CINAR

Annual Progress Report

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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.
- During the fourth year of operation (April 1, 2017 through March 31, 2018), CINAR received $8,732,229 from OAR, $2,067,179 from NMFS, and $851,119 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 this 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 three new fellows were appointed. Detailed progress reports from each CINAR Fellows and SMAST faculty are provided, beginning on page 162.
Robert Beardsley, WHOI
"Technical Support and improvement of FVCOM for NOAA Modeling Activities"

The objectives of this project are (1) hold an FVCOM (Finite-Volume Community Ocean Model) 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). Project highlights included:

- Provided the regular technical support for CSDL and GLERL in development of the FVCOM-based forecast system in NGOM, San Francisco Bay, and Great Lakes.
- Upgraded the FVCOM ecosystem models by standardizing the setup of model parameters and initial conditions using the name-list configuration approach as the same as the main codes of FVCOM.

The development of the FVCOM forecast system provides public societies with real time ocean environmental conditions for marine health evaluation, navigations, ocean rescues and storm-induced coastal inundation. By sharing FVCOM development with public users, FVCOM can be applied to other coastal regions in the world.

Alexa Dayton, GMRI
"Marine Resource Education Program: Fostering Industry Leadership Through Fisheries Science & Management Education in the Southeast"

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 Southeast workshops, a fishery science & management education program for commercial and recreational fishermen. This education enables fishermen and others to participate productively in the fisheries science & management processes, and leads to improved cooperation and trust between fishermen, scientists and managers. Project highlights included:

- 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.
- Fisheries science education program once again refined based on prior year evaluations, and we introduced a new hands-on activity where attendees provide stock status advice on a fictitious stock, using stock assessment tools.
- Performed extensive outreach and networking to generate a second year of program applicants. Workshop evaluations were universally positive and indicated a significant increase in participants’ likelihood to participate in fisheries science & management activities, such as cooperative research, data collection and fishery management council activities.
Jacqueline Grebmeier, UMCES

The Distributed Biological Observatory (DBO)-Northern Chukchi Integrated Study (NCIS): Hydrography, Sediment, and Macrofaunal Population Dynamics

The overall goal of our component of the DBO/NCIS project over the annual period of this report was to determine hydrographic and sediment characteristics that influence macrofaunal communities and ecosystem function in the northern Bering and Chukchi Seas, specifically evaluating status and trends of these parameters using time series studies. The 2017 sampling on the USCGC Healy (HLY1702) included: (1) time-series DBO transect lines DBO1 and 3-5, (2) water column oxygen-18 measurements in seawater as an indication of sea ice melt, and (3) macrofaunal and sediment process studies on a latitudinal basis to track benthic ecosystem response to sea ice retreat and seawater warming. Interdisciplinary investigations are addressing variability and forcing functions in the diverse water masses and benthic habitat types that are now subject to significantly longer sea-ice free periods and increasing seasonal seawater temperatures. Project highlights included:

- Sediment chlorophyll indicates recent phytodetritus deposition in the offshore DBO3 (SE Chukchi Sea) hotspot and in the NE Chukchi Sea primarily southeast of Hanna Shoal
- Highest organic carbon deposition is SE of Hanna Shoal in the NE Chukchi Sea, an area known for high bivalve biomass as prey for walrus.
- Highest bivalve biomass was observed in fine silt & clay sediment in the offshore areas in the southern Chukchi Sea and just SE of Hanna Shoal in the NE Chukchi Sea

This field program sampled the diverse water masses and benthic habitat types that are now subject to significantly longer open water periods as seasonal sea ice has declined and seawater warms seasonally. Data will be archived within two years after the data are collected or created, following the NOAA ARP data policy.

Klaus Huebert, UMCES

OA-Specific IBMs as Synthesis Tools for Northeast USA Finfish

We have undertaken a modeling effort to help synthesize experimental information on biological responses to elevated CO2 and to more fully understand population consequences of the observed experimentally induced effects of CO2 on individuals. The model is an individual-based model (IBM), meaning that biological responses and their derivative consequences are simulated at the level of the individual fish. The current rendition of our IBM uses basic life history and ecological rate parameter estimates as well as experimental data on biological effects of CO2 studies of winter flounder, *Pseudopleuronectes americanus*. The IBM captures key ecological and population processes of winter flounder and allows exploration of population-level consequences carried beyond the early life stages.

The winter flounder model will be used to evaluate population responses under multiple scenarios, such as high and variable CO2 depicting future inshore, estuarine habitats. Other environmental stressors (e.g., warmer water) will be included. Beyond providing a quantitative evaluation of responses of winter flounder to climate and OA scenarios, this work will develop a web-based modeling tool for 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 appropriate for the...
species and habitat of interest, then probe consequences of shifts in life history and environmental changes as might be expected under various scenarios for carbon combustion and atmospheric CO2.

**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?*

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 forecast 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*. A hindcast temperature timeseries provided continuous oceanographic conditions that were used to resolve seasonal minimum and maximum bottom temperature distributions over our study area. These temperature data were used to construct a fundamental niche model for sea scallops based on published thermal habitat. Project highlights include:

- Theoretical and realized niche models have been generated and compared over time.
- Estimated niche area, both theoretical and realized, has been shrinking in recent years in the MAB due to warming water temperature.

Ongoing work includes production of species distribution correlations, development of a trophically-linked species distribution model, and obtaining bottom water forecast timeseries that can be used to make predictions of scallop species range under climate change scenarios. This 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.

**Robert Pickart, WHOI**

*Distributed Biological Observatory – Northern Chukchi Integrated Study*

The inaugural cruise of the Distributed Biological Observatory – Northern Chukchi Integrated Study (DBO-NCIS) was carried out from 26 August to 15 September 2017 aboard the US Coast Guard Cutter *Healy*. The overall goal of DBO-NCIS is to document and understand ongoing changes to the Pacific-Arctic ecosystem in light of the changing physical drivers. The main objectives for the 2017 cruise were (1) to occupy DBO lines 3-5 in the Chukchi Sea with an extensive suite of water column and benthic measurements; and (2) to carry out a process study of the northeastern Chukchi shelf designed to understand the physical-biological links that result in the biological hot spots in this region. Project highlights include:

- An extensive hydrographic/velocity survey was carried out in summer 2017, which is the eighth such survey conducted since 2003 containing both high-resolution CTD sections and vessel-mounted ADCP data.
- We sampled the northeast Chukchi shelf in a strongly wind-forced state during part of the survey. The upwelling in Barrow Canyon was so pronounced that Atlantic water was found only 10 m beneath the surface. Water from the basin was progressing onto the central portion of the shelf.
Our cruise provided two valuable crossings of the Chukchi slope current, which were striking in two regards. First, in both instances there was a subsurface warm-core eddy situated on the seaward side of the current. Second, the westward transport of the current far exceeded the mean summertime value. These unexpected results are presently being addressed in the scientific analysis.

The cruise exceeded our expectations, due in part to the fast pace of work resulting from favorable weather conditions and lack of sea ice. Data collected is allowing us to address both the seasonality and interannual variability of the water masses and circulation on the Chukchi shelf, including the role of wind forcing.

**Malin Pinsky, Rutgers**
*Projecting and communicating changes in North American marine species distributions*

Species in many regions of North America have already shifted in response to climate, and further shifts are expected in the future. For commercially and recreationally important species, including many species of coastal fish and invertebrates, shifts in species distributions have clear and immediate impacts on coastal communities, economies, and societies. Understanding of these shifts, however, remains limited among policymakers and the public, in part because information on these shifts is scattered in the scientific literature, difficult to access, and often out of date. In this project, we are developing projections for future distributions of 200 species in North America over the 21st century. Project highlights include:

- We developed species distribution projections for 686 animals on the continental shelves of North America
- We prototyped visualizations for communicating future changes in species distributions to the public and to managers. A web team is now putting those visualizations online through OceanAdapt.

Species important to fisheries are projected to move up to 1000 km further north. The US West Coast is projected to have particularly large shifts in species distributions, which can disrupt fisheries, conservation measures, and fisheries management.

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

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. 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.

In February 2017 we observed clear evidence of Gulf Stream Water in the Northeast Channel, identifiable by high salinity (>35) and warm subsurface temperature (up to 14 °C), this influx continued to penetrate into the interior Gulf of Maine. The same phenomenon was observed this past year, as Gulf Stream Water penetrated into Jordan Basin in the Fall-Winter period. It is worth
pointing out that these unusual water mass influxes into the Gulf of Maine are coincident with first-time reports of ASP (Amnesiac Shellfish Poisoning, domoic acid) and the associated diatom, *Pseudo-nitzschia australis*, in the Gulf of Maine. 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.

**Zhaohui ‘Aleck’ Wang, WHOI**  
*Developing Carbon Dioxide Climatology and Ocean Acidification Indicators in the Northeastern U.S. Coastal Waters*

The Northeastern U.S. coastal region, including the Gulf of Maine (GoME) and the Mid-Atlantic Bight (MAB), may be susceptible to ocean acidification due to its relatively low pH, aragonite saturation state and buffering capacity. Such a chemical condition has significant implications for the region’s profitable shellfish industry and overall ecosystem health in the long term. A baseline assessment of the region’s ocean chemistry patterns, in particular water-column carbonate chemistry, is a critical step in diagnosing future changes and in making long term policies for adapting to and mitigating the effects of ocean acidification in the region. The goal of this work is to collaborate with NOAA’s Northeast Fishery Science Center (NEFSC) to synthesize existing and on-going observations of CO2 parameters and other related measurements in the Northeastern U.S. coastal waters, with the aim of generating a mechanistic understanding of the variability of carbonate chemistry caused by both natural and anthropogenic factors and to produce a baseline climatology of carbonate chemistry and ocean acidification indicators for the region. Project highlights include:

- We compiled a large data set that includes water-column carbonate chemistry measurements over the last two decades in the NE shelf water.
- We have started to integrate the data set to generate seasonally-resolved, preliminary surface maps of CO2 parameters. For example, aragonite saturation states show strong seasonal differences in NE shelf water, with winter time low and spring time high along with local ‘hot’ spots potentially due to various oceanic processes.

Stakeholders and the public are becoming increasingly interested in this looming problem and its potential impacts. The climatology and OA indicators will be valuable for informing decision makers of the current status of ocean acidification, and will be used in models to project future changes and impacts in the region.

**Robert Weller and Albert Plueddemann, WHOI**  
*Ocean Climate Observations and Analyses (2017-2018)*

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 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; (2)
Surface oceanographic data; 3) Ocean observations of temperature, salinity, velocity, and dissolved oxygen along the mooring line.

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 this reporting period, cruises were conducted to each of the three ORS. 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.

The surface moorings are a very effective methodology. In spite of biofouling, fishing gear entanglement, and other challenges 89.6% 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.

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

Working in partnership with the NOAA NCDC Northeast Regional Climate Center, The Gulf of Maine Research Institute (GMRI) set out to develop localized climate relevant data products using data sets available through the National Climate Data Center/Climate Data Record (NCDC/CDR) program. The data products were developed and delivered through an online data dashboard for the fisheries management community that was piloted through our second CINAR project entitled "Building tools for applying climate science to fisheries management". Over the last year, we have worked to implement recommendations from 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. Project highlights include:

- Redesigned dashboard application to improve presentation of visualizations based on user feedback [http://dashboard.gmri.org](http://dashboard.gmri.org)
- Rolled out beta application to stakeholders for testing and usage
- Presented talks at several national meetings to demonstrate functionality of the dashboard and share technical approaches to development
- Began work integrating additional datasets for bottom temperature, primary production and chlorophyll

The development of the climate and fisheries data dashboard has leveraged stakeholder engagement using an iterative process throughout the project. Development continues to occur in tandem with efforts focusing on data acquisition and integration and user interface development. We continue to work closely with this advisory group to scope and validate the content and functionality of the application to meet priority needs as they apply to locations, presentation of information, and interpretation of data. We are promoting the dashboard throughout the development through a series of targeted outreach efforts including webinars, and participating in relevant local and regional meetings and workshops.


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.
CINAR PIs

The CINAR PIs include Donald M. Anderson, CINAR Director, Woods Hole Oceanographic Institution; Lynne Trabachino, Director, Institute of Earth, Ocean, and Atmospheric Science, Rutgers University; Michael Roman, Director, Horn Point Laboratory, University of Maryland Center for Environmental Science; Rebecca Van Beneden, 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
- Michael Roman  CINAR PI, UMCES
- 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  
Lynne Trabachino, CINAR PI, Rutgers  
Michael Roman, CINAR PI, UMCES  
Rebecca Van Beneden, 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](http://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**

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<tr>
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<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donald Anderson</td>
<td>CINAR Director</td>
</tr>
<tr>
<td>Mindy Richlen</td>
<td>CINAR Associate Director</td>
</tr>
<tr>
<td>Ann Stone</td>
<td>CINAR Administrative Professional</td>
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</table>


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

**TASK**
- Task II, $9,746,139, 84%
- Task I, $411,161, 4%
- Task III, $1,398,973, 12%

**THEME**
- Sustained Ocean Observations and Climate, $5,999,662, 54%
- Ecosystem Management, $482,625, 4%
- Protection and Restoration of Resources, $2,160,419, 19%
- Ecosystem Monitoring, $1,251,769, 11%
- Education and Outreach, $1,037,346, 9%
- Ecosystem Forecasting, $307,545, 3%

**LINE OFFICES**
- NMFS, $1,969,532, 17%
- NOS, $851,119, 7%
- OAR, $8,732,229, 76%
Task I Activities with Distribution of Funding

Task I funding received from NOAA during this period totaled $411,161. WHOI provided $138,387 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 2017, 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 2018.

**WHOI-NEFSC Special Seminar Series on Fisheries and Ecosystems Acoustics:** This seminar series continued through 2017-2018, sponsored jointly by NEFSC, CINAR, and the WHOI Biology and Applied Ocean Physics and Engineering Departments, and co-convened by former 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 Climate vulnerability and adaptation in Northeast U. S. fishing communities (Kathy Mills, GMRI), Aquaculture sustainability (Gary Wikfors, NOAA) 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.
The following pages provide research summaries of the CINAR projects funded through the period April 1, 2017 through March 31, 2018, organized by theme.

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<th>CINAR Partner</th>
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<td>WHOI</td>
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THEME I. ECOSYSTEM FORECASTING
Gulf of Maine Annual Cyst Cruise and Sample Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Donald Anderson, WHOI

NOAA Sponsor – Richard Stumpf, NOS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

Amount Funded: $ 65,657

PROJECT OVERVIEW

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 concentrations in GOM bottom sediments, and a new map is produced each year from the samples collected from annual cyst surveys.

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. Since 2013, the research has been transitioned to NOAA for operations including the cyst collection, counting, and modeling tasks with WHOI providing support for that effort. 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.
ACCOMPLISHMENTS

During the 2017-2018 funding period, several attempts were made to collect benthic samples for the 2017 annual Gulf of Maine cyst survey. The first attempt was planned as a full survey of the Gulf of Maine domain including the Bay of Fundy, which had not been surveyed since 2013. The cruise was scheduled on the NOAA ship Gordon Gunter for October 17-27, 2017. All sampling gear and personnel were onboard and ready to sail out of Newport, Rhode Island as planned. Unfortunately, an oily-water separator for managing bilge water on the ship was out of compliance forcing cancellation of the cruise at the last hour. Attempts to delay and/or shift the ship schedule after repairs were completed were not possible.

An alternative plan was immediately developed to sample a limited number of cyst stations in the mid-Maine “seed-bed” from small 50-60ft vessels. Two attempts were made on the WHOI owned R/V Tioga. The first chance to implement the plan was while NOAA personnel were still in Newport, RI, but was canceled at the last minute when the open weather window closed rapidly. Another attempt (mid-Nov) failed due to mechanical issues that forced the Tioga to return to home port after the vessel was already underway and partway to Bigelow Labs to meet the science team. Immediate rescheduling after those repairs were made was not possible due to approaching foul weather conditions without a foreseeable window of opportunity. Finally, as a “last ditch” effort to collect cysts in the Gulf of Maine before the bloom season started in April, the 50ft R/V Gulf Challenger (University of New Hampshire) was chartered. A two-day weather window opened on Feb 12-13, 2018 with NOAA and WHOI personnel (with the gear) meeting the vessel in Portsmouth and spending one overnight at Bigelow Labs, ME. That attempt was successful, with the ship transiting into the study area and working the southern part of the mid-Maine cyst patch (with icicles hanging off the bow rails).

Nine stations of ~80 stations originally planned were occupied during the two-day cruise. Sample collection and processing procedures were very similar to previous cruises implemented on large vessels. At each station, a Craib corer was deployed and a relatively undisturbed surface sediment core was collected. To prevent resuspension of the top layer of the core when working on a small, unstable vessel, the cores were not sectioned immediately at sea. Instead, the cores were capped on the bottom and on the top with overlying seawater filled to the maximum level so that the integrity of the top layer would be preserved and then stored buried in crushed ice to prevent further disturbance. When in calm waters, cores were 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 and have been previously 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. Exchange into 100% methanol for long term storage is normally done at sea, but on a small vessel, this task was completed back at the WHOI lab. Samples were shipped to the NOAA Beaufort, NC for cyst counting.

Surface cyst concentrations at the 9 stations were obtained using a primuline staining technique with epi-fluorescence microscope counting methods were previously transitioned from WHOI to NOAA-Beaufort. Results were provided to Dr. Rick Stumpf (NOAA) and Dr. Yizhen Li (NOAA) for
*Alexandrium* GOM model simulations. In 2018, given the limited number of stations occupied (see Fig. 1 left panel), a statistical model developed by Solow et al, (2014) was particularly useful to generate a full map of the cyst concentrations and distribution for the Gulf of Maine and the Bay of Fundy (Fig. 1 right panel) and that method had also been transitioned to NOAA as part of separate funding. Dr. Dennis McGillicuddy (WHOI) prepared contour plots (Fig. 1) and cyst abundance calculations for each layer and sub-regions within the GOM (Table 1).

**HIGHLIGHTS**

- Model simulations based on the 2017 (actually collected in early, 2018) cyst concentrations were completed immediately following the counting during late winter in 2018, and the bloom predictions were released at a NOAA sponsored workshop in Portsmouth, NH in March, 2018.
- With the limited number of stations sampled, the statistical extrapolation of the cyst concentrations was put to its most exceptional “real world” test to date. Without that prior research, the valid cyst calculations for the entire domain would not be available for the forecast model simulations.
- Cyst abundances in 2017 were similar to 2016, but low compared to prior survey years (2004-2011). Please see Figure 2.
- 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 two Northeastern University cooperative program (undergraduate) students. One student helped prepare for cruises in the Fall, 2017 with significant gear shuffling tasks for the multiple attempts, while the next student received training in *Alexandrium* cyst collection, 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 MA shellfish resource managers), and NOAA managers as part of a 2018 seasonal PSP forecast discussion and workshop sponsored by NOAA.
Figure 1. Concentrations of *Alexandrium* cysts in the top 1cm layer of Gulf of Maine bottom sediments during Feb, 2018 determined using microscopic enumeration of samples from 9 stations (left panel). Extrapolation of the 9 cyst concentrations into a full map was determined statistically (right panel, following Solow et al. (2014)). These data were used in forecasting models to determine the intensity of the blooms in the region.
**Table 1.** Mean cell abundance ($10^6$) in the top 1cm of sediment for the western Gulf of Maine (WGOM), eastern Gulf of Maine (EGOM), Bay of Fundy (BOF) and the total domain.

