28 attendees at each module, from ports as far north as ME, but predominantly from NJ, VA, and MD. The standard MREP 100 curricula were adapted to the information needs these communities; the Science 100 added presentations examining linkages between estuarine/bay environments and the productivity of open-ocean fish stocks; the Management 100 included added information on the role of ASMFC, a presentation given by NOAA Office of Law Enforcement, and a presentation from the USCG.

The MREP 200 module was a two-day workshop that provided an in-depth look at the trawl survey methodology and the collection and processing of data used in stock assessments. The workshop included a visit to the NMFS gear loft to explore the trawl nets and scallop dredges used in survey work, a trip aboard the Henry Bigelow research vessel with a tour of the onboard labs and sample handling stations, a visit to the Woods Hole Age and Growth lab, a discussion with port agents on data reporting, and time spent at the northeast Observer facility. The program concluded with an in-depth discussion about how the various pieces all contribute to stock assessments. This workshop was especially well-timed given the current exploration for transitioning to an industry-based trawl survey, and provided an excellent venue for opening the dialogue between fishermen and scientists.

MREP for Recreational Anglers was a second-year venture for MREP in the Northeast, first added because of strong demand by that community and repeated because of the overwhelmingly positive feedback received from the inaugural workshop. We purposely structured it to provide a foundation for further outreach to the recreational community in the Greater Atlantic Region. A small group of recreational industry leaders were enlisted as advisors to offer continued feedback and on the workshop agenda and content, and to provide direct access to recruiting within the recreational community. The industry advisors adapted the combined science and management curricula to a shortened format, with added emphasis on the MRIP data-reporting system and alternatives to support and augment recreational data in stock assessments. Most of the participants were recruited through word-of-mouth by these advisors and through consultation; priority was placed on engaging members of the recreational fishing community who are prominent, vocal, and positioned to inform other recreational anglers. The result was an attendee list heavily weighted with fishing association leaders from CT, RI, DE, and MD, with additional attendees coming from as far north as ME and as far south as VA. Notable attendees included two NOAA Silver Spring staff with MRIP expertise (Tim Sartwell, Dave Bard), Deputy Director of the Marine Fish Conservation Network (Tom Sadler), President of the Coastal Conservation Association New Hampshire Chapter (Don Swanson), and numerous advisory panel members with both the NEFMC and MAFMC.

One challenge that came with the Recreational workshop was a blizzard that hit New England on the first day of the workshop. The poor timing resulted in a number of participants arriving late and caused two of our presenters, Gary Shepard and Brian Linton, to be unavailable in person. As a last-minute solution, we had both presenters present to the group via webinar and had the moderator take and relay questions from the audience. Both Gary and Brian listened in on the workshop for the entire day and jumped in multiple times to answer questions not asked directly of them. While not ideal, the system worked remarkably well and a number of attendees commented about how impressed they were that Gary and Brian could be so engaged while

participating remotely.

Notable quotes from the evaluations included:

- “This workshop allowed me to see the law enforcement in a different view and appreciate the work that everyone does in the fishing management roles.”
- “I think this was helpful to understand why regulations and changes and decisions take so long to come to fruition/take effect (months or years for simple changes). It's great to see how and when the best way to get involved is, and that it's not just a "black box".”
- “I realized how difficult these decisions are and that everyone is doing their best. I also learned the importance of public input.”
- “I had a lack of clarity about the entire process from beginning to end. Even though I came into different parts from time to time, I understand the whole process better.”

HIGHLIGHTS

- Underserved communities in NJ, VA, and MD were the focus of MREP Science and Management 100, with a high percentage of “peer leaders” in attendance.
- MREP for Recreational Anglers continues to successfully engage a large, diverse, and poorly-informed community, laying foundations for future outreach.
- Better understanding of MRIP as a recreational data-collection system that can be adapted and improved by concerted partnership between recreational fishing sectors and NMFS.
- Strong participation by top NMFS scientists and administrators helped fishermen realize the level of dedication the agency has to working with the industry. Multiple evaluations noted how impressed the fishermen were that people like Russ Brown took the time to attend.

SOCIETAL BENEFITS

This education enables fishermen and others to participate productively in the fisheries science and management processes, and leads to improved cooperation and trust between fishermen, and scientists and managers. Fundamentally, a co-learning approach is used in this program, where program participants and program presenters learn from one another through their interactions and collaborations. The program results in well-informed leaders, equipped with the tools and knowledge to act responsibly and effectively on behalf of the fishing communities they represent.

EDUCATION AND OUTREACH ACTIVITIES

With input from the MREP Implementation Team, a MREP outreach mailer was designed and mailed out to approximately 3000 New England and Mid-Atlantic commercial and HMS permit holders. Additionally, an electronic version was emailed out to all past MREP graduates for distribution within their networks. The MREP calendar and links to the MREP website were also made available from the NEFMC and MAFMC as well as the ASMFC.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. MREP 100 attendees work together on a conceptual model of factors influencing fluke abundance. Pictures here are (clockwise from front) Brady Lyebarger (NJ), Lisa Poyer (NY), and Cynthia Hanson (NOAA GARFO).

Figure 2. MREP 100 attendees watch as Gary Shepard (NOAA NEFSC) dissects and collects otoliths from a black seabass.

Figure 3. MREP Recreational Workshop attendees and NOAA staff enjoying some informal discussion time during a meal. Pictured here are (left to right) Sergio Radossi (NJ), Don Swanson (NH), Rick Bellevance (RI), Jesse Roche (CT), Tom Sadler (VA), and Earl Meredith (NOAA NEFSC).

Figure 4. MREP Rec workshop attendees engage the Rhode Island Division of Fish and Wildlife in a discussion on the biological drivers of fish abundance.

Figure 5. Attendees Curtis Tomlin (VA) and Christian Parisi (CT) chat alongside MREP facilitator Moira Kelly (NOAA GARFO) during a lunchtime networking session.

Marine Resource Education Program: Southeast Fisheries Region

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Alexa Dayton, GMRI

NOAA Sponsor – Kim Amendola, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme*: Education and Outreach*

Amount Funded: $ 215,874

PROJECT OVERVIEW, GOALS, AND MILESTONES

The Gulf of Maine Research Institute (GMRI) proposed to continue the collaboration with partners in the Southeast fisheries region to refine and implement another set of Marine Resource Education Program (MREP) Southeast workshops, including one 3-day fishery science workshop and one 3-day fishery management workshop for commercial and recreational fishermen, tailored to the region by an 18-member Steering Committee.

GMRI proposed to recruit 20 program participants for the Management workshop during the reporting period, and also recruit an additional 20 participants for a Science workshop, with class compositions that reflect a high degree of diversity. The format of the workshop creates an open dialogue among participants and presenters in which they explore ways of fostering cooperation among fishermen, scientists and managers.

GMRI further proposed to reconvene the regional Steering Committee for a fifth annual meeting, engage them in a program review and evaluation of the third year, and foster industry leadership.

ACCOMPLISHMENTS

The MREP Southeast Science Workshop was held April 19 - 21, 2016 in St. Petersburg, Florida. The 3-day workshop was held at the FWC Fish & Wildlife Research Institute (FWRI) facility. Participants in the workshop included fishermen, industry representatives, and a few others, such as council members, drawn from the South Atlantic and Gulf of Mexico council regions. The Fisheries Science course was exceptionally well received, and ran according to plan. We had 28 attendees plus 20 presenters and other planning team members attend the presentations, small group break out sessions, research lab tours and meals together, thus creating an unparalleled networking and open dialog opportunity between fishermen, scientists and managers in the region. We observed trust building, increased cooperation, and myths were dispelled.

The second of the two-part workshop series–the MREP Management Workshop–was held in Tampa, Florida October 4 – 6, 2016, and included participants from the South Atlantic, Gulf of Mexico, and the Caribbean. A total of 30 participants attended the workshop, representing commercial, recreational, and charter fishermen as well as fish house owners/dealers. Additionally, three fishermen from the US Virgin Islands attended the Management workshop with the intent of evaluating the program for application in their region. Most of our attendees had also taken the Science workshop, but due to scheduling conflicts, not all of them took part in Management. New attendees were added from the waiting list.

For the first time, MREP was confronted with a potential tropical storm, with Hurricane Matthew projected to impact the east coast of Florida on October 6. During the first two days a handful of east coast attendees decided to leave the workshop early to secure their homes and vessels, but the vast majority of the participants remained through the entire program. In the end, we cut the program slightly short to allow for safe travel home in an increasingly dire situation, but still managed to get through 90% of the presentation material and provided the final 10% to them as follow-up and take home learning. The workshop was overwhelmingly successful and the decision by most attendees to stay demonstrated both their commitment to the program and the immense value they see in attending.

In total, over 80 people attended the plenary presentations, small group break out sessions, and enjoyed meals and networking time together - creating an unparalleled open dialog opportunity between fishermen, scientists and managers in the region. Throughout both the Fishery Science and Fishery management workshops we observed shifts in attitudes, trust building, increased cooperation, and myths were dispelled.

As a final part of our program implementation for the second year of our proposal, we hosted a 5th annual Steering Committee Meeting, which comprised a 2-day meeting for 18 persons, where we evaluated the program and its outcomes thus far. The Steering Committee did a 5 year review of the program, evaluating program progress against the objectives laid out at the onset of Year 1 and deciding on a new set of objectives for the next few years. We also discussed the opportunities and challenges that have come up in the past five years and those foreseen in the future. This meeting re-affirmed the importance of the program in the region and within the fishing community for its neutral and unbiased forum and its ability to develop industry leaders and foster evidence-based thinking in the region. We shared stories and reviewed individual achievements of prior participants, which captured the long-term outcomes observed as program participants have gone forward to engage in fisheries management. We also focused on ways to expand the impact of MREP without losing the highly personal and immersive nature of the program, and ways in which we can continue to support MREP graduates beyond the workshops through mentoring and support materials.

One notable anecdote from this year was the involvement of Sam Young. Sam is a member of the Marco Sportfishing Club who arrived at the first meeting with many preconceptions typical of uninvolved fishermen and was somewhat vocal in relaying his opinions. Throughout the science workshop Sam made a perceptible shift from expressing biased opinions to asking pointed, probing questions and his attitude about fisheries management was clearly evolving.