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<th>Year</th>
<th>WGOM</th>
<th>% of Mean WGOM</th>
<th>EGOM</th>
<th>% of Mean EGOM</th>
<th>BOF</th>
<th>% of Mean BOF</th>
<th>Total</th>
<th>% of Mean Total</th>
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</table>

**Figure 2.** Time series of the cyst abundances (data provided in Table 1) since 1997 with the extrapolated data included from the cyst survey in Feb 2018. Because the Bay of Fundy has not been sampled since 2013, the corresponding cyst abundances are not shown.
Technical Support and Improvement of FVCOM for NOAA Modeling Activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Robert Beardsley, WHOI

NOAA Sponsor – Eugene Wei, NOS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

Amount Funded: $ 48,263

PROJECT OVERVIEW

The objectives of this project are 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

1. CSDL-WHOI-UMASSD organized a FVCOM workshop at CSDL on September 13-14, 2016 and September 28-29, 2017. On the 2016 workshop, Robert Beardsley (WHOI) and Changsheng Chen (UMASSD) first gave one joint presentation to provide an update of FVCOM development and improvements and then explained the FVCOM capabilities of potential interests of NOS on ice models, data assimilation, nesting and coupling. During the workshop, Beardsley and Chen addressed the questions about the use of the updated FVCOM codes, and worked together with CSDL scientists to solve the code issues in the NOAA FVCOM applications. The CSDL scientists updated the performance of the FVCOM forecast system development in the Gulf of Mexico shelf, San Francisco Bay, and Great Lakes. On the 2017 workshop, Beardsley and Chen report the updated development of FVCOM since FVCOM version 4.0 is released, and also introduced the new modules that will be released in FVCOM version 5.0. Two workshops were very productive and many questions were addressed and solved by the open discussion.

2. In 2016, we upgraded FVCOM and released FVCOM version 4.1. These changes include 1) a new community sediment transport module with cohesive model, 2) a module for the wave watershed partition, 3) modification of the offline sediment code, 4) modification of offline biological code, 5) vector operations for wave model and the code to treat the invalid scalar
assumption at high latitudes and singularity at the North Pole, 6) the addition of the ice-induced wave attenuation, 7) the addition of forcing variable pointer initialization to fix the problems for Intel FORTRAN version 15 or above, 8) the vertical interpolation from large domain to small domain in the one-way and two-way nesting modules and 9) bug fixing.

3. In 2017, we upgraded FVCOM and released FVCOM version 4.2. These changes include: 1) separating the subroutine coare26z from MOD_HEATFLUX and MOD_HEATFLUX_GL, 2) adding a new subroutine coare40vn, 3) adding Flag ICE_FRESHWATER and removing Flag HEATING_CALCULATED_GL in make.inc, 4) combining modules MOD_HEATFLUX and MOD_HEATFLUX_GL into a new module MOD_HEATFLUX, and 5) updating the ice code from NOAA GLERL for the freshwater ice case.

4. We arranged several conference calls with CSDL and GLERL scientists to help them solve several code issues. The conference calls were made by two procedures. First, CSDL collected all questions from NOAA FVCOM users and delivered to us. Second, we reviewed the questions and provided our answers and explanations through either on the conference calls or written texts.

5. We shared the results of the NOAA-UMASS-WHOI collaboration in FVCOM improvement with the FVCOM users at the 2016 and 2017 FVCOM User Workshops.

HIGHLIGHTS

- Provided the regular technical support for CSDL and GLERL in development of the FVCOM-based forecast system in NGOM, San Francisco Bay, and Great Lakes.
- Helped modify the FVCOM modules to meet the NOAA CSDL and GLERL need in the forecast system development.
- Debugged NOAA FVCOM codes and upgraded the FVCOM with inputs from CSDL and GLERL scientists.
- Upgraded the FVCOM ecosystem models by standardizing the setup of model parameters and initial conditions using the name-list configuration approach as the same as the main codes of FVCOM.

SOCIETAL BENEFITS

1. Shared the FVCOM development with public users, which helped utilize the applications of FVCOM to other coastal regions in the world.

2. The development of the FVCOM forecast system provided the public societies the real time ocean environmental conditions for the marine health evaluation, navigations, ocean rescues and storm-induced coastal inundation.

3. Updated the existing NOAA forecast system to the new technical level with better resolving coastal geometry.
EDUCATION AND OUTREACH ACTIVITIES

1. Helped trained the new generation modelers in NOAA labs, especially in using the unstructured grid models.

2. Enhanced the communication between graduate students in academic universities and scientists in NOAA laboratories.

PUBLICATIONS

Experimental studies of the biological effects of elevated CO2 on marine fishes indicate that the early life stages, including gametes, embryos, larvae, and young juvenile fishes, appear to be especially at risk. Further, monitoring studies of CO2 patterns in marine waters show some habitats (e.g., high latitudes, coastal NE USA) to be more likely to experience rapid changes than global CO2 averages. Inhabitants of regions of high and variable CO2 may also exhibit greater effects – or may be more resilient to ocean acidification (OA) because of the environment they have been experiencing. Few data collected to date shed light on the adaptive potential of these taxa. Importantly, these habitats and the finfish that occupy them may provide researchers with a preview into OA effects expected by living marine resources in other ecosystems as future levels of OA, climate, and environmental co-stressors increase in intensity.

We have undertaken a modeling effort to help synthesize experimental information on biological responses to elevated CO2 and to more fully understand population consequences of the observed experimentally induced effects of CO2 on individuals. The model is an individual-based model (IBM), meaning that biological responses and their derivative consequences are simulated at the level of the individual fish. The current rendition of our IBM uses basic life history and ecological rate parameter estimates as well as experimental data on biological effects of CO2 studies of winter flounder, *Pseudopleuronectes americanus*. Most studies providing such CO2-specific data have been conducted at the NOAA Northeast Fisheries Science Center Howard Laboratory in Sandy Hook, New Jersey with NOAA Ocean Acidification Program support. The IBM captures key ecological and population processes of winter flounder and allows exploration of population-level consequences carried beyond the early life stages. We expect the method to be translatable to other marine fish species in other habitats, and advance our understanding of community and ecosystem effects of OA on living marine resources.

Winter flounder is an economically important fish and prior studies provide measurements of CO2 effects on key early life history parameters (e.g., fertilization, development, larval growth, survival). The winter flounder model will be used to evaluate population responses under multiple scenarios, such as high and variable CO2 depicting future inshore, estuarine habitats. Other environmental
stressors (e.g., warmer water) will be included. Beyond providing a quantitative evaluation of responses of winter flounder to climate and OA scenarios, this work will develop a web-based modeling tool for 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 appropriate for the species and habitat of interest, then probe consequences of shifts in life history and environmental changes as might be expected under various scenarios for carbon combustion and atmospheric CO2.

PROJECT MILESTONES AND ACCOMPLISHMENTS

We have developed an R-language winter flounder IBM consisting of two components: a simple population model for age-1 to senescence in annual time-steps, and a sophisticated young of the year model for the early life stages (from the maternal reproductive biology leading up to spawning through the portion of the juvenile stage that is characterized by elevated, density-dependent mortality) in daily to hourly time steps. The model has been parameterized to mimic the population dynamics of winter flounder from the Southern New England / Mid-Atlantic population, given realistic temperature input data, such as a 25-y (1977-2001) time series of the Niantic River Estuary (Millstone Environmental Laboratory 2003, 2017).

Two areas with major updates during the past year over previous models by Chambers et al. (1995) and Rose et al. (1996) are spawning and mortality. Our model uses updated equations, consistent with literature data of winter flounder reproductive biology and spawning seasons at different latitudes, to predict the spawning season for each year-class by simulating temperature-dependent ovarian development starting in August of the preceding year. This can result in spawning as early as December and as late as June for US estuaries at different latitudes within the species range, based on temperature input from the NOAA National Estuarine Research Reserve System. In the past year, we also developed new equations for size- and temperature-dependent mortality during the early life history and additional density-dependent mortality for juveniles. The new functional relationships are based on matching modeled mortality to literature estimates, and matching the modeled stock-recruit relationship to SNE/MA stock assessment data. For example, the maximum sustainable yield conditions estimated by the 52nd Northeast Regional Stock Assessment Workshop were $SSB_{MSY}=44$ kt at $F_{MSY}=0.29$ (NEFSC, 2011). In simulations using Niantic River temperature input and $F=0.29$, modeled spawning stock biomass fluctuated between $SSB=37$ and $47$ kt with a median of $42$ kt, while modeled recruitment ranged from 39 to 79 million age-1 fish (on July 1) with a median of 60 million (near the 1981 maximum, NEFSC, 2011).

Using an earlier version of the SNE/MA winter flounder parameterization, we performed simulation experiments to study the potential cumulative effects of ocean warming and acidification on the SNE/MA population over the course of the 21st century. As temperature input, we repeated the 1977-2001 Niantic River Estuary temperature time series to provide a 100-yr model spin-up under baseline late 20th century conditions, followed by a gradual 3 °C increase over the next 100 yr, and then a 100-yr model equilibration period at +3 °C conditions. As potential effects of OA we used placeholders that illustrate two kinds of biological effects data from laboratory experiments: (1) a reduction in egg fertilization success from 65% to 55% and (2) a 10% reduction in the instantaneous larval growth rate from first-feeding until metamorphosis. Our preliminary results were that all three factors (warming, reduced fertilization success, and reduced larval growth) resulted in reduced SNE/MA winter flounder biomass, with warming having a much larger effect than fertilization, and
larval growth-rate having the smallest effect. We have substantially changed how the model represents density-dependent mortality since these simulations were performed, and therefore consider this only a proof of concept for ongoing and future experiments.

HIGHLIGHTS

We can use our computer model to simulate long-term changes in winter flounder populations in response to changes in life history parameters such as egg fertilization rate or larval growth rate.

EDUCATION AND OUTREACH ACTIVITIES


PUBLICATIONS

In preparation.
Figure 1. Schematic of winter flounder IBM showing how individuals advance through early life stages in the young of the year model (lower part) and are then aggregated into annual age-classes (upper part) with attributes relevant to the fishery.
Figure 2. Test runs of model to evaluate sensitivity of population size to 3 °C warming (year 100-200) and reductions in fertilization and larval growth rates of magnitudes similar to those observed in OA experiments at NEFSC Howard Laboratory.
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, 2017 – March 31, 2018

CINAR Investigator – Daphne Munroe, Rutgers University

NOAA Sponsor – Deborah Hart, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

Amount Funded: $37,516

PROJECT OVERVIEW

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 will investigate the effects of climate change on sea scallops in the MAB by using hindcast and forecast 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, that 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 MILESTONES AND ACCOMPLISHMENTS

Hindcast Temperatures: Bottom water hindcast temperatures were 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 occurs near the annual minimum and maximum bottom temperatures were 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 5-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 (Figure 1,2). A manuscript is in preparation describing the bias correction solution. We anticipate this manuscript will be of regional interest because the hindcast ROMS bottom water temperature timeseries has and is being used in a number of modeling efforts for which this bias correction will be important.

**Scallop Niche Analysis:** The bias corrected hindcast temperature timeseries provides continuous oceanographic conditions that were used to resolve seasonal minimum and maximum bottom temperature distributions over our study area. These temperature data were used to construct a fundamental niche model for sea scallops based on published thermal habitat. The fundamental niche thus estimates the maximum MAB habitat where scallops should be able to live based on temperature. The fundamental niche encompasses areas where maximum bottom temperatures do not exceed 23°C and minimum salinities remain above 25 ppt (Posgay 1953; Dickie 1958; Petrie and Jordan 1993; Stewart and Arnold 1994; Frenette and Parsons 2001). Observations from the federal sea scallop survey timeseries were used to recreate a realized niche model that represents the bottom oceanographic conditions scallops actually live. The realized niche encompasses areas in which minimal temperature does not exceed 7°C, and maximum temperature does not exceed 17°C. The realized niche is smaller than the estimated theoretical niche, with the constraint for minimum temperature associated with the habitat of the predator *Astropecten americanus* (Figure 3). The footprint of the theoretical and realized niche were then calculated annually based on bottom water temperature conditions, demonstrating that for both cases the niche area has declined in recent years (Figure 4).

**Next Steps:** Ongoing work includes production of species distribution correlations, development of a trophically-linked species distribution model, and obtaining bottom water forecast timeseries that can be used to make 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.
- Theoretical and realized niche models have been generated and compared over time.
- Estimated niche area, both theoretical and realized, has been shrinking in recent years in the MAB due to warming water temperature.

**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.

PUBLICATIONS


FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

![Figure 1:](image)

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 RFRMSE 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.
Realized Sea Scallop Niche

Figure 3: Realized sea scallop niche calculated from annual survey biomass and temperature timeseries hindcast. Scallops are observed in locations where the minimum winter temperature does not exceed ~7°C, and the maximum summer temperature does not exceed ~17°C.

Figure 4: Theoretical and fundamental niche area for sea scallops over time. Realized niche encompasses a smaller area than the theoretical niche, and both show declines in recent years.
**Nutrient Dynamics on the NE Continental Shelf: Sample Analyses**

NOAA Cooperative Agreement No. NA14OAR4320158  
April 01, 2017 – March 31, 2018

*CINAR Investigator – David W. Townsend, University of Maine*

*NOAA Sponsor – Jonathan Hare, NMFS*

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

*CINAR Theme: Ecosystem Forecasting*

**Amount Funded: $13,039**

**PROJECT OVERVIEW**

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 since our last project report (March/April 2017) 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

As of this writing (June 21, 2018) 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).

Our results from the February 2017 cruise showed clear evidence of deep winter convective mixing and nutrient recharge of surface waters in Wilkinson Basin (we believe this is the first such observation of this commonly-assumed oceanographic phenomenon). We also observed clear evidence of Gulf Stream Water in the Northeast Channel, 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.

This influx of Gulf Stream Water continued to penetrate into the interior Gulf of Maine, and was detected by our nitrate sensors on Buoy M in Jordan Basin (http://gyre.umeoce.maine.edu/buoyhome.php). Moreover, the same phenomenon was observed this past year, as Gulf Stream Water penetrated into Jordan Basin in the Fall-Winter period. It is unfortunate that for logistical reason, the NOAA ECOMON surveys did not reach the northeastern Gulf of Maine to perform CTD casts and collect ground-truth nutrient samples.

HIGHLIGHTS

It is worth pointing out that the second of the two unusual events just mentioned (unusually warm water penetrating into the NE Channel and interior Gulf of Maine) was reported in the press, as reported by our Canadian colleagues. It is worth pointing out that these unusual water mass influxes into the Gulf of Maine are coincident with first-time reports of ASP (Amnesiac Shellfish Poisoning,
domoic acid) and the associated diatom, *Pseudo-nitzschia australis*, in the Gulf of Maine. The Summer-Fall 2017 influx of Gulf Stream Water was also coincident with a bloom of *Karenia mikimotoi* in western Gulf of Maine coastal waters (unpublished).

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.

**EDUCATION AND OUTREACH ACTIVITIES**

Presentations made citing results of this CINAR project:
- NOAA HAB Workshop, Portsmouth, NH, March 27, 2018; Maine Dept. Marine Resources Workshop on ASP, E. Boothbay Harbor, ME, April 10, 2018

**FIGURES/PHOTOGRAPHS/ILLUSTRATIONS**

*Figure 1. Station Map: NOAA ECOMON Surveys 2009 to November 2017 (there are no data from 2018 to date).*
Table 1. Cruise dates, number of stations samples for nutrients, and number of water samples analyzed for nutrient concentrations at the University of Maine from the start of the program to date.

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<tr>
<td>Nov. 2011</td>
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<td>Nov. 2017</td>
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Sustaining Development of National Ocean Service Operational Forecast Systems Based on the Regional Ocean Modeling System

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – John Wilkin, Rutgers

NOAA Sponsor – Aijun Zhang, NMFS

Related NOAA Strategic Plan Goal: Resilient Coastal Communities and Economics

CINAR Theme: Ecosystem Forecasting

Amount Funded: $48,263

PROJECT OVERVIEW

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 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.
PROJECT MILESTONES AND ACCOMPLISHMENTS

On June 27-28, 2017, the Rutgers project team met with NOS scientists in Silver Spring (22 attendees in total) to present an overview of recent enhancements to the ROMS modeling system. These were primarily a description of the implementation in ROMS of the NUOPC (National Unified Operational Prediction Capability) coupling interface built upon the Earth System Modeling Framework (ESMF) software. This facilitates 2-way coupling of ROMS with a broad set of earth system component models used within NOAA and DoD (COAMPS, WRF, WRF-Hydro, SWAN, WAM, WaveWatchIII, ADCIRC, MOM, CICE). Both NOAA and DoD have committed their agencies to pursuing NUOPC as the coupler of choice for Federal systems, with the goal of fostering greater dynamical realism and integration of existing investments in earth system modeling, such as the National Water Model. ROMS NUOPC includes support for a “Data” model that allows the substitution of direct observations (e.g. satellite SST products, hydrographic climatology, etc.) beyond the perimeter of a ROMS regional domain instance to complete the information required by other dynamically coupled components in the event the models do not have the same geographic extent.

NOS were given an overview of the real-time U.S. East Coast forecast system (called “Doppio”) 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.

Also reported on was further experience with 2-way synchronous downscaling nesting capabilities for the NSF OOI Pioneer Coastal Array. These capabilities have matured and are being adopted by the general ROMS user community for other science applications. The 2-way nesting capability is supported by the NUOPC coupling interface. There is active development in 4DVAR data assimilation with nesting, but that is still work in progress.
THEME II. ECOSYSTEM MONITORING
Passive acoustic monitoring from autonomous platforms

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – April 30, 2018

CINAR Investigator – Mark Baumgartner, WHOI

NOAA Sponsor – Sofie van Parijs, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

Amount Funded: $ 241,313

PROJECT OVERVIEW

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 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 Gulf of Maine and conduct proximate visual surveys from the NOAA Ship Gordon Gunter during spring 2015 and 2016.
   • Deploy a wave glider in the Gulf of Maine 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 Gulf of Maine (GOM glider surveys)
   - Conduct Slocum glider surveys in areas of ecological or conservation importance to  
     baleen whales in the Gulf of Maine.

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

PROJECT MILESTONES AND ACCOMPLISHMENTS

1. ESTCP demonstration and evaluation:  A wave glider was deployed in the Gulf of Maine from  
   July 31 to October 6, 2017 to survey for large whales and to continue testing of a hydrophone  
   array designed to reduce flow noise.  A manuscript is now in preparation comparing near real-  
   time detections from Slocum gliders deployed in the Great South Channel during 2015 and 2016  
   to in-situ audio and aerial surveys to determine the accuracy of near real-time occurrence  
   estimates of large whales.

2. Nomans Land moored buoy:  The Nomans Land moored buoy was recovered on October 19,  
   2017.  The buoy was not re-deployed.  Data collected from the buoy in both 2015 and 2017 have  
   been analyzed and a manuscript on the accuracy of near real-time detections has been prepared  
   for publication.  It will be submitted in June 2018.

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:  This project is completed.

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
- Two manuscripts have been prepared or are in preparation to document the accuracy of the near real-time whale detection system.

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

No education and outreach has been conducted as yet. Several conference presentations have been made:


PUBLICATIONS

Two publications will be submitted in 2018 describing the accuracy of the near real-time whale detection system operated from Slocum gliders and moored buoys.
2017 AUV Sentry Nizinski Cruise

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Andrew Bowen, WHOI

NOAA Sponsor – Martha Nizinski, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

Amount Funded: $192,120

PROJECT OVERVIEW

For this project, the AUV Sentry was utilized in support of Dr. Martha Nizinski’s investigation of deep-sea coral habitats in canyons and slope areas off of Norfolk, Virginia, on NOAA’s R/V Pisces. Sentry was mobed in Norfolk, VA on August 26th and demobed in Morehead City, NC on September 9th.

WHOI operates the NDSF, which includes the human-occupied Deep Submergence Vehicle (HOV) Alvin, Remotely Operated Vehicle (ROV) Jason, and the Autonomous Underwater Vehicle (AUV) Sentry. These facilities are funded by federal agencies such as the National Science Foundation (NSF), the Office of Naval Research (ONR) and National Oceanic & Atmospheric Administration (NOAA) on a daily rate basis, to provide deep sea capabilities for funded science programs sponsored by these agencies. R/V Atlantis served as the support vehicle for HOV Alvin. The ROV and AUV can be installed on other vessels suitable for their deployment. This “fly-away” capability provides scheduling flexibility to meet a much wider range of requirements for the scientific community. These operations have provided scientists and students with the tools required to safely and productively pursue their research endeavors in the deep ocean using some of the most reliable and capable oceanographic research facilities in the world.
2017 AUV Sentry Jefferson Cruise

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Andrew Bowen, WHOI

NOAA Sponsor – Yvette Jefferson, OER

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

Amount Funded: $372,157

PROJECT OVERVIEW

The AUV Sentry aboard the NOAA Ship Pisces, was utilized in support of the NOAA funded cruise, to study the eastern continental margin which separates the oceanic crust from the continental crust. Sentry vehicle was used as directed by BOEM and in accordance with the capabilities discussed in the Sentry User Guide. Sentry was mobed in Morehead City, NC on September 9th and demobed in Morehead City, NC on September 29th. In addition, the Woods Hole Oceanographic Institution provided and installed one set of USBL cables to run from the NOAA Ship Pisces to the AUV Sentry control van. These cables were left installed in the NOAA Ship Pisces at the conclusion of the cruise.
The primary scientific goal for the NeMO project is to maintain the long-term time-series measurements and observations at Axial Seamount. R/V Revelle departed from Newport, Oregon on 13 July, 2017, with the Jason ROV and Sentry AUV on board and associated mission equipment staged for the cruise. The mission conducted ROV and AUV operations for a geodetics program funded by the National Science Foundation and led by Drs. Scott Nooner and William Chadwick. ROV Jason collected time-series samples for chemistry and microbiology using the PMEL Hydrothermal Fluid and Particle Sampler, titanium gas-tight samplers, and titanium major samplers. In addition to ROV operations, we recovered a mooring with 5 MAPR instruments recording hydrothermal plume data. The ship returned to Newport, Oregon on 23 July 2017.
Operational support for HabcamV4 on 2017 scallop surveys and post-cruise data processing

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Scott Gallager, WHOI

NOAA Sponsor – Peter Chase, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

Amount Funded: $ 200,611

PROJECT OVERVIEW

The use of underwater stereo imagery in stock assessment and ecosystem analysis is becoming widespread as an alternative to pelagic and benthic trawling. We have been collaborating with NOAA for the past six years in developing new, non-invasive technologies for cost effectively surveying sea scallops and ground fish. As such we have developed a stereo optical and acoustic imaging system that is currently being used by NOAA to survey scallops along the entire northeast continental shelf. This proposal was in support of our WHOI/NOAA initiative that directly relates to transition of this technology into NOAA’s operational survey and stock assessments of scallop and groundfish resources. This project supported the operations necessary to collect data for the annual scallop survey and assist in setting up the HabCam processing workflow on a NOAA Umbutu server.

Project Tasks supported in this project fall into three major categories:
1. To participate in the pre-cruise set-up of the V4 HabCam vehicle, calibration, computers, software, data storage, image processing, and training of NOAA personnel in these tasks.
2. To participate in the annual 2017 scallop surveys, and training of NOAA personnel in these tasks.
3. To participate in post cruise processing for the purpose of scallop stock assessment, and training of NOAA personnel in these tasks.

Objective 1) To participate in the pre-cruise set-up of the V4 HabCam vehicle, calibration, computers, software, data storage, image processing, and training of NOAA personnel in these tasks.

The following sub-tasks were initiated as soon as funds became available in order to make the V4 vehicle ready for the 2017 scallop surveys:
Objective 2) To participate in the annual 2017 scallop surveys, and training of NOAA personnel in these tasks.

In addition to participation in the cruises themselves, WHOI personnel completed the following:

1) Support data acquisition and deployment of HabCam and participate in scallop dredge deployment.

2) Process subsets of data (1:50 images) for annotations at sea by staff.

3) Create method to record .hab files for copying raw files to servers.

Objective 3
To participate in post cruise data processing, and training of NOAA personnel in these tasks.

Elements that have been discussed but were NOT covered by this CINAR project:

1) Process remaining images at WHOI, copy raw and pngs to WHOI servers as backup. Since the NOAA server and HabCam workflow will be operational at NOAA then these activities will not
be supported at WHOI.
2) Assist in developing a new database for interactive use with the annotator. This is beyond scope of the current project.
3) Provide support for interacting with VIAME automated image analysis software.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Tasks 1-19 were completed between the time that this funding started through to the shipping of HabCamV4 to Delaware on May 10th.

Tasks 20-23 took place during the time of the three legs of the survey.

Tasks 24-27 commenced at the end of Leg 3.

Tasks 28-34 began with the efforts of S Lerner while Leg 2 is in operation and continue throughout the Summer and Fall months.

Tasks 35-36 started at the end of Leg 3 and continue throughout the remaining year and into 2018.

HIGHLIGHTS

Data, both raw and processed were stored locally at NMFS and WHOI. Access to data for development of data products was made available to NOAA and WHOI investigators. WHOI personnel trained NOAA personnel to process and analyze data interactively with the database. Six NOAA people are now capable of operating HabCam.

EDUCATION AND OUTREACH ACTIVITIES

Gallager presented a talk at the 2017 American Fisheries Society meeting in Baltimore, MD.

Habitat Classification and Mapping Across Wide Spatial Scales Using Optical and Acoustic Sensor Fusion: The Towed and Autonomous HabCam Vehicles

Scott M. Gallager, Michael Saminsky, and Steven Lerner

PUBLICATIONS

None for 2017 but will submit two this year (2018) related to 2017 events.
Habitat Classification and Mapping Across Wide Spatial Scales using Optical and Acoustic Sensor Fusion: The Towed and Autonomous HabCam Vehicles

Scott Gallager
Michael Saminsky, Steven Lerner
Woods Hole Oceanographic Institution
American Fisheries Society 2017 Annual Meeting. Tampa, FL. August 21, 2017

NOAA Definition: Essential Fish Habitat describes all waters and substrate necessary for fish for spawning, breeding, feeding, or growth to maturity.

Our Definition: Habitat is the agglomeration of all biological, geological, chemical, and physical attributes that allow a given species or species assemblage to thrive.

Figure 1

Figure 2
### Figure 3

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
<th>Notes</th>
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<tbody>
<tr>
<td>2003</td>
<td>Start</td>
<td>CINAR V1 commissioning</td>
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<td>2004</td>
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<td>CINAR V2 commissioning</td>
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<td>V2 System survey NOAA</td>
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<td>2016</td>
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### Figure 4
The overall goal of our component of the DBO/NCIS project over the annual period of this report was to determine hydrographic and sediment characteristics that influence macroinfaunal communities and ecosystem function in the northern Bering and Chukchi Seas, specifically evaluating status and trends of these parameters using time series studies. The 2017 sampling on the USCGC Healy (HLY1702) included: (1) time-series DBO transect lines DBO1 and 3-5, (2) water column oxygen-18 measurements in seawater as an indication of sea ice melt, and (3) macrofaunal and sediment process studies on a latitudinal basis to track benthic ecosystem response to sea ice retreat and seawater warming. This approach was undertaken in concert with other DBO-NCIS investigators that are facilitating an evaluation key processes influencing the overall trophic structure and driving factors of the Pacific Arctic ecosystem. These interdisciplinary investigations are addressing variability and forcing functions in the diverse water masses and benthic habitat types that are now subject to significantly longer sea-ice free periods and increasing seasonal seawater temperatures. The field program sampled the diverse water masses and benthic habitat types that are now subject to significantly longer open water periods as seasonal sea ice has declined and seawater warms seasonally.

PROJECT MILESTONES AND ACCOMPLISHMENTS

The major accomplishment for FY17 was the planning and participation in the Year 1 research cruise on the USGCS Healy (August 26-September 15, 2017) as summarized next. The Chesapeake Biological Laboratory (CBL) research group of the University of Maryland Center for Environmental Sciences (UMCES) undertook both water column and sediment sample collections during the HLY1702 (Aug 26-Sept 15, 2017) cruise. There were two aspects to the study: first to occupy the Distributed Biological Observatory (DBO) transect lines in the southeast Chukchi Sea (DBO3), in the NE Chukchi Sea (DBO 4), and upper Barrow Canyon (DBO5), all areas of high benthic biomass, diversity, and observed change evaluated through time series studies. The second
aspect of the cruise was to undertake a Northern Chukchi Integrated Study (NCIS). Our component included measurements in the water column of oxygen-18/oxygen16 ratios (a tracer of melted sea ice content in surface waters) and a subsampling of phytoplankton taxonomy along the DBO lines and at select sites in the NECS. Surface sediment sample measurements included sediment chlorophyll, total organic carbon and nitrogen content, grain size, and isotopic content of the organic fractions. We also undertook sediment oxygen metabolism experiments, using sediment oxygen consumption as an indicator of organic carbon supply to the benthos as well as measurements of nutrient flux. Finally, we are determining macroinfaunal community structure and biomass through use of multiple grabs from the sea floor at each station. Additional measurements were made to investigate methane in water and sediments, sediment paleo markers, ostracod communities, and phytoplankton cysts.

**HIGHLIGHTS**

- Sediment chlorophyll indicates recent phytodetritus deposition in the offshore DBO3 (SE Chukchi Sea) hotspot and in the NE Chukchi Sea primarily southeast of Hanna Shoal (Figure 1-left panel)
- Highest organic carbon deposition is SE of Hanna Shoal in the NE Chukchi Sea, an area known for high bivalve biomass as prey for walrus.
- SE Chukchi DBO3 offshore stations continue to be the highest benthic biomass region in the Chukchi Sea
- Sediments over the Chukchi Sea ranged from sand and rock in the central channel and closer to the Alaska shoreline, whereas muddy sediments occurred in the offshore regions, with coarse sediments in the shallow portions of Hanna Shoal that were sampled (Figure 1-right panel).
- Highest bivalve biomass was observed in fine silt & clay sediment in the offshore areas in the southern Chukchi Sea and just SE of Hanna Shoal in the NE Chukchi Sea
- Astartid bivalves were dominant in the NE Chukchi Sea, along with maldanid polychaetes, whereas tellinid bivalves dominated the offshore SE Chukchi Sea DBO3 hotspot, all potential prey for walrus.

**EDUCATION AND OUTREACH ACTIVITIES**

Data will be archived within two years after the data are collected or created, following the NOAA ARP data policy. Subsequent long-term archiving of data will be through NOAA’s National Ocean Data Center and subsequently registered through the US Integrated Ocean Observing System (IOOS). We will also provide benthic macrofaunal data to the Circumpolar Biodiversity Monitoring Program (CBMP) and metafiles linked through the DBO parameter files for the DBO transect lines. We expect other researchers, and managers making decisions about protection afforded to critical habitat areas, will find our data and results useful.

We will continue our international partnership with the member countries of the Pacific Arctic Group (PAG). PI Grebmeier was the PAG project scientist prior to becoming the Chair from 2012-2014. She is continuing her activities within PAG on the Executive Committee as she leads the PAG-endorsed DBO project and she is also responsible for interfacing with international partners in that program. PI Cooper is the chair of the Marine Working Group (MWG) of the International Arctic Science Committee (IASC) and a US delegate appointed by the Polar Research Board of the
National Academies. Through its international research coordination activities, the IASC MWG continues to facilitate the DBO program, including providing travel support for the DBO data sharing workshops and requesting updates on the project during the annual MWG meeting held each year during the Arctic Science Summit Week.

Conference Presentations

2017 Invited plenary speaker: Ecosystem Studies of Arctic and Subarctic Seas, Tromsø, Norway, June 2017
2018 Invited Plenary Speaker: Marine Ecosystem Change, ISAR5: Fifth International Symposium on the Arctic Research, Tokyo, Japan, January 17, 2018
2018 Oral presentation: Central Arctic Ocean at ISAR5, Tokyo, Japan, January 16
2018 Poster presentation: Benthic Time Series Changes at ISAR5, Tokyo, Japan, January 16
2018 Oral presentation 2018 Time Series Trends in Benthic Macrofauna, Ocean Sciences Meeting, Portland, OR, 12 February
2018 Oral presentation IARPC Marine Ecosystem Collaborative Team Town Hall, Portland, OR, 14 February

PUBLICATIONS


Figure 1. **Left panel.** Distribution of surface sediment chlorophyll during HLY1702 in the Chukchi Sea, with higher chl a content in offshore waters in the SE Chukchi Sea DBO3 hotspot as well as the region SW of Hanna Shoal in the NE Chukchi Sea. **Right panel.** Distribution of surface sediment silt & clay content (≥5 phi), with higher percentage of silt & clay content indicative of slower current regimes. The open red circles are the DBO3 stations in the SE Chukchi Sea, DBO4 stations in the NE Chukchi Sea, and DBO5 in Barrow Canyon.
Compiling and Distributing Estimates of Assessment-probability for all US Stocks

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – April 30, 2018

CINAR Investigator – Olaf Jensen, Rutgers

NOAA Sponsor – James Thorson, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

Amount Funded: $ 19,304

PROJECT OVERVIEW

We proposed to compile “propensity scores” (representing the predicted probability of stock assessment in a given year) for all landed stocks in the U.S. Based on these scores, we set out to create an RShiny graphical user interface (GUI) where users can search for an individual stock and see its propensity score, or can download the database. For an individual stock (or set of stocks), the user will also see the predicted probability of assessment, either conditional on known assessment status (i.e., forecasted forward after the last year for unassessed stocks, or defined as 1.0 for assessed stocks) or not conditioned on known assessment status (i.e., the predicted probability of assessment for a stock with identical biological and economic characteristics). The RShiny GUI will be made publicly available online through the Rstudio RShiny server.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Project objectives:
1. Compile “propensity scores” for all stocks landed in the US
2. Create a graphic user interface (GUI) that users may search for specific propensity scores or download the entire database.
3. Disseminate results (primary literature and public Rshiny GUI).

Accomplishments:
1. A model to estimate propensity scores for stocks was developed, applied and published. The model estimates the probability (propensity) to be assessed for any year for 569 US stocks using information about assessments, life-history and NOAA landings and price data.
2. RSHINY GUI is in progress (20%) and expected to be operational by the end of 2018.
3. Results will be disseminated by March 2019.
HIGHLIGHTS

Developed and published (see below) a new method to estimate stock assessment propensity for all US stocks.

PUBLICATIONS


FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. Time-line of a) the number of stocks landed by region and assessment status, b) proportion of landed stocks that are assessed, and c) the proportion of landed tonnage derived from assessed stocks. Values in (a) and (b) are based solely on NOAA landings data resolved to species level, and exclude landings of higher taxonomic groupings (e.g., stock complexes). Some assessed stocks appear only as stock complexes prior to their first assessment; we manually added these stocks to our final dataset, but they lack a complete time-series of species-specific landings so do not appear in (a) or (b). The dotted vertical line marks the re-authorization of the Sustainable Fisheries Act in 1996 that required rebuilding of overfished stocks, and required biomass limits to be estimated.
Figure 2. Assessment status at time of last known status (censoring time) a) by taxonomic order and sorted by class and b) by habitat type. In a), classes are abbreviated as Ac: Actinopterygii, M: Malacostraca, Bi: Bivalvia, El: Elasmobranchii, C: Cephalaspidomorphi, Ga: Gastropoda, and Ce: Cephalopoda. Only orders with more than three stocks are shown.
Figure 3. Summaries of estimated posterior distributions for fixed effects, regional random effects, habitat random effects, and taxonomic class random effects in the time-to-event model. Circles show posterior medians, thick bars show inter-quartile ranges of the posteriors, and thin lines show 95% confidence intervals. A positive effect size indicates an increased assessment rate (decreased time to first assessment).
Evaluating Anglers Response to Catch Restrictions: An Application to Atlantic Striped Bass

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

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

The primary focus of our study during the 2017-2018 funding period was to understand anglers’ behavioral response to changes in recreational striped bass regulations. We developed a mail/web survey that was 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 is the primary data source for the behavioral model in which we measure the relative importance 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Much of the first five weeks of the funding period beginning on April 1, 2017 was devoted to collecting and formatting historical recreational striped bass fishing and biological data. We used these data in conjunction with the results of our recreational striped bass angler survey analysis to simulate the effects of alternative regulatory scenarios on fishing participation, angler welfare, and future stock levels (Objective #2). Striped bass catch-per-trip and harvest/release size information was obtained from the Marine Recreation Information Program (MRIP) public database, Maine's Department of Marine Resources, New Hampshire's Marine Fisheries Division, Massachusetts' Sportfish Angler Data Collection Team, Connecticut's Bureau of Natural Resources, New Jersey's Division of Fish & Wildlife, and Maryland's Department of Natural Resources. Recent striped bass age-to-length conversion charts were provided by Delaware's Division of Fish and Wildlife, Rhode Island's Department of Environmental Management, and New York's Department of Environmental Conservation.
We received the full set of data from our recreational striped bass angler survey roughly two weeks after the survey close date, April 24, 2017 (additional information about the survey development can be found in the 2016-2017 CINAR progress report form). The unadjusted survey response rate, which excludes observed ineligibles (those who have not fished for striped bass in the past three years), the deceased, those with non-working email addresses, and those for which mailings were undeliverable was 22.7%. However, it is likely that many non-respondents were ineligible. After accounting for ineligibility based on the results of the telephone pre-screening interview, the adjusted survey response rate was estimated to be approximately 35%.

Our model of angler behavior is based on responses to discrete choice experiment questions, contained in section three of the survey. 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.” A random utility model was used to determine factors that significantly influence recreational striped bass anglers’ fishing decisions and to measure the relative importance of these factors (Objectives #2 and #3). The model defines utility associated with a recreational 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).

The estimated coefficients on the striped bass catch attributes can be used to infer the relative importance of these factors on angler utility. We also calculate the marginal rate of substitution (MRS) between striped bass keep attributes to evaluate angler preferences for the size of fish harvested and tradeoffs with bag limits. The results from our angler behavioral model are then used as input into a simulation model which predicts the effects of regulations on trip behavior, aggregate welfare, and fishing mortality. Our simulation analysis focused on recreational striped bass fishing in Massachusetts, Rhode Island, and Connecticut because these states experienced the same decrease in the daily bag limit from two to one fish between 2014 and 2015.

The external data sources mentioned above were used to generate distributions of trip-level outcomes over anglers. From these probability distributions, we simulate recreational fishing trips in the study region, where, on each trip, an angler is randomly assigned a number and size of striped bass caught on the trip. The imposed regulations (actual or hypothetical) dictate whether these fish are kept and released. Using the estimated parameters from the behavioral model, we calculate the probability of a trip occurring conditional on the number of striped bass kept and released by size and other trip factors, and a measure of trip-level angler welfare. We aggregate the probability-weighted number of fish kept and released, by size, across all simulated anglers, under both baseline and alternative regulatory scenarios and calculate changes to total and spawning stock mortality. Additionally, we examine the change in aggregate angler welfare (compensating variation) that accompanies these changes in regulations.

To gauge the accuracy of our model predictions, we first simulated observed changes in regulations in the study region between 2014 and 2015 and compared our model predictions to actual outcomes.
The simulation model calibration diagnostics shown in Table 1 reveal that the fishery outcomes predicted by our model approximate realized outcomes. We then calculated the likely effect of a variety of counterfactual 2015 regulations on fishery outcomes relative to outcomes induced by the actual 2015 regulations (one fish, 28” or longer). The counterfactual 2015 regulations that were analyzed held the 2015 bag limit at one fish but altered the legal-size restriction. We examined the effects to fishery outcomes induced by a 20” minimum size limit and three slot limit size restrictions (20”-28”, 20”-36”, and 28”-36”). Figure 1 displays the results of these simulated regulatory scenarios.

In the final part of our simulation analysis, we examined the impacts to fishery outcomes from a set of hypothetical size restrictions that could accompany a one-fish increase in the bag limit to two fish, as this is most likely future path of striped bass regulations in these states (Objectives #2 and #3). The regulations for these hypothetical scenarios were as follows: (a) 2 fish ≥ 28”, (b) 2 fish 20”-28”, (c) 2 fish 20”-36”, (d) 2 fish 28”-36”, (e) 1 fish 20”-28” and 1 fish ≥ 28”, (f) 1 fish 20”-28” and 1 fish 28”-36”, (g) 1 fish 28”-36” and 1 fish ≥ 36”. Figure 2 displays the results of these simulated regulatory scenarios.