Following his attendance at MREP, Sam was hired as Director of Fisheries Management for the Marco Sportfishing Club where he engages the club's more than 600 members in local and regional fisheries issues, working closely with NOAA and FWC to advocate for his club's interests and to recruit more members into participating in fisheries management. Below is a quote taken from an email received from Sam regarding his experience at MREP:

"The MREP program provided me a solid baseline to constructively move forward in joining the dialogue with NOAA and FWC on fishery issues. Every meeting I've been able to attend in person has always turned out to be a great learning experience, and has often caused me to bend or reverse course on the positions I held before attending, which ultimately makes for a more effective response to public input."

Another attendee, Angelo DePaolo, a recreational angler from Orange Beach, AL, arrived to the first workshop with a perspective that recreational anglers interests are not well served by current federal fisheries management and that shifting to State management of certain fisheries would lead to better results for his constituent group. After the first workshop, he expressed concern that he had been misinformed up until this time, but that with his newfound knowledge, felt he would be much more active and vocal in helping to dispel myths among his fellow fishermen. His has asked if his wife, the president of the local Coastal Conservation Association (CCA) chapter, could attend the MREP workshops in 2017. He also organized a meeting of the Mobile Alabama Big Game Fishing Club, and invited Roy Crabtree, Clay Porch, and Andy Strelcheck to meet with his constituents. Our NOAA partners were very pleased by this development and credit the MREP program for penetrating this hard to reach audience, and opening doors for improved cooperation.

HIGHLIGHTS

- Fisheries science education program delivered for 28 fishermen and an additional 20 speakers and other guests, in St Petersburg, FL April, 2016.
- Fisheries management education program delivered for 30 fishermen and an additional 20 speakers and other guests, in Tampa, FL October, 2016.
- Reconvened MREP Southeast Steering Committee in November 2016, and with two new members.
- Fisheries science education program refined based on prior year evaluations.
- Fisheries management education program refined based on prior year evaluations.
- Performed extensive outreach and networking to generate a fifth year of program applicants.

SOCIETAL BENEFITS

This education enables fishermen and others to participate productively in the fisheries science and management processes, and leads to improved cooperation and trust among fishermen, scientist,s and managers. Fundamentally, a co-learning approach is used in this program, where program developers, program participants and program presenters all learn from one another through their interactions and collaborations.

We fostered industry leadership through the Steering Committee construct, and workshop

moderator opportunities, and saw new individuals become engaged in fisheries discussions, delivering increased leadership capacity for the region.

MREP Southeast has prepared industry members for meaningful engagement in the Council process, as articulated and envisioned by Magnusson Stevens Act.

EDUCATION AND OUTREACH ACTIVITIES

We performed a multi-faceted outreach campaign to generate workshop program applicants. We did this in part by creating a postcard mailer, which was circulated to a large randomly selected subset of 5,000 fishing permit holders in the Southeast region. We also mailed a small stack of 20 postcards and a few posters to each of our 18 Steering Committee members, encouraged them to hand these out and generate program referrals, and hang posters in their local ports, as well as submit opinion columns to their local fisheries newspapers, and post on discussion boards, and electronic forums. This yielded 56 applicants for a total of 32 program slots.

We then convened our industry planning team to review the applications and selected a group of 32 program participants to accept into the workshop, representing a balanced cross section of interest groups, with at least two thirds being a mix of recreational and commercial fishermen. We placed the other people on the waiting list for next year. We also included one council member from each of the three council regions, and these individuals were nominated by the Councils. In addition, we included three fishermen from the US Virgin Islands in the Management workshop.

We recruited program presenters, many returning from prior years and some new presenters. They were coached by our industry planning team in ways to effectively communicate complex scientific concepts to a stakeholder/non-scientific audience, specifically the fishing industry. Program presenters were drawn from NOAA Fisheries Southeast Fisheries Science Center, University of South Florida, Gulf of Mexico and South Atlantic Fishery Management Councils, Florida Fish & Wildlife Research Institute, the NOAA Fisheries Southeast Regional Office. We have evaluated the workshop program delivery with post-program evaluations. The full Steering Committee was provided with periodic updates on curriculum development progress, which was written and sent by GMRI staff. They were invited to work in sub-committees and the planning team as a way to directly shape the program content.

A unique website page was developed for this effort. We used photos provided by Steering Committee members, and NOAA staff to ensure the proper look and feel for the Southeast region.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. MREP Science attendee Ken Cottle (FL) gets his hands dirty extracting an otolith from a red drum.

Figure 2. FWRI staff helps Pat Bennett (FL) mount an otolith for aging.

Figure 3. John Carmichael (center, SAFMC) assists MREP Science attendees with a population modeling exercise. Pictured here are (sitting, l to r) Lee Southard (GA), Samuel Todd (GA), Greg Mercurio (FL), Ken Cottle (FL), (standing, l to r) Susan Macken (FL), Bob Dooley (CA), John Carmichael (SAFMC), and Amber Von Harten (SAFMC).

Figure 4. Participants are treated as professionals and the room is arranged in a board room setting. This allows for a series of presentations, coupled with ample Q&A throughout. Each session is moderated by a fisherman who is able to interpret and bridge gaps in understanding.

Figure 5. Fisherman and SAFMC member, Ben Hartig, offers personal tips on how to engage with the council, how to provide compelling and actionable public comment, and highlights when fishermen should get involved in the process for optimal results. Ben attributes his career in the council to his early participation in the MREP program in New England over 10 years ago and offers mentoring to newcomers.