Finally, preliminary analysis exploring calibration and estimation approaches to empirical bioeconomic models (Objective #4) highlighted some key tradeoffs between these approaches. While calibrated models allow a more complex description of stock dynamics and fisherman behavior, they can be sensitive to ad hoc parameter selection by the researcher. Similarly, while estimation approaches provide internally consistent model parameters they require strong simplifying assumptions (e.g., reduced form descriptions of fisher behavior and/or stock dynamics) to ensure statistical identification of these parameters. Ongoing work is focused on developing a “fair” baseline comparison for simulating potential differences in predictions/recommendations between these alternative approaches.

HIGHLIGHTS

- We find that anglers prefer keeping and releasing larger striped bass to smaller ones, as the magnitude of the keep and release parameters increase as the size of striped bass increases.
- Marginal rates of substitution between striped bass keep parameters were estimated as follows:
  - Small/Medium-sized = 1.19
  - Small/Trophy-sized = 1.90
  - Medium/trophy-sized = 1.60
  - From these ratios, we can infer that an angler forced to forgo harvest of a medium-sized (29”) striped bass would need to harvest of 1.19 small (22”) striped bass for utility to remain unchanged. Similarly, the compensation required to hold utility constant if an angler was forced to forgo harvest of a trophy-sized (38”) striped bass would be 1.6 medium-sized striped bass or 1.9 small striped bass.
- The decrease in bag limit from two to one fish in the study region between 2014 and 2015 generated a roughly $5 million loss in consumer surplus (Figure 1).
- A one fish, 20” minimum size regulation in 2015 would have likely resulted in net positive change in angler welfare, even with the decreased bag limit. Compared to the actual 2015 regulation, this would have resulted in a fewer number of spawning striped bass killed, but a slightly higher number of total fish killed (Figure 1).
A one fish, 20”-28” slot limit regulation in 2015 would have likely resulted in a loss of angler welfare comparable to the loss induced by the actual 2015 regulation. This regulation is found to be the most effective at reducing total and spawning fish mortality across all evaluated scenarios (Figure 1).

A one fish, 20”-36” slot limit regulation in 2015 would have likely resulted in a net positive change in angler welfare. Compared to the actual 2015 regulation, this would have been more effective at reducing both total and spawning fish mortality (Figure 1).

A one fish, 28”-36” slot limit regulation in 2015 would have likely resulted in a substantial loss in angler welfare more than doubling the loss induced by the actual 2015 regulation (Figure 1).

Tradeoffs between angler welfare and stock impacts in the advent of a two fish bag limit seem most balanced with full or partial restrictions on the harvest of large, trophy-sized striped bass (Figure 2).

EDUCATION AND OUTREACH ACTIVITIES

Results from the simulation analysis were presented at the Southern Economic Association (SEA) conference. “Using length-based regulations to meet multiple management objectives: an analysis of the recreational fishery for Atlantic striped bass” Andrew Carr-Harris. Tampa, FL. November 19, 2017.
Figure 1. Aggregate compensating variation (top) and change in number of total and spawning fish harvested (bottom) in 2015 evaluated over four counterfactual scenarios. Policy A is the actual 2014 regulations and is used as the baseline. Policy B is the actual regulations in 2015.
Figure 2. Aggregate compensating variation (top) and change in number of total and spawning fish harvested (bottom) in 2016 evaluated over eight counterfactual scenarios. Policy B is the actual 2015 regulations and is used as the baseline.

Table 1. Simulation Model Calibration Diagnostics

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<th>2014</th>
<th>2015</th>
<th>%Δ2014–2015</th>
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<tr>
<td>Actual regulations</td>
<td>2 fish, 28”</td>
<td>1 fish, 28”</td>
<td></td>
</tr>
<tr>
<td>Total harvest</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Actual</td>
<td>673,832</td>
<td>529,467</td>
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<tr>
<td>Simulated</td>
<td>694,918</td>
<td>455,503</td>
<td>-34</td>
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<tr>
<td>Dead spawners</td>
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<td></td>
<td></td>
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<tr>
<td>Actual</td>
<td>28,869</td>
<td>17,672</td>
<td>-39</td>
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<tr>
<td>Simulated</td>
<td>29,740</td>
<td>16,831</td>
<td>-43</td>
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<tr>
<td>Releases</td>
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<tr>
<td>Actual</td>
<td>2,293,511</td>
<td>2,757,722</td>
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<tr>
<td>Simulated</td>
<td>2,207,685</td>
<td>2,338,116</td>
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Support for updating stock assessments in the Southeastern US

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Genevieve Nesslage, UMCES

NOAA Sponsor – Erik Williams, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Management

Amount Funded: $44,970

PROJECT OVERVIEW

In 2017, we conducted a supplemental analysis of golden tilefish data for the NOAA Southeast Fisheries Science Center's Beaufort Laboratory. This research focused on identifying patterns in and potential environmental drivers of the MARMAP survey's catch of golden tilefish. Our objectives were to identify sex-specific differences in catch and to correlate trends in catch with climate indices and temperature.

PROJECT MILESTONES AND ACCOMPLISHMENTS

We requested an extension to this project in order to allow supplemental analysis of golden tilefish survey data to be conducted during summer 2017 by an REU student. Golden tilefish are a demersal, stenothermic species that support an important fishery off the Southeast coast of the United States. The current stock assessment model relies heavily upon fishery-dependent data over fishery-independent data, and does not incorporate environmental effects on catchability. In 2017, we analyzed longline survey data from the fishery-independent MARMAP (Marine Resources Monitoring Assessment and Prediction) program, catch data from the South Atlantic fishery, and climate data to determine the effects of a variety of environmental drivers on catchability and abundance indices. Our results suggest the presence of sex-specific catchability and time-varying catchability, neither of which is accounted for in the current assessment. We also detected marked declines in the MARMAP abundance index following 3-5 years after anomalously cold years, and identified the North Atlantic Oscillation as a potential predictor of relative abundance. These tentative findings require more data to verify, but suggest that survival of juvenile tilefish is affected by low temperatures and that existing climate data could be used to predict future stock declines. We recommend that the stock assessment for this species consider increasing the weight of fishery-independent data relative to fishery-dependent data, and begin collecting sex-specific data to support stock assessments.
HIGHLIGHTS

- Golden tilefish appeared to exhibit sex-specific catchability in the MARMAP longline survey.
- Fishery-dependent and independent indices of abundance did not track the same trends in relative abundance, indicating a problem for stock assessment.
- Marked declines were detected in the MARMAP abundance index following 3-5 years after anomalously cold events.

EDUCATION AND OUTREACH ACTIVITIES

Work on this project was conducted by an NSF REU student, Connor Neill of the University of Minnesota, who was supervised by PI Nesslage. The REU student presented the results of his work at the Annual Meeting of the Southern Division of the American Fisheries Society.
**Ecosystem Based Management: An Analysis of Needs and Opportunities by the Cooperative Institute for the North Atlantic Region (CINAR)**

NOAA Cooperative Agreement No. NA14OAR4320158  
April 01, 2017 – March 31, 2018

**CINAR Investigator – Michael Roman, UMCES**

**NOAA Sponsor – Felix Martinez, NOS**

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

**CINAR Theme: Ecosystem Management**

**Amount Funded: $482,685**

**PROJECT OVERVIEW**

The overarching objective for the ecosystem-based management (EBM) project is to develop an updated document for use by NOAA and NCCOS that reviews coastal marine ecosystem issues and identifies candidate ecosystem research topics for locations where an investment in research by NOAA might enable an EBM approach. Investigators will assess results and lessons from existing EBM and EBM-like programs. Investigators are also reviewing regional partnerships and resource management characteristics to determine critical science gaps and potential barriers to EBM strategies. The project plans to engage coastal marine resource scientists, managers, and policy-makers in three data collection phases, beginning with an online survey and following with structured interviews and regional workshops. This research is aimed at gaining a better understanding of where perceived management challenges exist in practice and identifying research gaps that impede EBM strategies.

**PROJECT MILESTONES AND ACCOMPLISHMENTS**

The entire team has met twice with the NCCOS Program Manager to discuss project goals and directions. The PI and NCCOS Program Manager have also kept regular monthly meetings to share updates on progress. A post-doctoral research assistant was hired in February 2018.

The EBM team has developed a research plan, specific activities, and an anticipated timeline to achieve projects goals.

Investigators have formally described the responsibilities of an advisory committee that will be engaged in project developments and review. Three individuals have agreed to join the advisory committee: Larry Crowder, Kristin Baja, and Heather Leslie.
The team has developed a preliminary EBM evaluation tool and begun case studies. The team is also currently preparing the initial online survey, including requirements for the Institutional Review Board process and compiling email lists of potential participants, for release in the coming weeks.

HIGHLIGHTS

- Hired post-doctoral researcher
- Formed the advisory committee
THEME IV. PROTECTION AND RESTORATION OF RESOURCES
Supporting the National Oceanic and Atmospheric Administration’s (NOAA) Office of Ocean Exploration and Research (OER)’s New 2017 program with the National Science Foundation

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Andrew Bowen, WHOI

NOAA Sponsor – Yvette Jefferson, OER

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

Amount Funded: $1,797,303

PROJECT OVERVIEW

WHOI and OET operate a suite of equipment intended to offer scientists and researchers access to the deep sea. In an effort to make their combined programs cost-effective, WHOI and OET are collaborating to maximize their operational efficiencies, between WHOI’s deep submergence operating base on the East Coast of America with OET’s deep submergence program which is based on the West Coast of America. The purpose of this project was to update and expand the capabilities of OET’s vehicle systems.

In Fy-17 NOAA’s Office of Ocean Exploration (OER) received a $4 million increase in funding over FY-16 that "encourages NOAA to partner with non-government organizations, academic institutions and other government agencies including the National Science Foundation (NSF)" to expand their ocean exploration program using tele-presence exploration technology and to "share costs with their partners." Of these funds, $2 million were requested in order to accomplish three objectives in support of a new program between NOAA OER and NSF. The first was to up-grade OET’s three vehicle systems ARGUS, HERCULES and LITTLE HERC from a 4,000-meter capability to 6,000-meter capability given the greater depth of the Pacific compared to where it has been working since 2008. The second was to prepare these vehicles for use on other ocean-going platforms that might become available during the course of this new joint NSF/OER program. The third objective was to conduct a shakedown cruise for these new systems on the R/V RON BROWN in April 2018, during a traverse from Jakarta to Guam.
Incorporating Environmental Variables to Improve Assessment and Predictive Capacity for American Lobster in a Changing Gulf of Maine and Southern New England

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – April 30, 2018

CINAR Investigator – Yong Chen, School of Marine Sciences, University of Maine

NOAA Sponsor – Michael Ford, Burton Shank (NMFS)

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

Amount Funded: $ 85,099

PROJECT OVERVIEW

- **Objective I:** Project possible spatio-temporal changes in suitable habitat, molting and abundance of American lobster in changing SNE and GOM.
- **Objective II:** Incorporate key environmental variables into the lobster stock assessment model to better assess the SNE and GOM lobster stocks.

To achieve the first objective, we planned to develop habitat suitability model and lobster distribution model for the SNE and GOM lobster stocks in the proposal to hindcast and project changes in lobster habitat quality and distribution. This has resulted in the publication of several papers and the models developed have been extended to other species (e.g., Atlantic sea scallop). We planned to incorporate the environmental variables and changes in habitat quality in the current stock assessment. We have partially achieved this goal. We have been working with ASMFC Lobster Technical Committee and Stock Assessment Committee to improve existing lobster stock assessment for the GOM-Georges Bank lobster stock. We have presented the results to the Lobster Assessment Committee and are encouraged to continue developing the models.

PROJECT MILESTONES AND ACCOMPLISHMENTS

The following is the milestone table we included in the proposal:

<table>
<thead>
<tr>
<th>Project timeline</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Months 0-3</td>
<td>Compile all the data and thorough literature review</td>
</tr>
<tr>
<td>Months 4-6</td>
<td>Evaluate and quantify possible spatio-temporal dynamics in suitable habitat, molting, and abundance of American lobster in SNE and GOM</td>
</tr>
</tbody>
</table>
### Months 7-9
Compare and identify the quantitative relationships for incorporation of habitat information in the length-structured shrimp stock assessment model, and start to code the computer program

### Months 10-12
Code and debug the computer program, and outreach with Atlantic States Marine Fisheries Commission Lobster Technical Committee and Maine Department of Marine Resources

### Months 13-15
Design and conduct the simulations study for testing the impacts of including habitat information on lobster stock assessment using the new model

### Months 16-18
Continue the simulation study and possible improvement of the model based on the simulation results, present the preliminary results to Atlantic States Marine Fisheries Commission Lobster Technical Committee

### Months 19-21
Continue the simulation and model improvement, and start to compile the data for the actual stock assessment; present the revised results to Atlantic States Marine Fisheries Commission Lobster Technical Committee

### Months 22-24
Complete the simulation and stock assessment, and present the final results to Atlantic States Marine Fisheries Commission Lobster Technical Committee and Maine Department of Marine Resources

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*The following provides a summary of our research activities:*

We have compiled all the data and thorough literature review; evaluated and quantified possible spatio-temporal dynamics in suitable habitat, molting, and abundance of American lobster in the Gulf of Maine; compared and identified the quantitative relationships for incorporation of habitat information in the length-structured stock assessment model, and coded the computer program; and outreached with Atlantic States Marine Fisheries Commission Lobster Technical Committee and Maine Department of Marine Resources. We have presented the new stock assessment results with the incorporation of habitat quality in the recruitment dynamics at the ASMFC Lobster Stock Assessment Committee. Two of my students have been involved in the on-going lobster benchmark stock assessment with the newly developed model.

We are in the process of design and conducted a simulations study to test the impacts of including habitat information on lobster stock assessment using the new model

During April 2017-March 2018, we have published four peer reviewed papers and there are currently two manuscripts in review.

We have presented at 3 conferences (2 domestic and 1 international). We have received total $190625 of research and travel grants.

Kisei R Tanaka was invited to give guest lecture at National Research Institute of Fisheries Science (Japan) and Princeton University. Tanaka was also received the 2017 University of Maine Graduate Research Excellence Award.
HIGHLIGHTS

- Four peer reviewed papers (four manuscripts in review)
- Presented the results to the ASMFC Lobster Technical Committee and Lobster Stock Assessment Committee, and the new model will be used in the on-going benchmark stock assessment in 2018-2019 for the GOM-Georges Bank lobster stock.
- Oral and poster presentation at 3 conferences (2 domestics, 1 international)
- Additional funding received
  - K. R. Tanaka - International Council for the Exploration of the Sea (ICES) Early Career Scientists Travel Funds, €500
  - K. R. Tanaka - University of Maine Graduate Research Excellence Award, $1,500, 2017
  - K. R. Tanaka - Maine Sea Grant Program Development Award, $4,000, 2017

EDUCATION AND OUTREACH ACTIVITIES

Conference presentations


Invited Seminars


PUBLICATIONS

Peer Reviewed Publications

Developing a framework to incorporate prey abundance in species distribution models. Marine Biology Research.


Manuscripts in Review


FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. Five graduate students from the Chen lab, University of Maine received travel funding to present their research at the ICES Annual Science Conference in Riga, Latvia.
PROJECT OVERVIEW

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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Major accomplishments this project year have centered on honing the research plan for the postdoc, Dr. Felix Massiot-Granier. Felix’s work has focused on Objective 3 (Model how ecosystem changes are affecting energy flow to Atlantic salmon and the impacts of these changes to salmon growth, survival, and productivity). He is currently approaching this objective by developing a dynamic energy budget (DEB) model for Atlantic salmon. This model determines growth as a function of several parameters, such as temperature and food intake, at multiple life stages. As such, it provides the capacity to estimate and predict growth of Atlantic salmon in dynamic ecosystems.

To develop this model, Felix tested various approaches for aligning growth measurements with calendar dates so that growth can be paired with environmental data. He has also gathered data from a variety of local sources (e.g., hatcheries, ME DMR) to parameterize and bound variability associated with specific functions in the model. These local data have been valuable since the Penobscot run of Atlantic salmon is largely hatchery-supported, making it unique from wild
populations or controlled experiments that are represented in the literature.

Initial results indicate that growth patterns observed in the Penobscot population are consistent with changing food intake in the marine ecosystem. Across the time periods for which we have growth data, the DEB model indicates that food intake of 2-seawinter females declined in the 2000s compared to the 1980s-1990s (Figure 1). In contrast, grilse (1-seawinter males) appear to have experienced low food intake during the 1990s-early 2000s (Figure 2). This dip in food intake aligns with a shift in the North Atlantic zooplankton community (Figure 2), which Mills et al. (2013) found was correlated with Atlantic salmon population trends.

The DEB model accounts for individual variability in environmental conditions that may be encountered and growth responses that may occur. Outputs can be incorporated into population models by using individual-level variability from the DEB to parameterize uncertainty estimates at the population level. Felix will begin this population modeling in the coming year.

Substantial progress also has been made in collecting growth data from salmon sampled off of West Greenland (scale-collecting and reading led by Tim Sheehan and Ruth Haas-Castro). PI Mills has provided input to shape data collection and conferred on preliminary results. She also participated in a meeting of the Atlantic Salmon Research Joint Venture (Halifax, December 2017), where a variety of research efforts using West Greenland salmon samples were discussed. Mills has recently hired a technician who will support analysis of the Greenland growth data (and also help formalize and finalize a paper analyzing the Penobscot River growth patterns).

HIGHLIGHTS

Development of a dynamic energy budget model for Atlantic salmon that can be used to (1) estimate growth of Atlantic salmon based on past ecosystem conditions and identify conditions that most influenced salmon growth patterns, (2) predict Atlantic salmon growth under future ecosystem scenarios, and (3) provide inputs to a population model to determine impacts of changing growth and individual growth variability on population productivity and abundance.

EDUCATION AND OUTREACH ACTIVITIES


We also gave the following conference presentations:


FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

![Figure 1](image)

**Figure 1.** Estimated food intake of 2-seawinter female salmon that returned to the Penobscot River during four periods spanning 1978-2014.
Figure 2. Estimated food intake of grilse (1-seawinter male salmon) that return to the Penobscot River during four periods spanning 1978-2014 (red), and the alignment of food intake with zooplankton community composition in the North Atlantic at a 3-year lag (blue) (Mills et al. 2013).
**North Atlantic Right Whale Database Reorganization and Publication**

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

*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: $26,017**

**PROJECT OVERVIEW**

Data from necropsies of North Atlantic right whale (NARW) mortalities examined since 1970 were first collated and summarized in a paper published in 2004 (Moore et al. 2004). Data for that paper were assembled in an Access database along with case folders of all available documentation including field data, photographs, diagnostic reports, and summary case reports. The Access database has been maintained in subsequent years, although it was in need of updating, expansion and proofing.

The objective of this project is to bring the database up to date, and to report a summary of the available data between 2003 and 2018, publishing a paper that summarizes NARW whale morbidity and mortality 2004-2016

- Trends in mortality over time (ship strike, entanglement, other)
- Characterization of entanglement-related orthopedic lesions (using gross and histological data, as available)
- Characterization of fatal entanglement wounds (body site, depth, chronicity)

The resulting database will be submitted for inclusion in the Marine Mammal Health and Stranding Response Health Map database.

**PROJECT MILESTONES AND ACCOMPLISHMENTS**

- Database entry and quality control: complete
- Publication of cases from 2003 to present: manuscript in draft
HIGHLIGHTS

- 144 right whale mortalities documented and databased to varying degrees of detail between 1970 and 2018
- Database fields include morphometrics, location, date, cause of death and many others
- Documents and other files associated with each case are filed in a single folder for each case
- A manuscript is in draft form, titled “Gross and histopathological findings from North Atlantic right whale (Eubalaena glacialis) mortalities between 2003 and 2018.”