Figure 6. Regional Administrator, Roy Crabtree, listens closely to recreational angler from the South Atlantic, Charlie Schoonmaker, as he describes the data gathering and data reporting challenges associated with the charter-for-hire sector. Charlie became aware of the need for better data as a result of his MREP experience, and indicated a willingness to speak with his fellow anglers and encourage improved reporting of landings.

Enhancing Industry Input in Stock Assessments

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Mary Hudson, GMRI

NOAA Sponsor – Mike Simpkins, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Education and Outreach***

Amount Funded: $ 40,945

PROJECT OVERVIEW, GOALS, AND MILESTONES

The objective of this project is to enhance industry participation, and the use of industry input, in the stock assessment process. This will be accomplished through an extensive outreach process with Science Center staff and industry, which will inform the development of a new process for integrating industry input into stock assessments. After compiling the necessary information GMRI will compile recommendations for how to better incorporate industry input, and what a new process might entail. We have divided this project into three steps:

<u>Step 1: Information gathering and synthesis</u>
Outcome/Deliverable: Synthesis document, data flow map, process/timeline map
Includes: 1:1 conversation with Science Center staff and industry to understand where more industry input in the assessment process would be useful, feasible, and wanted, as well as how to best reach out to industry during the process.

<u>Step 2: Working meetings</u>
Outcome/Deliverable: Finalized synopsis document
Includes: A series of small closed meetings with Center staff and industry to dig further into ideas/recommendations that came out of Step 1.

<u>Step 3: Recommendation development</u>
Outcome/Deliverable: Modified industry-engagement process design
There have been no changes to project objectives or methods; however, due to staffing changes and project lead health issues, we are a few months behind our timeline.

ACCOMPLISHMENTS

We are currently wrapping up Step 1 of our process. Interviews with Science Center staff and industry members have proven insightful, and we are working towards developing a variety of

recommendations and ways forward to delve further into with Center staff and industry. Thus far, we have had conversations with seven Center scientists and 20 industry members around New England. We are looking to continue our conversations with industry in New England, as well as expand to industry in the Mid-Atlantic in the next month.

We've heard a handful of common themes from both Center staff and industry on what improved industry involvement and input would ideally look like. There is consensus that input needs to come earlier, meetings should be small and oriented around specific questions, one-on-one interactions enhance relations and process outputs, and that research questions should be developed cooperatively. There is also a general consensus among industry interviewed thus far that altering outreach approaches will do little to reduce the controversies currently facing stock assessments. Instead, there has been much emphasis on the need for a shift in how fishermen knowledge and experience, and science and data from outside of the Center, is received.

Below are a few examples of the recommendations developing from our conversations.

1) *Industry data meetings*: Providing industry an opportunity for more directed input on data earlier in the process is important. Equally important is for stock assessment scientists to better understand the fishing behavior behind fisheries dependent data, a more difficult task since the shift to sector management. For a number of reasons, the working group data meetings are not the correct setting for these conversations to be had. Industry data meetings should be:
   - Before the working group data meetings
   - Structured around specific questions that there may be concerning data
   - Small groups, rather than the widespread outreach calls/meetings

2) *Industry "expert guide"*: We have heard from both Center staff and industry a strong desire for more casual, one-on-one interactions. Center staff expressed that it'd be helpful to be able to more easily contact industry when questions arise rather than waiting to get input from outreach meetings. Likewise, industry has expressed both desire and willingness to offer their insight when prompted outside of meeting settings. This idea would put together a framework to allow these interactions to happen more easily. The guide would identify fishermen by region, gear type, and targeted fisheries for assessment scientists to contact. Importantly, only fishermen that agree to involvement would be place in the guide.

3) *Collaborative research design*: There is concern that the research priorities that come out of each assessment process do not often get addressed, as well as a frustration among industry that their own questions and ideas do not have easier paths to becoming research. Furthermore, it can be difficult for research and data from outside of the Center to make its way into the process, often due to project methodology. While the Center is dedicated to collaborative research, particularly in using industry vessels as research platforms, it is important to further the industry-science partnership by involving industry more in the entire research project, from start to end.

This idea proposes that there be a structured mechanism to enable this growing collaboration. This could take the form of an annual or biennial workshop that brings together industry and

scientists (from within and outside the Center) to develop a variety of projects around specific priorities, and offers leads on opportunities to fund such projects.

HIGHLIGHTS

- Many Center scientists are enthusiastic about working more closely with industry, and would like to find ways to better incorporate their input
- Industry is dedicated to collecting verifiable data and enthusiastic about participating in the entire research process
- Both scientists and industry have expressed a desire for more collaborative data collection and research as we look towards the future

SOCIETAL BENEFITS

By working towards increasing industry participation and input into the stock assessment process, this project aims to help bridge the gap between industry and science and, in turn, improve relations in the region.

Advancing the 6th International Deep-Sea Coral Symposium Supplement

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Timothy Shank, WHOI

NOAA Sponsor – Jeremy Potter, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Education and Outreach***

Amount Funded: $ 10,360

PROJECT OVERVIEW, GOALS, AND MILESTONES

Understanding the role, function and value of deep-sea coral ecosystems has become a priority topic for many national governments and international regional resource management bodies. Continuing in the tradition of past Symposia in Halifax, Canada, Erlangen, Germany, the 6th International Symposium on Deep-Sea Corals will facilitate global exchange of current scientific knowledge and rapidly developing hypotheses on deep-water corals and their associated fauna and to discuss potential statutory means available to conserve and protect deep-sea habitat.