EDUCATION AND OUTREACH ACTIVITIES

Requests for access to data are processed through the North Atlantic Right Whale Consortium Data Access Protocol

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. Screenshot of the front page of the database.
Global Ocean Observing Coordination Activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Champika Gallage, WMO

NOAA Sponsor – Steve Piotrowicz, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean and Observations and Climate

Amount Funded: $ 586,000

PROJECT OVERVIEW

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 is the Physics Panel of GOOS, and leads on delivering the Climate Theme, working across the GOOS panels to deliver to GCOS. The panel also leads on delivering to operational services for GOOS, and provides advice to JCOMM; particularly the Observations Coordination Group. The panel therefore has a substantive engagement role, brokering the relationship between GCOS and GOOS, working with WCRP and JCOMM and also into the World Meteorological Organisation in support of Operational Services.

The OOPC is chaired by Bernadette Sloyan and John Wilkin, and secretariat support is provided by Katherine (Katy) Hill. Given the complexity of Katy’s role in supporting the work plan of OOPC and the engagement overhead outlined above, Katy has stepped away from additional activities this year, including oversight of the JCOMM Observation Coordination Group, and OceanObs’19 coordination to focus on core business. Katy has successfully mentored new staff to support the JCOMM OCG and handed over responsibility, though continues to act as ‘international coordinator’ for OOPC, given the importance of plugging the project back into international governance structures. However, the GOOS and GCOS leadership recognize that further support is needed to effectively oversee activities at the GCOS-GOOS interface, and until resources are identified, rigorous prioritization of OOPC and secretariat priorities will be needed. The GCOS and GOOS leadership have agreed to work together to strengthen support and guidance to OOPC and the secretariat.

Following the completion of the 2013-2018 work plan, and delivery of the GCOS Implementation
Plan, OOPC is forming it’s next work plan: focused on developing and reviewing EOV and ECV requirements including engaging in WMO requirement setting, and observing system evaluations focused on Heat and Freshwater Storage, Air Sea Fluxes and Boundary Currents, in addition to developing a strategy for working with the modelling community.

OOPC is contributing strongly to the organization of the OceanObs’19 conference, with two panel members are co-chairs of the Programme Committee, and one panel member is Co-Chair of the Sponsors Committee. The OOPC secretariat has also contributed strongly to establishing governance and initial planning efforts, before stepping away to focus on core business.

2. **WMO-IOC Joint Commission for Oceanography and Marine Meteorology in-situ Observing Platform Support Centre (JCOMMOPS)**

JCOMMOPS contributed to the World Meteorological Organization (WMO) global ocean observing coordination activities for 2017-2018 focusing 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).

- JCOMMOPS provides a centralized information and technical support facility, required for coordinating the design, evolution, implementation and maintenance of many of the existing in situ operational ocean observing networks operated under Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) by WMO Members and IOC Member States such as drifting and fixed data buoys, ship-based observations, hydrography surveys, sea level observations using tide gauges, oceanographic measurements made with profiling floats and ocean gliders, etc. Coordination of strategies for the deployment of instruments between national actors, and quality monitoring activities are key to the success and effectiveness of ocean observing systems. A number of essential ocean observing system monitoring tools are provided by JCOMMOPS in support of the national operators in charge of implementing such observing systems. Moreover, JCOMMOPS encourage the integration within the WMO Integrated Global Observing System (WIGOS) and GOOS, and the required cooperation and optimization of observing systems.

- 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

1. Ocean Observations Coordination (OOPC and JCOMM OCG)

- Successfully ran and reported on the 21st Session of OOPC in March 2018
- Contributed to the development of GCOS and GOOS Strategic plans, and successfully organized a joint GCOS-GOOS leadership meeting to discuss how GCOS and GOOS could work together into the future, including agreements on support and guidance for OOPC.
- Participated in the Cross GOOS Panel meeting, and contributed to the development of the GOOS programmatic Implementation Plan
- 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.
- Participates in online GOOS Staff meetings to facilitate coordination across GOOS activities.
- Successful transition of support for JCOMM OCG to IOC Staffer Emma Heslop.
- 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

JCOMMOPS has managed to achieve some important tasks in 2017, including the following examples:

Metadata
- In 2017 JCOMMOPS has been able to report and analyze the Argo network implementation status in depth (see 2017 report & 2018 presentation). When the tool box is operational, the
Technical Coordinator can spend much more time in analyzing rather than producing the tools, and then provide useful recommendations for the Steering Team and early gaps detection.

- The other networks need much more work on metadata quality before enabling such reporting. Thus JCOMMOPS has been putting a lot of efforts in addressing the metadata issues for these Networks. This information management is now on the rails for DBCP, OceanSITEs and SOT. It needs a strong and labour intensive work by the respective Technical Coordinators(TCs) to check the metadata quality and help the community to use the central system.

- There was active discussions with OceanSITEs to develop the metadata management at JCOMMOPS. A set of teleconferences with Data team and key experts was used to finalize JCOMMOPS database and web site, and start to define reference tables. A number of key SITES were registered to test and finalize the interface. OceanSITEs platforms are rather complex in term of instrumentation and this work will be very useful beyond this Network. There are very rich cruise reports on-line that capture all information aside moorings maintenance that could be exploited further.

- A substantial effort went to support the SOT metadata management. The system initially set up at Meteo-France/ESURFMAR for PUB 47 metadata was migrated to JCOMMOPS infrastructure through a rather transparent process for users. In parallel the SOT management within the JCOMMOPS integrated database/web was being finalized.
  - As the Ship Coordinator was replaced temporarily by a data manager, this was an ideal opportunity to boost this task, in conjunction with the work of the Web developer, the IT Engineer and the Lead.
  - A global survey of Pub47 historical metadata was achieved to define new requirements for JCOMMOPS, rationalize the content through reference tables, and develop a new web service to facilitate operators work.

- In parallel, the work on DBCP moored buoys metadata started and the JCOMMOPS system is ready to handle the information properly (priority for DBCP).

- A substantial work was achieved for GO-SHIP, with the archiving of all WOCE and CLIVAR cruises (including variables measured) and many ad hoc information that are cross-programmes and complete the integrated database. A lot of information needs now to be exploited to develop indicators and routine monitoring products.

- The gathering of cruise plans was made but not fully completed. The community starts as well to register the cruise plans directly.

**JCOMM V**

JCOMM conference has been an opportunity to review key documents for JCOMMOPS. The Centre visibility was clearly elevated by co-presidents and secretariats and JCOMMOPS has gained now some important responsibilities (see [JCOMM-5 meeting report](#)). The preparation of submission of metadata to WIGOS was tested in close cooperation with the WIGOS/OSCAR development team and evolve gradually with new requirements and specifications.
I.T. Web Developments

Number of developments were made in line with the metadata management. Since JCOMMOPS had almost a full time web developer along 2017, updates have been made almost daily on JCOMMOPS websites.

It is recalled that there is one single application to drive all JCOMMOPS websites. Access to these websites specialized by Network is only triggering a filter on the system elements and a few specificities. Any development made is in theory available for all Networks, provided they have the metadata ready.

The feedback from the community on the new web application is varied and sometimes “extreme”. It is improving but is calling for a strong communication and regular interaction with users. The integrated vocabulary used is challenging for different communities. Hence JCOMMOPS is building up a help desk, including vocabulary definitions and tutorials.

Progress was made on the GIS engine to test some 3D capacities for the monitoring and would deserve to be further investigated for outreach.

JCOMMOPS websites include:

- argo.jcommops.org
- dbcp.jcommops.org
- sot.jcommops.org
- oceansites.jcommops.org
- go-ship.jcommops.org
- http://www.jcommops.org/board?t=atlantos
- www.jcommops.org (beta)

KPIs

The development of KPIs is gradually progressing as long as Networks define their targets and interact with their TCs. Indicators have been regionalized to have clear view on smaller basins. So far about 400 indicators (and time series) are ready and updated routinely. The interfaces allows many comparisons between the indicators and can be embedded on any website (as most of existing monitoring tools available on www.jcommops.org).

Projects

JCOMMOPS has been delivering what was expected by its AtlantOS work package with a very good rating through the review process: A full dashboard is enabled to monitor the AtlantOS system.
JCOMMOPS has started to participate in the TRUSTED project, funded by EUMETSAT, and led by CLS together with MeteoFrance, SHOM, NKE and BSH to deploy 150 HR SST drifters. JCOMMOPS will develop the metadata format and flow from manufacturer to user within the DBCP context. This is an ideal project for the team and the new Technical Coordinator to develop its expertise along a substantial contribution to the Global Drifter Array, with link to the HRSST pilot project.

HIGHLIGHTS

1. Ocean Observations Coordination (OOPC)
   - OOPC strongly engaged in the organization of OceanObs’19, and also contributing strongly to Community Whitepapers. The OOPC Secretariat played a key role in establishing organizing committees, and initial sponsors engagement.
   - Panel has ongoing focus on brokering EOV/ECV requirements, working with OCG and regional bodies to coordinate observing networks.
   - Establishing new forward work plan with a focus on observing system evaluations for ocean heat and freshwater storage, air sea fluxes and boundary currents.
   - OOPC has also initiated discussions with GODAE OceanView (renaming to OceanPredict) regarding strengthened collaborations, and is discussing the connection to the modelling communities more broadly.
   - Successfully advocated for continuance of microwave SST missions with satellite agencies.

2. JCOMMOPS
   - A new generation of Information System, integrated metadata management and web applications
   - Development of Key Performance Indicators to track network status and anticipated gaps
   - Release of the JCOMM Report Card to communicate on OCG network status and value
   - Enhanced responsibilities adopted at JCOMM V (see new ToR), and greater visibility.

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 http://www.goosocean.org/index.php?option=com_content&view=article&id=60&Itemid=169.

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.’

**OceanObs19 Conference** - Planning the OceanObs’19 Conference has commenced, which will be held from the September 16-20, 2019. The Secretariat assisted in identifying leadership for the program committee, and securing sponsorship from key agencies and programs. More details can be found at [www.oceanobs19.net](http://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.

<table>
<thead>
<tr>
<th>Dates</th>
<th>Meeting</th>
<th>Location</th>
<th>Person(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-7th April 2017</td>
<td>GODAE OceanView COSS TT</td>
<td>Cape Town, South Africa</td>
<td>John Wilkin</td>
</tr>
<tr>
<td>3-7th April 2017</td>
<td>WCRP Joint Steering Committee</td>
<td>Paris, France</td>
<td>(Carolin/Albert)</td>
</tr>
<tr>
<td>09-11 May 2017</td>
<td>NOAA OOMD Community Workshop</td>
<td>Paris, France</td>
<td>Katy (by remote)</td>
</tr>
<tr>
<td>10-18th May 2017</td>
<td>WMO Executive Council</td>
<td>Geneva, Switzerland</td>
<td>Katy</td>
</tr>
<tr>
<td>22-25th May 2017</td>
<td>JCOMM Observations Coordination Group</td>
<td>Qingdao, China</td>
<td>Katy</td>
</tr>
<tr>
<td>19-30th June 2017</td>
<td>IOC Assembly</td>
<td>Paris, France</td>
<td>Katy</td>
</tr>
<tr>
<td>10th-11th July 2017</td>
<td>CoReSyF User Board Meeting</td>
<td>Lisbon</td>
<td>John Wilkin</td>
</tr>
<tr>
<td>10th-14th July 2017</td>
<td>WCRP / IOC Sea Level Conference</td>
<td>Columbia University, USA</td>
<td>Katy</td>
</tr>
<tr>
<td>5-7 September 2017</td>
<td>GOOS Regional Forum</td>
<td>National University of Singapore, Singapore</td>
<td>John Wilkin</td>
</tr>
<tr>
<td>11-15 Sept 2017</td>
<td>GOOS SC</td>
<td>Singapore</td>
<td>John Wilkin</td>
</tr>
<tr>
<td>25-29th September 2017</td>
<td>GCOS SC</td>
<td>Hangzhou, China</td>
<td>Bernadette,</td>
</tr>
<tr>
<td>16-20 October 2017</td>
<td>TPOS 2020 SC4</td>
<td>Seattle, USA</td>
<td>Katy</td>
</tr>
<tr>
<td>25th October - 1st November 2017</td>
<td>JCOMM 5 Session</td>
<td>Geneva, Switzerland</td>
<td>Katy</td>
</tr>
<tr>
<td>20-24th November 2017</td>
<td>AtlantOS General Assembly</td>
<td>Gran Canaria, Canary Islands, Spain</td>
<td>Katy</td>
</tr>
<tr>
<td>February 2018</td>
<td>Ocean Sciences meeting, GOOS Exec, TAOS Review</td>
<td>Portland, Oregon</td>
<td>Katy, other panel members.</td>
</tr>
<tr>
<td>28th Feb-5th March</td>
<td>Cross GOOS, GOOS Exec, GOOS Staff Meetings</td>
<td>Hobart, Australia</td>
<td>Bernadette, John, Katy</td>
</tr>
</tbody>
</table>
2. **JCOMMOPS**

**Webinars** – A set of webinars was made to engage discussion with community around the JCOMMOPS and its website. List is available at:

http://www.goosocean.org/index.php?option=com_content&view=article&id=60&Itemid=169

**JCOMM Report Card** - The first JCOMM Report Card 2016 ([www.jcommops.org/reportcard](http://www.jcommops.org/reportcard)) was released during JCOMM V conference after an active work within JCOMMOPS and with the OCG Report Card Editorial Board. The JCOMM Report Card 2016 was the first ever effort by JCOMM to standardize and publish the annual status and health of the Global Ocean Observing System. The Report Card 2016 assessed: the status of the observing system, in term of international contribution and performance; and the value of the system, critical for many applications and socio-economic needs.

**Workshop** - An outreach workshop, the 1st Ocean Observers Workshop, was successfully hosted in Brest in June 2017 to bring together ocean scientists, educational authorities and teachers, marine communicators, sailing community and other stakeholders (public, policy-makers, and etc.), who were willing to share marine science educational resources and experiences for exploring the possibilities to establish new international collaborative activities. A key focus of the initiative is to gather and share experience on educational activities related to in situ ocean observations, to be able in the longer term, to assemble all educational materials in a unique repository under the UNESCO auspices. (More details at: [www.oceanobservers.org](http://www.oceanobservers.org))

**Opportunistic third party data** - During the [Volvo Ocean Race 2017-2018](http://www.volvo-ocean-race.com), JCOMMOPS teamed up with an international group of meteorologists, oceanographers and the Volvo Ocean Race skippers to use “sailing ships of opportunity” to gather data away from the main shipping routes. In particular, during the Volvo Ocean Race, the racing yachts were committed to acquire metocean data. The meteorological data and metadata collected by the Volvo Ocean Race vessels were made available in near-real time to the public and to met-offices providing weather forecasts as part of a pilot project developed by JCOMM partners.

During 4 of the Volvo Ocean Race legs, a total of 28 drifter buoys from the National Oceanic and Atmospheric Administration(NOAA) drifter program were deployed by each of the 7 vessels, at crucial oceanic regions to measure sea surface temperature and ocean current velocities. A number of similar partnerships are being prepared and could offer some sponsoring opportunities (for instruments).
PUBLICATIONS

1. **Ocean Observations Coordination (OOPC and JCOMM OCG)**


   - WMO Cross Cutting Position Paper on Ocean issues (2018) - Ocean information is increasingly important across a broad range of WMO priorities, given the need to integrate information more; including the move towards earth system modelling, seamless prediction and coupled weather prediction; while ocean related activities and expertise is fragmented across the organization and lacked coordination mechanism. I led the development of a cross cutting paper, highlighting priority time horizons for provision key services, and outlining how ocean research, observations and services contribute to these services, and aligned with the WMO Strategic Plan; ensuring the breadth of ocean issues of importance to WMO were highlighted. The document will be a cross cutting paper at the upcoming WMO Executive Council.


2. **JCOMMOPS**

   JCOMMOPS does not publish scientific papers but its monitoring and communication tools (e.g. status maps for observing systems) are regularly used by the community in publications and presentations.
Figure 1. *The JCOMMOPS vision*: Give body, structure and take the pulse of the Global Ocean Observing System, “certifying” every component that is operating, or will operate in the ocean. Latest monthly map.
**Figure 2.** Patchwork of outreach initiatives led by JCOMMOPS: sponsoring of instruments by civil society partners, Report Card, interventions in classrooms, Ocean Observers workshop, cooperation with sailing races.

**Figure 3.** A view on a JCOMMOPS website and dashboard dedicated to one observing system, including a 3D map real-time viewer based on ESRI technologies.
**The Argo Project: Global Observations for Understanding and Prediction of Climate Variability**

NOAA Cooperative Agreement No. NA14OAR4320158  
April 01, 2017 – March 31, 2018

**CINAR Investigator – Steven Jayne, WHOI**

**NOAA Sponsor – Stephen Piotrowicz, OAR**

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

CINAR Theme: *Sustained Ocean Observations and Climate*

Amount Funded: $ 2,212,325

**PROJECT OVERVIEW**

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.

**PROJECT MILESTONES AND ACCOMPLISHMENTS**

WHOI continues to deploy floats in the Atlantic Basin with an emphasis on increasing coverage of the Intra-Americas seas. Other areas of deployments include the Arabian Sea and eastern South Pacific Ocean. 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 66 Argo floats between April 1, 2016 and March 30, 2017, and currently operates a fleet of 352 active floats (see Figures 1 and 2).
EDUCATION AND OUTREACH ACTIVITIES

"Autonomous Platforms and Sensors", February 2017 at the Tropical Atlantic Observing System workshop

PUBLICATIONS

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Figure 1. Deployment locations for WHOI Argo floats deployed between April 1, 2017 and March 31, 2018.

Figure 2. Map of WHOI Argo floats active on March 31, 2018.
Distributed Biological Observatory – Northern Chukchi Integrated Study

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Robert S. Pickart, WHOI

NOAA Sponsor – Monique Baskin, Jeremy Mathis, Emily Osborne, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

Amount Funded: $200,000

PROJECT OVERVIEW

The inaugural cruise of the Distributed Biological Observatory – Northern Chukchi Integrated Study (DBO-NCIS) was carried out from 26 August to 15 September 2017 aboard the US Coast Guard Cutter Healy. The overall goal of DBO-NCIS is to document and understand ongoing changes to the Pacific-Arctic ecosystem in light of the changing physical drivers. The main objectives for the 2017 cruise were (1) to occupy DBO lines 3-5 in the Chukchi Sea with an extensive suite of water column and benthic measurements; and (2) to carry out a process study of the northeastern Chukchi shelf designed to understand the physical-biological links that result in the biological hot spots in this region. In addition to the core components of the program, a number of ancillary projects were added which enhanced the breadth of the scientific measurements conducted during the cruise.

PROJECT MILESTONES AND ACCOMPLISHMENTS

The cruise exceeded our expectations, due in part to the fast pace of work resulting from favorable weather conditions and lack of sea ice. A total of 141 conductivity-temperature-depth (CTD) casts were occupied, comprising 12 sections (see Figure 1). Our shelf survey spanned the region around Hanna Shoal and included two sections extending across the continental slope. We also occupied an additional DBO line (DBO-1) before returning to port. All of the CTD and vessel-mounted acoustic Doppler current profiler (ADCP) data have been processed and quality controlled. We created a project website which contains the cruise report and the final shipboard data. The scientific analysis of the hydrographic and velocity data is currently underway. To help put our 2017 data set into historical context, we assembled data from seven previous hydrographic/velocity surveys of the Chukchi Sea during the period 2003 to the present. We’re also using data from the PacMARS CTD data base, which extends back to 1981. This collection of data is allowing us to address both the seasonality and interannual variability of the water masses and circulation on the Chukchi shelf, including the role of wind forcing.
HIGHLIGHTS

- An extensive hydrographic/velocity survey was carried out in summer 2017, which is the eighth such survey conducted since 2003 containing both high-resolution CTD sections and vessel-mounted ADCP data.
- We sampled the northeast Chukchi shelf in a strongly wind-forced state during part of the survey. The upwelling in Barrow Canyon was so pronounced that Atlantic water was found only 10 m beneath the surface. Water from the basin was progressing onto the central portion of the shelf (see Figure 2).
- Our cruise provided two valuable crossings of the Chukchi slope current, which were striking in two regards. First, in both instances there was a subsurface warm-core eddy situated on the seaward side of the current. Second, the westward transport of the current far exceeded the mean summertime value. These unexpected results are presently being addressed in the scientific analysis.