In the last decade, the global presence of deep sea, cold-water corals in a range of ocean margin settings has been established, and is still being expanded. Associated with the corals is the presence of huge carbonate mound structures and deep-sea reefs which contain unique records and a detailed history of ambient ocean water conditions over periods of rapid climate change. The coral reefs and mounds form very rich benthic habitats, of spectacular biodiversity, housing more coral species in deep cold-waters than in tropical coral reefs. Because of their function as a nursery for commercially important fisheries, in combination with increasing environmental pressures, the cold-water corals, reefs and mounds are seriously threatened and management and policy making is a must. This project supported the initiation of the 6th International Deep Sea Coral Symposium, held in September 2016, as a venue to address new developments and knowledge of deep-sea coral systems through a range of themes and topics in Boston, USA.

ACCOMPLISHMENTS

In 2016, the 6th International Symposium on Deep-Sea Coral (ISDSC) was hosted and organized by the Woods Hole Oceanographic Institution in Boston. With over 200 attendees from over 10 countries, the ISDSC crossed the boundaries between marine geology, biology, chemistry and physics, and addressed key scientific issues such as ecosystem functioning, biodiversity, environmental forcing factors, coral carbonate mound initiation, and their role in past and present biogeography, deep-water reef development and diagenesis as well as more applied aspects including reservoir capacities of carbonate mounds (under past and present constraints) and the

effects of climate change. All these issues were discussed in a global context alongside dedicated science-policy interface sessions outlining the most recent developments in management and conservation.

HIGHLIGHTS

- International Symposium on Deep-Sea Corals web site completed.
- Over 75 talks, 6 keynote addresses, and 150 posters were presented on the Biology, Demography, and Ecology; Habitat and Environmental Settings; Modeling of Oceans Past and Future; Anthropogenic Threats and Management Strategies to deep-sea coral ecosystems.
- Mini-symposium was held on the European Union and the United States of America signing *The Galway Statement*, providing opportunities for trans-Atlantic Ocean research cooperation. During this meeting a number of potential areas of collaboration were identified.
- Town Hall meeting was held on the debut of the recent NOAA report on the State of the Deep-Sea Coral and Sponge Ecosystems of the U.S.
- Mini-workshop was held on "Monitoring the Effects of Ocean Acidification on Cold-Water Corals" and recommendations for the Global Ocean Acidification Observing Network, in which specific alternative metrics for cold-water corals (which are not the same for shallow-water corals) for monitoring the impacts of ocean acidification on coral reefs were identified.

SOCIETAL BENEFITS

Two of NOAA's four mission goals are to "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management," and to "understand climate variability and change to enhance society's ability to plan and respond." CINAR was thus formulated with explicit recognition that effective management of human activities on deep-water coral ecosystems requires understanding how these activities interact with each other and with other processes that affect the ecosystem, including climate. The vast majority of deep-ocean resources, specifically coral ecosystems that support commercially-important fisheries, and endemic biological diversity are currently unknown and only through the communication, exchange and advancement of scientific information will the first order discovery and characterization of these resources be known for the subsequent and effective ability to protect and manage such resources and the impacts of climate change on these resources and their stewardship.

EDUCATION AND OUTREACH ACTIVITIES

The ISDSC #6 hosted educational programs, including the following:

Student Oral and Poster Presentation Awards

Awards for the best student oral and poster presentations were presented during the conference.

Deep-Sea Biology Society Awards for Oral and Poster Presentations by Early Career

Scientists
The Deep-Sea Biology Society provided awards for the best oral and poster presentations by early career scientists. Early Career scientists were defined as anyone who has graduated from a Ph.D. program and pre-tenure, or is in an equivalent research or governmental position.

Student Mentorship Program
A student mentorship program, where students met with established researchers in a similar field who helped get them acquainted with the symposium and the attendees. The program paired a subset of student attendees with more experienced attendees for an in-person mentoring experience.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