EDUCATION AND OUTREACH ACTIVITIES

A visiting graduate student from Guangdong Ocean University in China participated on the cruise.

PUBLICATIONS


Figure 1. Hydrographic stations occupied during the 2017 DBO-NCIS cruise (magenta stars).
Figure 2. Top panels: Timeseries of shipboard wind speed and direction during the 2017 cruise (black lines). The magenta line denotes the 10 m/s threshold used to divide the record into high-wind versus low-wind conditions. The times of occupations of the sections are denoted by the red line segments. The boxes mark those sections occupied during strong easterly/northeasterly winds. Bottom panels: Wind vectors (left) and depth-averaged ADCP velocity vectors (right) during the high wind conditions.
Creating and evaluating indices of climate-induced changes in spatial distributions of North Pacific fishery resources

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Malin Pinsky, Rutgers

NOAA Sponsor – Elliot Hazen, NMFS

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

Amount Funded: $32,100

PROJECT OVERVIEW

We proposed to:
2. Process these new data and integrate them into the fish distribution indicator website;
3. Update the software pipeline to streamline data acquisition from NMFS science centers where possible

PROJECT MILESTONES AND 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).

EDUCATION AND OUTREACH ACTIVITIES

- Jim Morley presented to the South Atlantic Fisheries Management Council in June 2016.
- Jim Morley presented at the International Marine Conservation Congress (IMCC) in August 2016.
- Malin Pinsky was an invited seminar speaker at the Bevan Series of the University of Washington's School of Aquatic and Fishery Sciences. He was introduced by Dr. Elizabeth Clarke from the NWFSC.
- Malin Pinsky was an invited speaker at the "Blue Economy" conference at Monmouth University.
Developing Carbon Dioxide Climatology and Ocean Acidification Indicators in the Northeastern U.S. Coastal Waters

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Zhaohui ‘Aleck’ Wang, WHOI

NOAA Sponsor – Libby Jewett; Dwight Gledhill, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

Amount Funded: $38,610

PROJECT OVERVIEW

The Northeastern U.S. coastal region, including the Gulf of Maine (GoME) and the Mid-Atlantic Bight (MAB), may be susceptible to ocean acidification due to its relatively low pH, aragonite saturation state and buffering capacity. Such a chemical condition has significant implications for the region’s profitable shellfish industry and overall ecosystem health in the long term. Coastal ocean acidification in the Northeast region is likely multi-factored, involving multiple anthropogenic and natural driving forces and effects, many of which are poorly understood. Stakeholders and the public are becoming increasingly interested in this looming problem and its potential impacts. A baseline assessment of the region’s ocean chemistry patterns, in particular water-column carbonate chemistry, is a critical step in diagnosing future changes and in making long term policies for adapting to and mitigating the effects of ocean acidification in the region. Such an assessment is lacking. The goal of this proposed work is to collaborate with the National Oceanic and Atmospheric Administration (NOAA) Northeast Fishery Science Center (NEFSC) to synthesize existing and on-going observations of CO2 parameters and other related measurements in the Northeastern U.S. coastal waters, with the aim of generating a mechanistic understanding of the variability of carbonate chemistry caused by both natural and anthropogenic factors and to produce a baseline climatology of carbonate chemistry and ocean acidification indicators for the region. The climatology and OA indicators will be valuable for informing decision makers of the current status of ocean acidification, and will be used in models to project future changes and impacts in the region.

The original objective of this project was to help Dr. Nathan Rebuck and Dr. Jon Hare at the NEFSC to complete data analysis of legacy pH and alkalinity data from the MARMAP program 1980's and newer 2009-present dissolved inorganic carbon (DIC) and total alkalinity (TA) data from the NEFSC EcoMon program in the NE coastal/shelf region. The goal was to produce a peer-reviewed paper focusing on seasonal and potentially inter-annual variabilities of carbonate chemistry in this region to serve as a climatology baseline for any future changes in carbonate chemistry to compare with under ocean acidification.
However, there has been a delay for the project this year. Dr. Hare has left his position to accept a new job as the NEFSC Science and Research Director. Dr. Rebuck’s contract has expired and he is no longer employed to work on this project. An initial manuscript by Dr. Rebuck was submitted and rejected due to concerns from reviewers over the calibration and accuracy of pH data from the 1980’s. This created the delay of data synthesis and the planned manuscript. Late in 2017, Dr. Chis Melrose at NEFSC was introduced to the project to re-establish NEFSC participation and he has started working with PI. Wang. We are moving forward again.

PROJECT MILESTONES AND ACCOMPLISHMENTS

We have made some necessary changes to the original objectives of the project to address changes in personnel and data-driven concerns. As the original lead author (Rebuck) of the planned manuscript has moved on to other employment, Wang now leads and works closely with Melrose in order to complete the paper related to the NE carbonate chemistry climatology. We will no longer use the legacy un-calibrated MARMAP pH data from the 1980s to avoid the questions about data quality that contributed to the rejection of the initial Rebuck manuscript. The objective is now to use only high-quality datasets such as EcoMon, GOMECC, and ECOA. We will generate surface and bottom chemistry climatology maps and cross shelf sections in the NE region. These products will be seasonally resolved where coverage is sufficient. We plan to finish the paper draft within this year. So far we have made important progress with the new team and objectives:

1. We have obtained all data files, documents and computer codes that Rebuck used to work with for the project.
2. We have compiled all relevant data sets from the region, including ones not included in the original Rebuck manuscript.
3. We are generating preliminary surface and bottom maps of carbonate parameters (e.g. TA, DIC, aragonite saturation state) of the region using a modified version Rebuck’s original MATLAB code.
4. We are developing a new method of compiling spatially and temporally less resolved data in order to obtain sufficient resolution for producing carbonate chemistry climatology maps.

HIGHLIGHTS

We compiled a large data set that includes water-column carbonate chemistry measurements over the last two decades in the NE shelf water. We have started to integrate the data set to generate seasonally-resolved, preliminary surface maps of CO₂ parameters. For example, aragonite saturation states show strong seasonal differences in NE shelf water, with winter time low and spring time high along with local ‘hot’ spots potentially due to various oceanic processes. See Figures section below.
Figure 1. Seasonally compiled and gridded surface maps of aragonite saturation states (Omega) between 2007 and 2018 in the NE shelf water. The data collected from EcoMon, GOMECC, ECOA cruises, and the Gulf of Maine seasonal study by Wang’s group. The results are preliminary for reporting only.
**PROJECT OVERVIEW**

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.

Cruises were conducted to each of the three ORS. NTAS was serviced by the RV *Endeavor* in January–February 2017 and will be serviced again in May 2018 from the NOAA Ship *Pisces*. Stratus was serviced by the NOAA Ship *Ronald H. Brown* during a May 2017 cruise and again using the Chilean Navy vessel *Cabo de Hornos* during an April 2018 cruise. WHOTS was recovered and redeployed in July 2017 on the NOAA Ship *Hi‘ialakai*. Stratus and NTAS cruises on *Endeavor* and *Cabo de Hornos* involved charter funding that was supported under 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 variability in
wind speed, wind stress, latent heat flux, and heat heat flux. Weller (2015) had found significant
trends in the first ten years of observations, but the latest Stratus data now show that the increase in
the trade winds has stopped and that they are weakening. Comparing the magnitude of the wind
stress with the monthly Pacific Decadal Oscillation (PDO) index
(https://www.ncdc.noaa.gov/teleconnections/pdo/) suggests that the trade winds off Chile are
tracking a large-scale mode of ocean-atmosphere variability (Figure 1). 2) following up on links
between NTAS ORS upper ocean temperature structure and Atlantic storm activity where we see
that warm SST and humid marine atmospheric boundary layer conditions with higher sea level
pressures coincide with years of more storm activity, and working with University of New
Hampshire colleagues on salinity anomalies at NTAS (Figure 2); 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 and comparisons between the in-situ
data and models and reanalyses (Figure 3); and 4) working with investigators both producing ocean
surface radiation products from satellite data and producing and assessing global, gridded air-sea
flux products, where the ORS buoy data serve as critical calibration points. 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. Work at Stratus includes collaboration with
colleagues at Geomar (Kiel, Germany) to make dissolved oxygen measurements; Stratus and
WHOTS carry CO₂ sensors in collaboration with NOAA Pacific Marine Environmental Laboratory
(PMEL); and NTAS fieldwork is carried out in collaboration with colleagues at Scripps Institution of
Oceanography and their maintenance of the nearby MOVE (Meridional Overturning Variability
Experiment) array.

PROJECT MILESTONES AND 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 formulae 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) pCO₂ 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 95% of the planned
station time. Close to a complete (99.3%) record of surface meteorology has been delivered by the three ORS. In spite of biofouling, fishing gear entanglement, and other challenges 89.6% 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 pCO₂ observations from Stratus and WHOTS.

**HIGHLIGHTS**

- New insight into the role of ocean eddies in transportation of water offshore, in mixing, and in contributing to the local heat and freshwater budgets at the Stratus ORS is presented in Czechel et al. (2018). Analysis of the evolution of dissolved oxygen in the core of westward propagating eddies provided key insights into the evolution of dissolved oxygen and also into the evolution of the temperature and salinity fields at Stratus.

- The previously reported upward 10-year trend in wind stress magnitude and 10-year downward trend in net heat flux at the Stratus ORS reversed in the 2010-2012 time period, at the time that the PDO index reached a minimum and began to increase (Figure 1).

- 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 ended in 2012, at which time SST and air temperature started an ongoing warming trend. Sea surface salinity stopped increasing in 2011-2012, stayed the same until 2015 at which time freshening was observed (Figure 3).

- 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, and the anomalous NTAS SST has peaks in 2005 and 2010 as does the North Atlantic Accumulated Cyclone Energy index (Figure 2).
• New satellite surface radiation products were produced by the NASA CERES (National Aeronautics and Space Administration Clouds and the Earths Radiant Energy System) team (Kato et al., 2018) and by Dr. Rachel Pinker (Univ. of Maryland) (Pinker et al., 2018) that use ORS data as key calibration points.

EDUCATION AND OUTREACH ACTIVITIES

• Whenever possible, cruises to the Stratus and WHOTS ORS have involved NOAA Teachers at Sea and undergraduate and graduate students. The Stratus 2018 cruise had young investigators from the Universidad de Valparaiso on board.

PUBLICATIONS


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. Comparison of the 30-day running mean of anomalous SST at NTAS, where the anomaly has the long-term annual mean sinusoid removed, and the Atlantic accumulated cyclone energy index scaled by 150.
**Figure 3.** Anomalies, hourly observation minus long-term mean annual cycle. Black is hourly; in all plots except air temperature and SST, blue shows the 100-day running mean and red the 300-day running mean; hourly air temperature is black and hourly SST is green, 100-day and 300-day running mean air temperatures are blue and red, respectively, 100-day and 300-day running mean SSTs are cyan and magenta, respectively.
PROJECT OVERVIEW

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.

Cruises were conducted to each of the three ORS. NTAS was serviced by the RV Endeavor in January–February 2017 and will be serviced again in May 2018 from the NOAA Ship Pisces. Stratus was serviced by the NOAA Ship Ronald H. Brown during a May 2017 cruise and again using the Chilean Navy vessel Cabo de Hornos during an April 2018 cruise. Stratus and NTAS cruises on Endeavor and Cabo de Hornos involved charter funding that was supported under these associated supplemental grants; for Stratus, supplemental funds were also required to cover shipping to and from Valparaiso, Chile and to cover costs for work in that port.

PROJECT MILESTONES AND 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 bridge 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 formulae 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) pCO2 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 supplemental funds allow for timely recovery and redeployment of the ORS moorings when a NOAA vessel is not available. 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 95% of the planned station time. Close to a complete (99.3%) record of surface meteorology has been delivered by the three ORS. In spite of biofouling, fishing gear entanglement, and other challenges 89.6% 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.

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- **Ocean Carbon Uptake and Content.** Collaboration with NOAA PMEL provides pCO2 observations from Stratus and WHOTS.

**HIGHLIGHTS**

NTAS was serviced by the RV *Endeavor* in January–February 2017, and charter costs were covered under a supplemental grant. Preparation for use of the Chilean Navy vessel *Cabo de Hornos* during an April 2018 cruise were made under another supplemental grant covering ship day use charges and shipping and port services costs. We set up an updated Memorandum of Understanding and contract between Woods Hole Oceanographic Institution and the Armada de Chile for the use of *Cabo de Hornos*. 
EDUCATION AND OUTREACH ACTIVITIES

- Whenever possible, cruises to the Stratus and WHOTS ORS have involved NOAA Teachers at Sea and undergraduate and graduate students. The Stratus 2018 cruise had young investigators from the Universidad de Valparaiso on board.
Accessing and visualizing satellite data for use by fisheries managers in the Northeast

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Riley Young Morse, Gulf of Maine Research Institute

NOAA Sponsor – Ellen Mecray, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

Amount Funded: $27,027

PROJECT OVERVIEW

Working in partnership with the NOAA NCDC Northeast Regional Climate Center, The Gulf of Maine Research Institute (GMRI) set out to develop localized climate relevant data products using data sets available through the National Climate Data Center/Climate Data Record (NCDC/CDR) program. The data products were developed and delivered through an online data dashboard for the fisheries management community that was piloted through our second CINAR project entitled "Building tools for applying climate science to fisheries management".

During the course of this work, we have secured additional funding from NOAA COCA and NASA ROSES, which is allowing us to continue to develop and serve climate relevant data products to fishery stakeholders that are intuitive and useful.

At the completion of the three years of the project, we have met our primary goal of:

1) Data Acquisition and Integration
   - Access/Understand/Document structure and accessibility of data through NCEI/CWC/CDR
   - Develop web services and scripts to access and subset data by temporal/spatial boundaries
   - Develop standards-based web services to access data and update on the fly
   - Pilot in NE with an eye toward reuse/extensibility

Leveraging additional funding for an online dashboard, we were able to further enhance this work by developing the following capacities and data products:

2) Spatial Averaging
   - Subset global data set for the NES LME and sub-regions
- 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
- Develop climatologies for sub-regions from the 30 year time series

4) User interface: Seasonal and Decadal Visualizations
- Integrate current data and climatologies into online data dashboard

As noted in last year’s progress report, we had significant setback accessing data from our primary product, the Optimum Interpolation Sea Surface Temperature (OISST) for a large part of the reporting period. The data services we had been using to acquire daily SST files from NOAA’s NCEI underwent a major upgrade in early 2017, which led to difficulties reliably accessing the daily files for the OISST dataset. This set us back on our plan to begin rolling out the dashboard a wider audience through demonstrations and webinars until it was resolved. We worked with NCEI staff during this period who kept us informed by providing updates on when we could expect the process to be completed. We worked on outreach with stakeholder groups and revision of the application during this period. This issue resolved in early 2018 and we are once again able to access the latest available data.

Over the last year, we have worked to implement recommendations from 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 so data can be more accurately compared. We have also developed techniques to do temporal averaging, specifically developing data products with a decadal and seasonal focus (e.g average summer and fall SST and anomaly maps).

The development of the climate and fisheries data dashboard has leveraged stakeholder engagement using an iterative process throughout the project. Development continues to occur in tandem with efforts focusing on data acquisition and integration and user interface development. The working group on this project was formed during our pilot work at a sponsored by CINAR in Woods Hole, MA in June 2014. Outcomes from this initial workshop supported the direction of the dashboard and the identification of climate and fisheries data sources to include. The core working group is contributing to project as a primary user group from which to obtain feedback on the development and design of the dashboard, and helping to identify and access existing content from NOAA Fisheries as well as others including NOAA ESRL, USGS, academia (CINAR). We continue to work closely with this advisory group to scope and validate the content and functionality of the application to meet priority needs as they apply to locations, presentation of information, and interpretation of data. Throughout development, we are re-engaging the stakeholders to test and evaluate. We are promoting the dashboard throughout the development through a series of targeted outreach efforts including webinars, and participating in relevant local and regional meetings and workshops. We envision further outreach at upcoming events such as the Maine Fishermen’s Forum, as well as more direct engagement with the NEFMC and MAFMC through the Science and Statistical Committee (SSC) and presentations at council meetings.
PROJECT MILESTONES AND ACCOMPLISHMENTS

1) Data acquisition
   - Years one and two – We developed scripts 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 three – Continue to use and improve scripts developed during the first two years of the project to acquire new data sets for the project (to include: chlorophyll, precipitation, fisheries landings, etc.)

2) Spatial averaging
   - Years one and two - 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 (Lucey and Fogarty 2013). With the boundaries selected, we then average the values within that region.
   - Year three – Developed new data products for OISST and additional data sets using the spatial averaging techniques. Based on stakeholder input, we began applying a spatial averaging approach to develop temporal averages for seasonal/decadal views of the data.

3) Build reference level/climatology of data
   - Years one and two - Used the OISST 30 year period (1/1/1982-12/31/11) and applied a suite of statistics against the time series to build high/low means, averages and standard deviations for the time series 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 three – Develop additional data products to enable year-to-year comparison of climatologies. Apply climatology techniques to new datasets for both spatial (sub-region) and temporal (seasonal/decadal) aggregations.
HIGHLIGHTS

- Received additional funding from NOAA COCA and NASA ROSES to continue development of the Fisheries and Climate Data Dashboard for the next two years.
- Redesigned dashboard application to improve presentation of visualizations based on user feedback [http://dashboard.gmri.org](http://dashboard.gmri.org)
- Rolled out beta application to stakeholders for testing and usage
- Presented talks at several national meetings to demonstrate functionality of the dashboard and share technical approaches to development
- Began integration of additional datasets for bottom temperature, primary production and chlorophyll
- Continued work to produce monthly or seasonal data aggregate products

EDUCATION AND OUTREACH ACTIVITIES

- Presentation at the American Meteorology Society 23rd Conference on Applied Climatology, June 26-29th, 2017, Asheville, NC (submitted as attachment - YoungMorse_AMS_2017.pdf)
- Project briefing to NCEI June 28th, 2017, Asheville, NC
- Poster at the Gordon Research Conference on Visualization in Science and Education, Bates College, Lewiston, ME July 14-19, 2017 (submitted as attachment - GRC_Climate_Fisheries_Dashboard_Poster.pdf)
- Briefing and project demo for the NOAA NEFSC Ecosystem Dynamics and Assessment and Oceanography Branches, Woods Hole, MA September 28th, 2017
50 Year Global Ocean Surface Heat Flux Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Lisan Yu, WHOI

NOAA Sponsor – Kathy Tedesco, OAR

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Sustained Ocean Observations and Climate

Amount Funded: $180,586

PROJECT OVERVIEW

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 26,206 times and the data download page 23,934 times. The OAFlux products have been cited in 1,057 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 (IPPC) 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.

**PROJECT MILESTONES AND ACCOMPLISHMENTS**

1. **Continuation of the OAFlux global analysis of ~60 years (1958 onward)**

Two updates were made to the OAFlux 1°-gridded global analysis of daily/monthly ocean evaporation, latent heat flux, sensible heat flux, and related surface meteorology. One was in August 2017 and the other in January 2018. Both updates were fully validated using in situ validation database that consists of buoy time series at 120+ locations. The time series encompasses the past 60 years from 1958 to the present, making it highly useful for climate assessment and attribution studies.

2. **New dataset development: OAFlux high-resolution (HR) satellite-based fluxes (1988-present)**

Major efforts were placed on the validation and refinement of the high-resolution (HR, 0.25°-
gridded), all satellite-derived analysis that we have been intensively working on in recent years. The essential datasets that are being developed include the near-surface humidity (qa) and temperature (Ta), and wind speed and direction. These flux-related variables are then used as input for the bulk flux algorithms to compute air-sea turbulent heat, moisture, and momentum fluxes. The OAFlux-HR analysis is constructed from a platform completely different from the OAFlux-1° analysis. This HR version is all satellite based, retrieving qa and Ta from 11 microwave scanners and sounders and constructing wind speed and direction from 16 scatterometers and microwave radiometers.