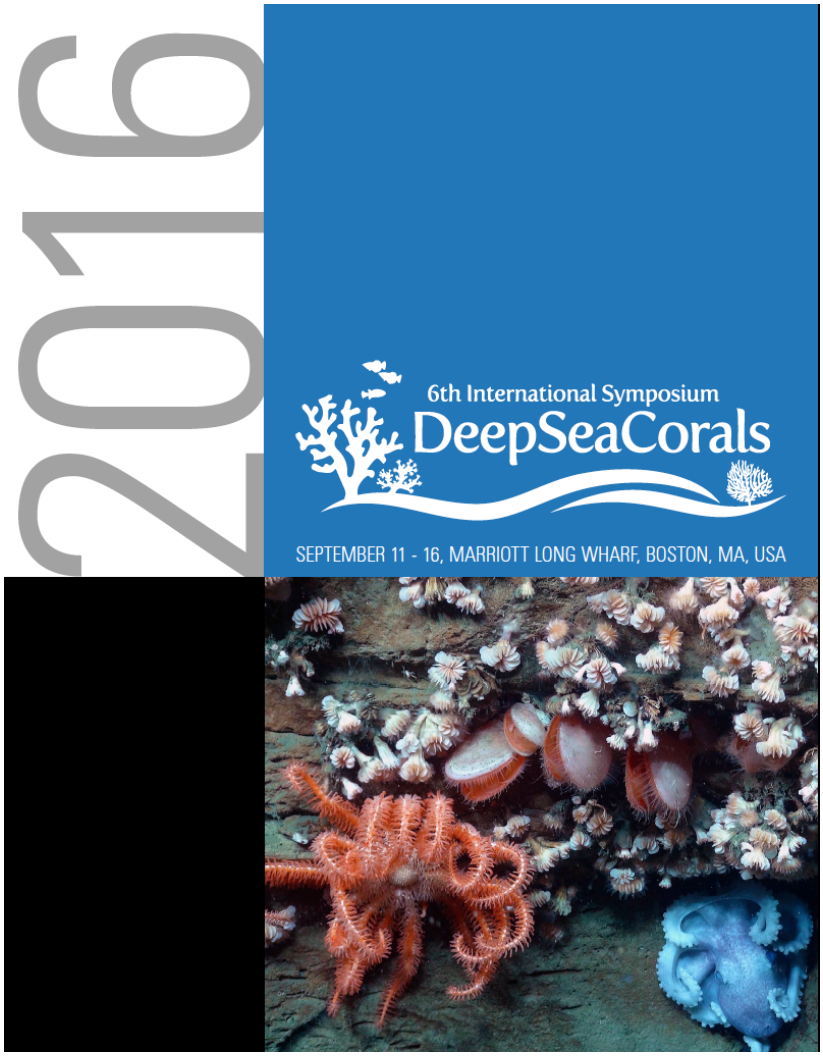


Figure 1. The 6th International Deep-Sea Coral Symposium abbreviated program, illustrating the breadth of 15 sessions on the Biology, Demography, and Ecology, Habitat and Environmental Settings, the Modeling of Oceans Past and Future, and the Anthropogenic Threats and Management Strategies involving deep-water coral ecosystems**.**

Figure 2. Deepwater coral off the U.S coast. Photo credit, NOAA OER and T. Shank

UMaine Cooperative Education

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2016 – March 31, 2017

CINAR Investigator – Gayle Zydlewski, University of Maine

NOAA Sponsor – Richard Langton, NMFS

Related NOAA Strategic Plan Goal: ***Healthy Oceans***

CINAR Theme: ***Education and Outreach***

Amount Funded: $ 29,021

PROJECT OVERVIEW, GOALS, AND MILESTONES

The main objective in Year 3 was to hire additional undergraduate students to continue work previously started and conduct new internships with the NOAA Maine Field Office. Two previously established undergraduate projects were continued and five more were added.

ACCOMPLISHMENTS

- Five new internships were developed
- Advertisements were made in early April 2016
- Applications were reviewed and interviews conducted in mid-April (15 interviews of students from three departments)
- Six summer internships were filled (two of which continued into the fall and even spring)
- Two fall internships were filled
- A new round of projects has been initiated for summer 2017

HIGHLIGHTS

Amanda Shuman. In 2016 I worked with Dr. Gayle Zydlewski to observe populations of sturgeon in the Penobscot River. Field work in May and June involved drift net sampling throughout the night to locate sturgeon eggs or larvae. Four drift nets were set for three hours at a time, with two sets carried out each night. No signs of sturgeon spawning were found. Beginning in July and continuing through the fall, field work consists of gill netting to capture adults to estimate population sizes of both Shortnose and Atlantic sturgeon. Two 100 yard nets were set for an hour each before being pulled and searched for fish. When a fish was caught, it was tagged with an internal PIT tag and an external FLOY tag, and morphometric data was collected. In addition to field work, I assisted with data entry and website design.

Spencer Kelly. I was a research technician in summer 2016, and participated in a project examining fish assemblage changes following the Penobscot River Restoration Project. For the

first half of the summer, I was a crewmember on an electrofishing boat conducting shoreline transects between Howland and Hampden. As a technician I was responsible for netting fish, notifying my supervisor of boating hazards, and assisting in all aspects of fish identification, measuring, and weighing. I learned a lot about boat maintenance and maneuvering, electrofishing, fish communities, the Penobscot River Restoration Project, and the intensity of field seasons. During the second half of my internship, I carried out data entry, database management, and data proofing, and also helped with otolith sectioning and mounting. This internship allowed me to realize what it feels like to be personally invested in a research project and that I am in the correct field, two invaluable feelings that classes had failed to bring.

Audrey Dean. This summer I completed and/or assisted with eight projects while working at the Maine Field Station. I entered data for the avian and marine mammal survey and the Penobscot trawl survey. I helped to collect data on 700 river herring collected in 2015, including identifying sex and species, removing otoliths, and collecting samples for genetic analysis. In addition, I removed otoliths from six frozen Atlantic salmon heads. I audited scale data for the Carlin tag project, and I cleaned, mounted, imaged, and measured 600 salmon scales collected from the Penobscot River from 2012 to 2015. I contributed to a literature brief on Atlantic salmon smolt production. I also assisted with the Penobscot River hydroacoustics survey, and examined 2000 sea pens for the presence of redfish larvae. This internship gave me further insight into the importance of river restoration and a multi-species approach to recovering a species such as Atlantic salmon.