3. Explore the possibility of extending OAFlux products to the marginal ice zones in the Arctic and Antarctic

This is a new direction that we are undertaking. The OAFlux products are currently constructed for the ice-free ocean only, and we are exploring the possibility to expanding OAFlux products to the marginal ice zones (MIZs) in the Arctic and Antarctic. Our first step is to understand air-sea measurements obtained by the icebreaker *Aurora Australis* (Fig. 4) and gain first-hand experience in computing the air-sea fluxes in the two different regimes: the open ocean surface and the mixed sea-ice surface. The analysis of air-sea flux variability along the icebreaker tracks is published in 2017 (Yu et al. 2017; JGR), and a new work that analyzed the performance of four atmospheric reanalyses using the icebreaker measurements is now under review in Journal of Climate.

**HIGHLIGHTS**

- A 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 improvement in resolving air-sea interaction on meso and frontal scales, and assessing decadal trends and variability over the global ocean.
- The project moves toward extending OAFlux products to the marginal ice zones in the Arctic and Antarctic.

**EDUCATION AND OUTREACH ACTIVITIES**

L. Yu routinely presents the data and research results from the OAFlux project 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 actively involved in supervising graduate students and postdoctoral researchers and training them to utilize observations and models to understand the challenges and issues of the changing ocean climate and to quantify the role of the ocean in climate change and variability.
PUBLICATIONS

Published


Submitted (under review)


FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

See following page.
Figure 1. Annual-mean (a) surface heat input to the ocean (positive denotes ocean heat gain and negative denotes ocean heat loss), (b) surface freshwater input to the ocean (positive denotes freshwater gain and negative denotes freshwater loss), and (c) wind stress vector and wind stress curl (colors). OAFlux satellite-based high-resolution flux analysis is used in all three panels, aided by CERES EBAF surface radiation in (a) and GPCP precipitation in (b).
THEME VI. EDUCATION AND OUTREACH
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:

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, and receives between 6,500 to 7,500 visits per month. In addition to maintaining the Web Site, conference announcements, funding opportunities, position announcements, reports, etc. of interest to the HAB community are routinely posted and circulated through our numerous listservers, including the US HAB mailing list (US-HAB@whoi.edu) and the NortheastPSP mailing list (northeastpssp@whoi.edu). Major activities over the past year included work to update the content, structure, and design of the Harmful Algae website, which has been a significant effort.
redesigned webpages are currently in draft format, and Richlen is soliciting feedback regarding the new structure and design, and is also assembling new images to use throughout the website. This work is expected to be completed over the summer, after which the new website will go live. Part of this effort included redesigning the US HAB maps that depict the distribution of HAB toxins in US coastal waters. These maps were completed, and work on producing new world maps is currently underway.

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 during the current reporting period (4/1/17 - 4/31/18) the Harmful Algae Facebook page had a total reach (the number of people who have seen a post during this timeframe) of over 210,000 with the highest daily reach of 8,209 for a story on Global Warming Making Oceans More Toxic (https://www.sciencedaily.com/releases/2017/04/170424153809.htm).

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 multiple 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). This year, PI Anderson presented a summary of U.S. events for 2017 at the 2018 WGHABD meeting held in Sant Carles de la Ràpita, Spain. Additionally, a document summarizing US HAB incidence over the past several decades is now being prepared and will be used in the Global HAB Status Report, being organized by the Intergovernmental Panel on Harmful Algal Blooms (IPHAB).

National and international bloom reports are provided to all U.S. network participants, as well as to other interested parties – note that this is the most comprehensive 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).
The Intergovernmental Panel on Harmful Algal Blooms (IPHAB)

This intergovernmental panel did not meet in 2018, so all activities were intersessional. PI Anderson chairs the Task Team on Harmful Algal Blooms and Desalination. A major activity of that task team that required considerable time during the last year was the preparation of chapters and final 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, and is now published. 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 administrators from the National Centers for Coastal Ocean Science (NCCOS). 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. During the past year the National Office also worked with scientists and managers on several unexpected or unique HAB events and/or targeted projects. These projects were funded across the country in response to both coastal and freshwater blooms, and are summarized below.

The first involved an unusual mortality event in birds in Ventura County, CA as well as an influx of sea lions at several of the marine mammal rescue centers in southern California exhibiting signs of domoic acid (DA) poisoning. A series of beach surveys of birds from Santa Barbara, Ventura and Los Angeles counties revealed DA detected from seabirds, and DA was also detected from sea lion fluids from >30 animals. The event response project led by Dr. Meredith Howard (Southern California Coastal Water Research Project) sought funding to: (1) determine acute impacts to marine birds; provide domoic acid analysis for birds showing signs of DA poisoning or dead animals suspected of DA poisoning (confirmation of DA); (2) evaluate long-term impacts through analysis of domoic acid in sediment samples and in benthic organisms collected from the affected areas; (3) and expand water sampling to include offshore subsurface regions (not routinely monitored and not visible to satellites).

An event response request was also received from Dr. Timothy Davis (Bowling Green State University) to monitor emerging of an algal bloom that developed in Maumee River (Fig 1), which flows through Toledo. This event sparked concern throughout the city of Toledo regarding about the safety of that city’s drinking water, and prompted the City of Toledo to issue a water quality advisory. Samples were collected from multiple sites in the Maumee River, and analyzed for particulate anatoxins, saxitoxins, cylindrospermopsins, BMAA and microcystin congeners. A second set of samples were analyzed for potential toxin producers via multiplex qPCR. Preliminary results showed that microcystins were detected in 64% of the samples and that levels of other cyanobacteria toxins tested were below the limits of detection. The final report on the results is forthcoming.
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 NCCOS 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 9th Symposium on Harmful Algae in the U.S. (Maryland) and the 19th International Conference on Harmful Algae, to be held in Nantes, France in 2019.

**U.S. HAB symposia.** Richlen served on the Steering Committee for the 9th Symposium on Harmful Algae in the U.S., which was held in November, 2017 in Baltimore, MD. She coordinated with the conference organizer Dr. Allen Place to communicate updates and announcements to the U.S. HAB community, and she solicited and processed travel awards for both students and managers for the symposium. This year, Richlen also coordinated the evaluation of student presentations at the symposium, which involved lining up at least four judges for each student presentation and poster, compiling results, and administering awards for best oral presentation, best speed talk and best student presentation. These awards were given out on at the last day of the meeting.

In addition to coordinating student travel awards, as well as the awards for best student presentations, Richlen coordinated with the NHC and Dr. Place to give out the first-ever National HAB Committee Lifetime Research and Service Award. The first recipients of this award were Rob Magnien and Ted Smayda. Further details regarding this award are below.

**International HAB Conferences.** The National Office will provide travel support for U.S. students to attend the 19th International Conference on Harmful Algae, to be held in Nantes, France in 2019. Richlen is coordinating with Christine Band Schmidt, chair of the ICHA student awards committee, to distribute these awards.

**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, and the NHC Awards subcommittee. The National Office arranges conference calls for the group as well as in-person meetings typically held in conjunction with the U.S. HAB Symposium.

In the past year, the NHC established an award to be given out at the HAB Symposium, called the “National HAB Committee Lifetime Research and Service Award”. The purpose of this award is to “recognize and honor individuals who, throughout their careers, have significantly advanced the
science and awareness of harmful algal blooms in the United States through their research achievements or their service, education and outreach efforts to students, Federal and State leaders and the general public.” In the past, recognition of certain members of the HAB community was done informally, but going forward, this award will be given at every meeting, coordinated by the NHC and National Office (Richlen). At the HAB Symposium in Baltimore, the NHC presented awards to Rob Magnien and Ted Smayda. A new NHC ad-hoc subcommittee was formed to identify the criteria and process for selection, and nominations will be solicited for this award in 2019.

As part of a broader effort to help prepare organizers of future symposia, the National Office (Dortch and Richlen) organized a conference call discussion with the organizers of the 2019 US HAB Symposium (Alabama), and several organizers of past symposia. Topics discussed included managing finances related to the HAB symposium, approaches to budgeting and accounting, and sources of cost overruns. A new NHC subcommittee called the “HAB Symposium Advisory Subcommittee” will continue this effort, and will update an existing symposium manual that outlines planning guidelines.

HIGHLIGHTS

- Preparation and presentation of data on bloom reports in the U.S. in 2017 and attendance at the ICES Working Group on Harmful Algal Bloom Dynamics meeting in Sant Carles de la Rápita, Spain.
- Ongoing work to update the design and content of the National Office Harmful Algae Webpage, and redesigned U.S. HAB maps (world maps currently underway).
- Coordination for event response projects, which included support for monitoring for cyanobacteria taxa and toxins in the Maumee River, and DA surveys of environmental samples and wildlife in southern California.
- Intersessional work for the International Panel on Harmful Algal Blooms and specifically, editing and publishing of the book *Harmful Algal Blooms (HABs) and Desalination: A guide to impacts, monitoring, and management*.
- Served on the steering committee for the 9th Symposium on Harmful Algae in the U.S. (Baltimore, MD); solicited and processing travel award applications for students and managers.
- Plenary talk on the history of the US National HAB program at the 9th Symposium on Harmful Algae in the U.S. (Baltimore, MD).
- Coordinated the evaluation of student presentations at the symposium, and administered awards for best oral presentation, best speed talk and best student presentation.
- Coordinated the “National HAB Committee Lifetime Research and Service Award”, which was given to Rob Magnien and Ted Smayda at the US HAB Symposium.
- Coordinated elections for new NHC members as well as election of new NHC co-chairs.

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 – 2017, ICES WGHABD, Sant Carles de la Ràpita, Spain, April, 2018
- 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. Anderson also often receives requests for guidance and referrals from congressional staff.

**FIGURES/PHOTOGRAPHS/ILLUSTRATIONS**

![Figure 1: Aerial view of the Maumee River bloom on Sept 22, 2017. Photo: Zach Haslick, Aerial Associates Photography/NOAA GLERL](image-url)
Marine Resource Education Program Northeast: Fostering Trust and Shared Information in Fisheries Science and Management

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Alexa Dayton, Gulf of Maine Research Institute

NOAA Sponsor – Earl Meredith, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

Amount Funded: $ 187,625

PROJECT OVERVIEW

For the period April 1, 2017 to March 31, 2018 the MREP Implementation Team proposed to carry out two initiatives:

• Deliver one MREP for the Recreational angler in a central New England and Mid-Atlantic location covering both science and management, tailored to the needs of recreational fishermen;

• Develop and deliver a new MREP for Ecosystem-based fisheries management, offered in partnership with the collaborative research branch to MREP graduates.

• Perform active outreach in building a fishing community network to support MREP training and recruiting throughout the Northeast Region, 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

We delivered the following workshops as outlined in our proposed scope of work:

• February 26 – 28, 2018 – MREP Ecosystems-based fisheries management 200 at the NOAA/NEFSC Narragansett Lab, RI and New Bedford, MA (three days).

• March 20 - 22, 2018 – MREP for Recreational Anglers in Hanover, MD (three days).

New Bedford, MA was chosen as the venue for the MREP 200 EBFM module in an effort to engage communities of fishermen who have become reticent in participation in fishery management, based on input from multiple sources. The MREP 200 EBFM curricula were adapted to the information needs of this community and to foster dialog around cooperative research.
MREP for Recreational Anglers was a new venture for MREP in the Northeast, added because of strong demand by that community. We purposely structured it to provide foundation for further outreach to the recreational community in the Greater Atlantic Region. A small group of management-savvy recreational leaders, enlisted as 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. The MREP for Recreational Anglers included a variation on the Super Fish Case Study, which continues to evolve as a teaching tool.

MREP 200: Ecosystem-Based Fishery Management, also new, was an attempt to meet strong demand from graduates of previous MREP workshops and the community at large. The chosen venue showcased NOAA’s unique research capability for understanding the contribution of ecosystem function to fishery productivity. Presentations by NEFMC scientists laid the groundwork for discussion of directions management might take in the future as models are refined. A general discussion on the theme What Fishermen Want Scientists to Know About Ecosystems allowed the 23 fishermen and 13 scientists attending to explore in depth their mutual perspectives.

HIGHLIGHTS

- Underserved fishing communities in NC, VA and MD were the focus of MREP for Recreational anglers, with a high percentage of “pier leaders” in attendance.
- MREP held its first workshop in New Bedford, MA and was warmly received by local fishing industry.
- MREP for Recreational Anglers successfully established lines of engagement with a large, diverse and poorly-informed community, laying foundations for future outreach.
- Better understanding of MRIP as a recreational data-collection system resulted, which can be adapted and improved by concerted partnership between recreational fishing sectors and NMFS.
- Beginnings of an open-ended dialog by fishermen and scientists working on models of ecosystem-based fishery management with opportunities for new partnerships.
- Strong participation by NMFS scientists and managers not previously engaged in MREP workshops, including Silver Spring personnel and Population Dynamics staff.
- Graduates from the Recreational angler program engaged in the National Recreational Angler summit in Washington D.C. immediately after the workshop, where through a show of hands it became clear that more that 50% of the summit’s 150 attendees reported their MREP attendance as their motivation to become engaged.

EDUCATION AND OUTREACH ACTIVITIES

A general 3000-piece mailing went out to commercial and highly-migratory permit holders in the Greater Atlantic and Mid-Atlantic region, followed by direct one-on-one recruiting through prior MREP graduates, and the efforts of industry moderators Rick Bellevance, Charter Boat operator from RI and David Sikorski of CCA Maryland.

Most of the participants were recruited through word-of-mouth by MREP planning team members 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, tackle shop owners, and moderators of recreational blog-sites. Also attending as participants were a NOAA/Silver Spring expert on MRIP reporting.

The result was an average of 25 attendees at each module, from ports as far north as ME, but predominantly from RI, NC, VA and MD.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Senior NOAA Fisheries scientists and regional office staff field questions during the open questions wrap up period of the MREP for Recreational anglers in Hanover, MD.
Full house at the Hanover, MD MREP for recreational anglers!

NOAA/NEFSC’s Gary Shepherd performs a fish dissection to demonstrate otolith removal for proper fish age analysis and stock assessment input.
Marine Resource Education Program: Fostering Industry Leadership Through Fisheries Science & Management Education in the Southeast

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – April 30, 2018

CINAR Investigator – Alexa Dayton, Gulf of Maine Research Institute

NOAA Sponsor – Kim Amendola, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

Amount Funded: $ 206,195

PROJECT OVERVIEW

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 Southeast workshops, a fishery science & management education program for commercial and recreational fishermen, tailored to the region by an 18-member Steering Committee. This education enables fishermen and others to participate productively in the fisheries science & management processes, and leads to improved cooperation and trust between 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.

GMRI proposed to recruit twenty 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. Program implementation consists of a series of two workshops, which build upon each other: a multi-day fishery science workshop, followed by a multi-day fishery management workshop. 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 third annual meeting, and engage them in a program review and evaluation of the second year.
PROJECT MILESTONES AND ACCOMPLISHMENTS

Fisheries Science Workshop

The MREP Southeast Science Workshop was held April 23-25, 2017 in St. Petersburg, Florida. The 3-day workshop was held at the Florida Fish and Wildlife Conservation Commission’s Fish & Wildlife Research Institute (FWRI) facility. Participants in the workshop included fishermen, industry representatives, and a few others such as Yamaha Motors, Engle coolers, and other stakeholders from the South Atlantic, Gulf of Mexico, and the Caribbean. A total of 29 industry members participated, along with 15 presenters and other staff.

All of the program attendees, including the fifteen program presenters plus other fisheries technicians from the research labs, joined in the program and discussions with fishing industry participants for multiple days, and the networking resulted in increased understanding of the challenges facing each of the sectors represented. The personal interactions helped to build mutual trust, and break down barriers to communication between fishing industry, scientists and managers.

Regional Administrator, Dr. Roy Crabtree, and his staff also joined the program for the bulk of the three days, and new and productive dialog has been initiated with many new fishing industry members. Their staff reported that this was an unparalleled opportunity for them, bridging the gap between NOAA and fishing industry in a way that no other program has yet demonstrated.

Fisheries Management Workshop

The second of the two-part workshop series, the MREP Management Workshop was held in Tampa, Florida October 31 – November 2, 2017 and also included participants from the South Atlantic, Gulf of Mexico and Caribbean. A total of 22 participants attended the workshop, representing commercial, recreational and charter fishermen as well as fish house owners/dealers and media. Most of our attendees had also taken the science workshop, but due to scheduling conflicts not all of them took part in Management. We added new attendees from the waiting list as we were able. The program had originally been scheduled for early October but two hurricanes (Irma and Maria) required us to reschedule this event. This caused attendance issues, and we learned the Halloween also creates a conflict for participants, leading to further complications. As part of lessons learned for the future, we have decided to shift the management workshop later into the season to avoid prime hurricane timeframe.

In addition to the presentations and the very popular Council Case Study Scenario and role-play, we also included small energizer activities, designed to reinforce the learning, liven up the discussion, and provide a bit of movement to the day. In particular, we developed a power-point based game of Fisheries Management ‘Jeopardy’, and had groups of 4 to 5 people on a team, using different buzzers if they wanted to answer the question, with each team awarded points for correct answers.

Meals and break times continued to be invaluable moments for networking, asking questions, and allowing casual interaction among the presenters and attendees. There were times when we decided to allow a slightly longer break in the presentations than planned, for the discussions were so relevant and engaging that all attendees felt it was a very good use of their time. We observed that
phone numbers were exchanged and follow-ups for post workshop contact were developed on an individual basis.

HIGHLIGHTS

- We delivered the MREP Southeast Fisheries Science & Management workshops, as a foundation for improved trust in the Fishery Management process.
- We delivered the MREP USVI, as a foundation for local engagement in Fisheries Management and building trust among commercial and recreational sectors.
- 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 as articulated and envisioned by Magnusson Stevens Act.

Details:
- Fisheries science education program once again refined based on prior year evaluations, and we introduced a new hands-on activity where attendees provide stock status advice on a fictitious stock, using stock assessment tools.
- Fisheries management education program refined based on prior year evaluations
- Speaker’s bureau was expanded and enhanced for science & management workshops. Development of new speakers is a focus for future years.
- New industry moderators was selected, and learned to facilitate discussion at a large meeting developing newfound leadership skills.
- Fisheries science education program delivered for 29 fishermen and an additional 15 speakers and other guests, in St Petersburg, FL April, 2014
- Fisheries management education program delivered for 22 fishermen and an additional 15 speakers and other guests, in Tampa, FL September, 2014
- Reconvened Steering Committee in November 2014, and with one new member selected from prior year workshop attendees.
- Identified Steering Committee meeting feedback and suggested modifications to program approach based on evaluations.
- Performed extensive outreach and networking to generate a second year of program applicants.
- Launched MREP USVI Led by MREP graduates from prior year and in collaboration with NOAA fisheries, Caribbean Fishery Management Council, Dept. of Natural Resources and local stakeholders and interested parties such as Fisheries Associations, and TNC.
- Held 3-day combined fishery science, management and Law enforcement MREP USVI workshop for 35 participants in May 2017.

Workshop evaluations were universally positive and indicated a significant increase in participants’ likelihood to participate in fisheries science & management activities, such as cooperative research, data collection and fishery management council activities.
EDUCATION AND OUTREACH ACTIVITIES

- The full Steering Committee was provided with periodic updates on curriculum development progress, which 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.
- Program awareness and recruiting for attendees for the science program took place primarily during the months Jan – March 2018.
- We enlisted the Steering Committee members and prior years program attendees as program ambassadors, and the response was tremendous. They reached out to their networks and helped spread the word.
- August 2017 – At Caribbean Council Meeting, MREP USVI workshop attendees, Julian Magras, provided summary of implementation outcomes and gave enthusiastic testimony about the pilot MREP USVI.
- We developed another colorful postcard that could be easily circulated and handed out by Steering Committee, and councils alike and provided each person with 20 to hand out, each council with 250.
- We obtained a mailing list of all Federal permit holders in the Southeast region, and another list of dealers and seafood processors. The total potential mailing list size was 18,000 from which we randomly selected 5,000 names to receive the postcard via bulk mail.
- We employed a combination of tactics whereby we requested the councils include an announcement in their council meeting updates, and communications to their lists, on behalf of the program.
- As well, individual Steering Committee members engaged in social media such as Facebook posts to reach a younger audience
- A unique website page continues to serve this effort. We used photos provided by Steering Committee members, and NOAA staff to ensure the proper look and feel for the Southeast region.
Industry leadership capacity is fostered through program participation; outreach efforts are a community effort, with MREP steering committee members and past graduates reaching out to their constituent groups. The number of applications each year exceeds the number of seats available, and we have a waiting list.