Sameera Salame. This past summer was the second I spent in Woods Hole, Massachusetts at the Northeast Fisheries Science Center. I worked with Ruth Haas- Castro organizing and updating an inventory of scales. I imaged Atlantic salmon smolt scales from the East Machias River in Maine. I also imaged and aged smolt scales from the Sheepscot River, ME. Upon returning to UMaine I continued my internship at the Maine Field Station. As a senior marine sciences major I am required to complete a capstone independent research project where I applied the valuable skills learned throughout this internship. For this project, I analyzed data taken from imagepro to back-calculate age, and worked closely with John Kocik and Ruth Haas- Castro in completing my project titled: "Examining the effects of river flow on growth of juvenile Atlantic Salmon (*Salmo salar*) in Two Maine USA Rivers".

Braden Adams. Braden joined the project to assist with the sorting of invertebrates and detritus from Surber samples taken adjacent to large wood additions and in un-manipulated control reaches. In addition to sorting invertebrate samples and developing a taxa list for the project, Braden also developed protocols to quantify coarse and fine organic matter from samples as a measure of how large wood influences the resource base of invertebrate food webs. The project enabled Braden, who had previous experience with wetland invertebrates, to expand his knowledge of stream invertebrate identification. He also developed skills in data management, protocol development, and training other students in laboratory methods in freshwater sciences.

Nicole Keefner. Nicole counted and identified invertebrates to genus, and digitized samples by photographing each sorted Surber sample and archiving sample information. Scale references were included in all photographs so that the biomass of invertebrates (and hence salmon prey) can be determined using length-dry mass regression approaches for each taxa. Nicole had no

prior experience with aquatic invertebrates, and this internship afforded her the opportunity to developed sophisticated identification skills. Nicole's data indicated that invertebrate diversity and the abundance of taxa that feed on leaf detritus is greater adjacent to large wood additions. However, substantial variation in insect abundance and diversity among samples suggest future projects should aim for greater sample replication to have sufficient power to detect modest changes in invertebrate communities in response to large wood restoration.

Bethany Stevens. Over the past seven months I worked with Dr. Gayle Zydlewski to continue a survey of individual participation in acoustic telemetry networks. Building on a capstone from the previous year, I examined previously collected data through Qualtrics and gained a better understanding of what how researchers use data from acoustic telemetry networks. Upon reviewing the data, we realized that we did not have data from researchers outside of networks and arguably that was the pool of individuals we should be surveying. With this in mind, I helped edit the survey for clarity and developed more specific questions related to topics we felt were lacking from the previous survey. In addition, I helped edit the previous student's capstone paper, and produced graphs for key data that were published in the VEMCO newsletter along with the revised survey.

SOCIETAL BENEFITS

These internships are giving undergraduate students the opportunity to interact with NOAA scientists concerning societally-relevant marine science issues. These experiences could be instrumental in the students' career paths and their active involvement in fisheries issues.

EDUCATION AND OUTREACH ACTIVITIES

2017: Consultation with Marine and Freshwater Scientists at Maine DEP on the use of macroinvertebrates to monitor large wood restoration in mid-coast Maine rivers. 03/22/2017. We discussed sampling design sample processing and future collaborations that combine work in Midcoast Maine with Downeast Maine.

2017 Narraguagus River Focus Area Team meeting to discuss research priorities for the restoration of Atlantic salmon and their habitat in the Narraguagus River and other Downeast river catchments.

2016 University of Maine Collaborative Forestry Research Unit listening session.

Presentations:

Greig, H. S. 2017. *Integrating food-web processes into salmon restoration: Examples from the top and the bottom of freshwater food webs.* Invited Speaker at the annual meeting of the Atlantic Salmon Recovery Framework's Downeast Region SHRU, 31 January 2017, Machias, ME. 50 attendees

Greig, H. S. 2016. Maine's rivers in a changing climate. Invited talk. Climate change impacts on Wabanaki tribal planning symposium. Presque Isle, ME. June 2016. Number of attendees: 20.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

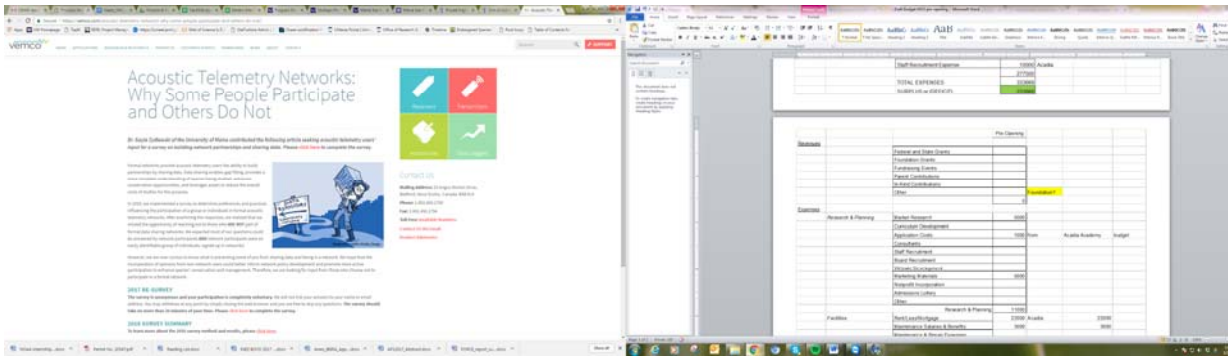


Figure 1. Vemco newsletter announcement of Bethany Stevens' project.

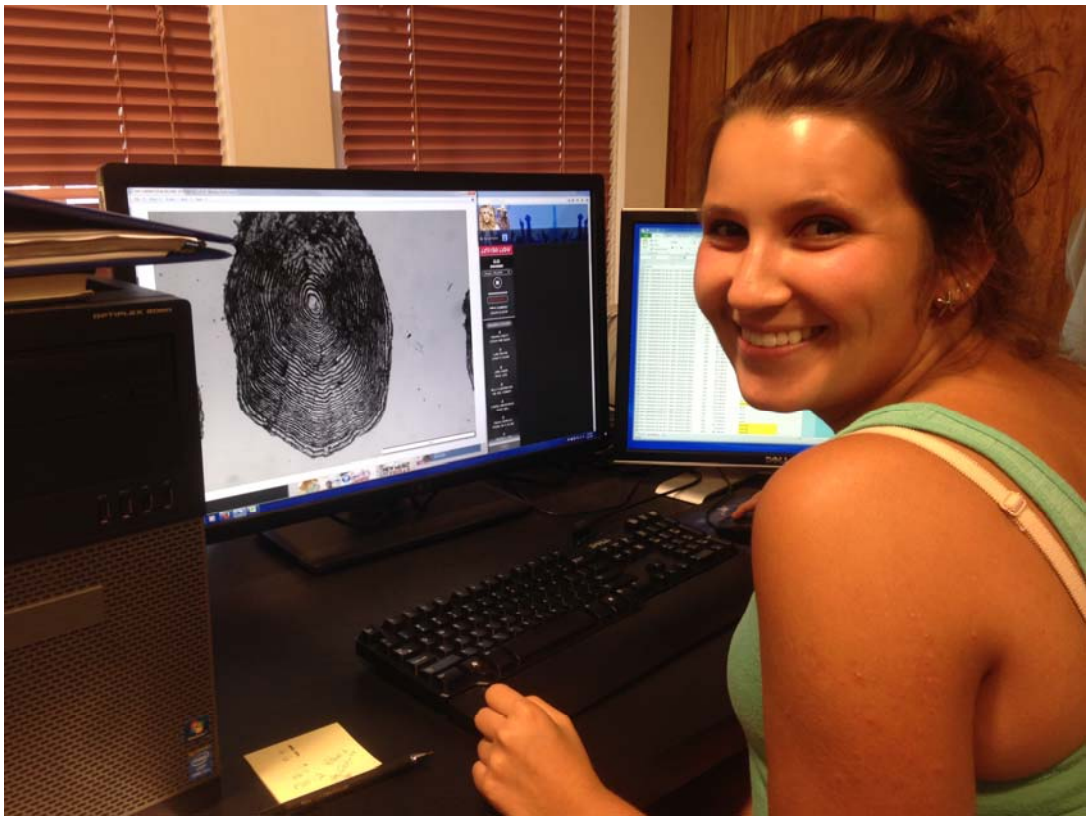


Figure 2. Sameera Salame working in Woods Hole, MA on a scale sample.

Figure 3. Sameera Salame in Woods Hole, MA at an outreach event.

APPENDIX 1: CINAR Personnel Summary

NA14OAR4320158
July 01, 2016– June 30, 2017

Task 1 Support

Employees	**Appt. Dates**
Don Anderson, CINAR Director	7/01/09 - present
Judy Kleindinst, CINAR Administrator	7/01/09 – 7/31/2015
Mindy Richlen, CINAR Associate Director	6/01/15- present
Ann Stone, CINAR Administrative Professional	9/26/09 - present

APPENDIX 2: CINAR Personnel Summary Chart

April 1, 2016 – March 31, 2017

Category	Number	B.S	M.S	Ph.D.
Employees who receive ≥ 50% NOAA Funding (not including Students)				
Research Scientist	14	1	2	11
Visiting Scientist	1	0	0	1
Post Doctoral Fellow	7	0	0	7
Research Support Staff	17	10	3	4
Administrative	5	3	2	0
Total	43	14	7	22

Category	Number	B.S	M.S	Ph.D.
Employees who receive < 50% NOAA Funding (not including Students)				
Total	66	14	8	44

Students	Number	-	-	-
Undergraduate Students	17	0	0	0
Graduate Students	9	3	5	1
Total	26	3	5	1

Obtained NOAA employment within the last year	6	5	0	1

APPENDIX 3: CINAR Publications for Reporting Period

	2014-2015	2015-2016	2016-2017
CI Lead Author	8 peer-reviewed 3 non peer-reviewed	17 peer-reviewed 3 non peer-reviewed	21 peer-reviewed 13 non peer-reviewed
NOAA Lead Author	0 peer-reviewed 0 non peer-reviewed	8 peer-reviewed 1 non peer-reviewed	1 peer-reviewed 0 non peer-reviewed
Other Lead Author	3 peer-reviewed 0 non peer-reviewed	31 peer-reviewed 6 non peer-reviewed	9 peer-reviewed 2 non peer-reviewed

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