USVI Fisheries stakeholders from a variety of regions and sectors (Recreational, Commercial, Charter) work together in small groups during hands-on otolith extraction and ageing activity.
Figure 3. Science and Management workshop presenters drawn from NOAA fisheries’ most senior leadership and leading local academic and research institutions, devote time to presenting at MREP, answering questions, and enable application of concepts learned into real world situations.

Figure 4. Conversations during meals and social hour allow participants and presenters to establish relationships, and build trust with fisheries stakeholders outside the regulatory arena.
Train the Trainers Workshops – for Mussel Farmers and Extension Agents

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2017 – March 31, 2018

CINAR Investigator – Scott Lindell, WHOI

NOAA Sponsor – Clete Otoshi, NMFS

Related NOAA Strategic Plan Goal: Resilient Coastal Communities and Economics

CINAR Theme: Education and Outreach

Amount Funded: $ 7,447

PROJECT OVERVIEW

The project objectives were to train half a dozen individuals so that they would individually and collectively be able to train others in the use of special mussel farming equipment. Ultimately, the goal is to promote a sustainable mussel farming industry in Morocco. Hands-on training was planned over 3 days in October 2017 with cooperation of the Moroccan National Agency for the Development of Aquaculture (ANDA) and members of a fishing cooperative who have started a mussel farm near their home port of Cala Iris with financial support from NOAA’s Aquaculture Program and US State Department, and expertise provided by the PI, Scott Lindell. The project successfully met or exceeded all target objectives.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Lindell and assistant David Bailey led mussel farmer training workshops with 2 ANDA staff members and 5 members of the Cala Iris Fishermen's Cooperative in October 2017. The workshops covered the operation and maintenance of special mussel socking machines (for planting seed) and mussel declumpers and graders (for harvesting and processing market product) for efficient mussel farming. The workshops took place over 3 days (10/23 – 10/25) and were devoted to preparing seed for mussel socking (declumping and grading), operating and maintaining the mussel socking machinery, conducting farm assessments, maintenance and operational steps.

HIGHLIGHTS

1. Farm improvements that the PI and assistant implemented in 2016 were evident and well managed.
2. One ton of mussel seed was successfully procured and Moroccan participants were trained how to prepare it for socking with special declumping and grading machinery.
3. Grow ropes were successfully harvested, cleaned and prepared for the socking exercise.
4. Approximately 200 meters of mussel socks were creating from the prepared seed, and hung for
grow-out on the farm.
5. Buoys were deployed alongside the new socks to maintain proper line configuration on the farm lines. The buoyancy of other lines was improved.
6. Left-over seed was stocked on subtidal rocks near the farm to encourage future natural seed recruitment on special seed collecting ropes hung at the farm.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS
All photos were either taken by Lahoussine Aarab (ANDA) or Scott Lindell (WHOI)

Figure 1. The continuous rope seed collectors that our project established in 2016 now support market-sized mussels. This was harvested to provide growing ropes for our training exercise. (credit: ANDA).

Figure 2. Newly harvested growing ropes being cleaned and dried prior to re-use for replanting in our training exercise. (credit ANDA).
Figure 3. Cala Iris Fishing Cooperative purchased 2 tons of seed that were transported in these plastic sacks and stored in the harbor for the mussel grading and socking training. (credit ANDA).

Figure 4. Lindell (right) and Bailey (left) with the equipment that NOAA funding provided to the Cooperative; hydraulic power pack and seed declumper/grader in the foreground, and Aguin mussel socking machine in the background (credit ANDA).
Figure 5. Lindell and Bailey lead hands-on training with the seed declumper/grader (credit ANDA).

Figure 6. Freshly declumped seed sits in dockside mesh trays ready for socking (Credit ANDA).

Figure 7. Lindell and Bailey lead hands-on training on use of mussel socking machine (Credit ANDA).
Figure 8. Mussel socks are stored in the water (right) until they are ready to be loaded onto barge (left) and transported to farm for planting. Extra bags of seed are visible stored in water (bottom left) until they can be planted to supplement wild seed source and spat-fall.

Figure 9. Cala Iris Fishermen being trained by Dave Bailey in appropriate spacing and best ways to attach continuous mussel socking to the headrope (credit WHOI).
Figure 10. Mussel socks and appropriate buoys are rigged and ready to be deployed from barge (Credit ANDA).

Figure 11. Rocky site in the foreground where extra mussel seed was planted, with Port of Cala Iris in the background (Credit ANDA).
PROJECT OVERVIEW

- 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.

PROJECT MILESTONES AND ACCOMPLISHMENTS

This grant provided Dr. Gavin Fay, tenure-track assistant professor of Fisheries Oceanography at SMAST, with 21% of his salary support during academic year 2017-2018. Dr. Fay was a co-instructor of the QUEST/ICES training workshop “Application of Quantitative Methods in Fishery Management”, a one-day course for 50 students held in Fort Lauderdale in September 2017 as part of the ICES Annual Science Conference. Dr. Fay also co-convened a session on “Management Strategy Evaluation” at the IMBER IMBIZO meeting “Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management”, held in Woods Hole in October 2017.

Graduate student Amanda Hart was fully 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 presented her work on applying ecosystem-based management strategy evaluation at the American Fisheries Society Annual Meeting in Tampa in August 2017, and at the ICES Annual Science Conference in Fort Lauderdale in September 2017.

Classroom activities:

Dr. Fay taught the following four classes during the 2017-2018 academic year:

- MAR536 Biological Statistics II (solo taught 4 unit course)
- MAR580-02 Science Communication for Research Scientists (co-taught with Dr. O’Keefe (Mass DMF) and Prof. Cadrin, 3 unit course)
- MAR580-01 Advanced Population Modeling (co-taught with Prof. Cadrin, 3 unit course)
- MAR700 Graduate seminar in Fisheries Oceanography (1 unit seminar course)
- Quantitative Workshop in Fishery and Ecosystem Science
MAR 580-02 (Science communication) was a new course, organized around the importance of messaging and storytelling for communicating science, and comprised many types of presentations and writing assignments for practice communicating to diverse audiences. Brief description of these courses is provided below.

MAR 580: Science Communication for Research Scientists
Practice and development of skills for communicating scientific research to a diverse set of audiences is important for applications to fisheries management and policy. This course is for students in the sciences and focuses on the importance of defining the ‘so what’ of research and adapting messaging to specific audiences, using storytelling techniques to produce compelling presentations of scientific research. Drawing on communication case studies and their own academic interests as context, students practice delivering their message effectively for different audiences, including defining goals, identifying main points, explaining meaning and context, responding to questions, and using multimedia elements. Students develop and apply skills for communicating their research to scientific peers, the management community, stakeholders, and the general public. In-class activities and assignments emphasize presentation skills, writing, reflection, and constructive criticism through peer-review of classmates’ work. The role of the review process for how best available science is incorporated into policy and decision-making in the context of fisheries management was used as a case study during the course. Topics and activities have relevance for many disciplines at the science-management-policy interface.

MAR 580: Advanced Population Modeling for Management of Living Marine Resources
Instruction, demonstration and exercises in advanced population modeling, as applied to fisheries. A wide range of stock assessment methods was introduced 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, was 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).

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 are presented by students, including analyses of example data sets and problems. In addition to core course content, students 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, is held for the first half of the semester.

MAR 700 Graduate Seminar in Fisheries Oceanography
Dr. Fay organized the Department of Fisheries Oceanography seminar series for spring 2018, which is a weekly series of talks by external speakers in marine fisheries and ecosystem science. As in previous semesters when I have run the seminars, Dr. Fay committed to inviting a diverse set of speakers, in gender, area of employment, and career stage. In addition to seminars, Dr. Fay started a student lunch with seminar speakers during their visit. This was a chance for students to talk with speakers about a range of topics, not just the research being covered during the talk later that afternoon.
Quantitative workshops in Fishery & Ecosystem Science
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.

Dr. Fay also co-chaired an International Council for the Exploration of the Sea (ICES) student review group with Prof. Cadrin (May 2018). 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 co-taught a one-day course on Quantitative Methods in Fisheries Science to 50 students at the ICES annual science conference as part of the NOAA QUEST program. Dr. Fay’s contributions included a lecture and computer lab exercise on Management Strategy Evaluation. Other instructors included QUEST faculty from other NOAA supported institutions.

Dr. Fay led a small group of students during Spring semester in statistical catch at age modeling using the stock assessment package Stock Synthesis. Students worked with NOAA Fisheries Northeast Fisheries Science Center scientist Dr. Jonathan Deroba to produce a working paper for the 2018 Atlantic herring stock assessment.

Dr. Fay was a co-convener for the following conference: Marine biosphere research for a sustainable ocean: Linking ecosystems, future states and resource management. Integrated Marine Biosphere Research (IMBER) IMBIZO 5 conference. Woods Hole, MA. 2017.

Newly Funded Grants:


Hatch J, Haas H, Upite C, Keane E, Smolowitz R, Patel S, Fay G, Winton M, Saba V. Analysis & Applications to Improve Protected Species Assessments in the Greater Atlantic Region. Protected Species Branch, Northeast Fisheries Science Center, National Marine Fisheries Service, NPST Initiative FY 18-20. $300,000. (Fay and Winton co-investigators, no funds to UMassD)

Submitted Proposals (Pending)
- Wildermuth, RP, Fay G. Performance evaluation of qualitative and Bayesian network social-ecological models for use in Integrated Ecosystem Assessment. NMFS/Sea Grant Population and Ecosystem Dynamics Graduate Fellowship. $67,539. (pending)

Submitted Proposals (Rejected)
- He, P., C. Rillahan, G. Fay. Large mesh, small fish: The effects and implications of unobserved escapee mortality in the large mesh groundfish trawl fishery. NOAA Bycatch Reduction Engineering Program. $245,000. (co-PI).

HIGHLIGHTS

- Six peer-reviewed publications published or in revision, and nine technical reports.
- Sixteen conference presentations at national, international, and regional meetings by Dr. Fay and his research group.
- Three courses, one seminar, a QUEST/ICES training, and a conference session taught in topics relevant to NOAA QUEST program priorities.
- Support for proposal development has resulted in 9 newly funded grants to help Dr. Fay continue to establish his research program at UMass Dartmouth.
- Full 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, and is a member of the ICES Working Group on Northwest Atlantic Regional Sea. Dr. Fay’s project with the New England Fishery Management Council 2017 Atlantic herring Management Strategy Evaluation helped to create materials used to disseminate information about Council proposed management actions to public and stakeholders. Dr. Fay also serves as a member of the ADMB Foundation, which supports development of the software used for the majority of fisheries stock assessments worldwide. 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:

(bold = Fay lab member; *postdoc, **grad student, §undergrad, presenter in italics)


Dr. Fay also gave the following invited seminars during 2017-2018:

PUBLICATIONS

(bold = lab member; *postdoc, **grad student, §undergrad)

Refereed journal articles


In review


Technical Reports


PROJECT OVERVIEW

There are three objectives in this fellowship project:

- **Objective 1** Quantification of demersal fish using HabCamV4.
- **Objective 2** Quantifying the impact of swimming in early life history stages of sea scallop on post-settlement distribution.
- **Objective 3** Habitat and ecosystem resiliency.

**Details:**

**Objective 1** Quantification of demersal fish using HabCamV4. HabCamV4 images are being used directly to quantify the distribution and absolute abundance of skates, flounders (particularly Yellowtail [YT] Flounder), and gadids (cod and Haddock). Two issues are 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 have developing an automated fish detector primarily using stereo segmentation and classification using Deep Learning machine vision and learning tools (See Figures) and built this capability into the standard HabCam processing workflow. Starting is 2016 and continuing into 2018, 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, Jonathan Duquette, a NOAA stock assessment scientist, and Patti Keaton, a subcontractor to my lab. The next step was 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 and is using statistics developed by Miller, Hart, Hopkins, Vine, Taylor, York and Gallager. *Estimation of the capture efficiency of Atlantic sea scallops 2 Placopecten magellanicus from paired photographic-dredge tows 3 using hierarchical models*.

**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 NES LME, which can go on for 10s of km.
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 Changsheng Chen, Professor at 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 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. We are now completing this project and will have results on our website shortly.

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 using Deep Learning 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 100’s 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 money to write a successful proposal in 2017 and again in 2018 to the scallop RSA program that specifically address habitat resiliency in the closed area II HAPC. We are now deeply entrenched in processing 40TB of data to characterized habitat in this area. I am currently funded to complete a third year in the CLAI HAPC impact study area next month (July 2018), which will provide a follow-up pass on the impact site that we started in 2016. I am also funded to complete a full scallop survey of the entire northeast Continental Shelf from Virginia to Georges Bank that will commence in July 2018. A third RSA project that was funded is to develop a spatially and temporally explicit scallop Gonadal Somatic Index for the entire scallop survey area using 3D imaging of shucked scallops and the NOAA Observers Program. 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 spawning areas and times.

PROJECT MILESTONES AND ACCOMPLISHMENTS

- I have developed an automated fish detector primarily using stereo segmentation and classification using machine vision and Deep Learning tools
- I am the process of building this capability into the HabCam standard processing workflow
- I am in the process of quantifying species-specific fish avoidance behaviors by viewing sequential, overlapping images of swimming fish together with NOAA scientists
- I am co-author on one manuscript with NOAA personnel and working on a second 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 Chen at UMass Dartmouth SMAST to model the potential transport of juvenile scallops using FVCOM. This study is nearing completion.

• 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 100’s km) information on available surface structure and complexity.

HIGHLIGHTS

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 (Lough et al, 1989). I am completing a BACI impact study of the impact of dredge gear on habitat for sensitive ground fish juveniles using survey data we collect using HabCam repeatedly following an initial impact with dredges where a depletion study brought scallops and epifauna down to bare substrate. I am now in the third year to following recovery of these impact sites.

EDUCATION AND OUTREACH ACTIVITIES

Gallager presented a talk at the 2017 American Fisheries Society meeting in Baltimore, MD.

Habitat Classification and Mapping Across Wide Spatial Scales Using Optical and Acoustic Sensor Fusion: The Towed and Autonomous HabCam Vehicles

Scott M. Gallager, Michael Saminsky, and Steven Lerner

PUBLICATIONS

During the process of building habitat maps and models using habitat suitability modeling, we need to convert from the scales of side scan sonar data to that of image data. To do this I developed a Modulation Transfer Function that describes the relationship between information gathered at the scale of 1m using images to the scale of 100s of meters using side scan sonars. Thus habitat information obtained at the image scale can now be transferred to 100s of meters on either side of the towed vehicle.
Three composite images of side scan sonar data extending out to 100m on either side of the towed vehicle (HabCam) and stereo images being acquired down the nadir of the side scan data for three habitat types: shellhash/gravel, sand/epifauna, sand/large sandwaves. In each of these habitats scallops may be found associated with different features such as between the hydrozoan epifaunal assemblages and on the lee side of the sand waves.
Dominant substrate type as estimated using machine vision and Deep Learning from the HabCam stereo images along the Northeast Continental Shelf. The next step is to interpolate these data to a standard grid to allow a full map of the Shelf to be produced at the 1 m scale.
Four different habitat types as autonomously identified using our Deep Learning machine vision tools.

Abundance of the colonial tunicate *Didemnum vexillum* as predicted using our habitat suitability modeling in the HAPC of Closed Area II on Georges Bank. With this model we can now do simulations under different climate change scenarios to see how these invasive tunicates respond.
CINAR Fellow: Joel Llopiz, WHOI

PROJECT OVERVIEW

My research interests and activities focus on fish ecology, with particular emphases on fish early-life stages and fish-zooplankton trophic 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. Research activities in 2017 specifically supported by my fellowship have been focused on larval and adult sand lance on Stellwagen Bank (with NOAA collaborators), investigating the ecology of bluefin tuna larvae in the Slope Sea (with NOAA collaborators), deployment of a video monitoring system to examine juvenile river herring emigration dynamics, and expanding work related to our NSF LTER project involving NOAA collaborators. These and other activities are detailed below.

PROJECT MILESTONES AND 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 summer of 2017, I deployed a camera system in the Monument River (which connects the Cape Cod Canal to Great Herring Pond) with the ambitious goal of counting every juvenile river herring heading to sea. An incredibly informative 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 will allow us to reach this goal, since in 2017 it was deployed for the entirety of the juvenile emigration period (June to December), continuously recording almost the entire time. I am currently working with WHOI computer scientists and a graduate student at UMass Amherst to automate the detection of herring in the footage and using crowd sourced (i.e. citizen science) efforts to enumerate herring in the frames.

The other major research activity is a collaboration with NOAA’s Stellwagen National Marine Sanctuary (led by Dave Wiley) 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. The time I devoted to this work led to being a co-PI on a large proposal submitted to BOEM (led by Dave Wiley) that was successful. This project started in earnest in 2017, and my 2nd-year PhD student Justin Suca is making sand lance the focus of two of his dissertation chapters. 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. The initiation and participation in this collaboration would certainly have not been possible without CINAR Fellow support, and is the best example for me of
how my award has led to opportunities for long-term collaborations with NOAA and a remarkable research experience for my graduate student—one where quantitative skills and ecosystem-level questions are front and center.

A collaboration with David Richardson (NOAA) and the Oceanography Branch at the NEFSC continued in 2017, 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 3rd-year PhD student Christina Hernandez. Christina participated on two 2017 NOAA cruises to the Slope Sea, co-leading the sampling and mapping of larval bluefin distributions and leading efforts releasing oceanographic drifters in patches of bluefin larvae to understand the physical mechanisms associated with retention of larvae in the Slope Sea.

Finally, I am a co-PI on the newly awarded NSF-funded Long-term Ecological Research site on the Northeast US continental shelf that began in 2017. However, the salary support available from this project is limited, and CINAR Fellow support has enabled expanding the analyses and activities related to the LTER project and my components focused around zooplankton and forage fish.

Educational activities have been numerous since receiving a CINAR Fellowship. Noted above, I advise two graduate (Ph.D.) students—a 2nd-year (Justin Suca—Hollings Scholar alumnus) and a 3rd-year (Christina Hernandez). In 2017, Justin switched the focus of his dissertation from the settlement dynamics of coral reef fish larvae to small pelagic fishes (aka forage fish) that occur on the Northeast US shelf (sand lance and river herring) and in the Arctic (Arctic cod). All of his proposed chapters are either highly quantitative or ecosystem-centric—or both (e.g. habitat modeling of sand lance). 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 has 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 and management-relevant results on the evolution of anadromy in herrings. Also advised this past year was Andrew Jones, a CINAR-funded Postdoctoral Scholar. Finally, during 2017, my fellowship has helped me host in my lab and mentor three undergraduates, four high school students, and a Fulbright Scholar from Spain.

Other activities included submitting a successful Sea Grant proposal focused on the source-sink dynamics of sand lance hotspots in the Northeast Region. Related to service, I served as the chair of the Regional Association for Research on the Gulf of Maine (RARGOM), an activity that has been exceptional for getting to know many of the region’s researchers, and would only be possible with CINAR Fellow support. As chair, I organized the RARGOM Annual Science Meeting held in Portland, Maine, focused on the ecological and sociological impacts of ocean and coastal acidification in Gulf of Maine. I also gave a talk at and participated in a sand lance workshop in Newburyport, MA and the Ocean Outlook Meeting in Bergen, Norway. 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, Herring Ponds Watershed Association), the public, and school-age children.
HIGHLIGHTS

- Deployment of a camera system for 7 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.
- Continued a collaboration with NEFSC to study the growth, feeding, and dispersal of bluefin tuna larvae in the Slope Sea.
- Expanded on our NSF LTER project’s efforts focused on the NE US shelf ecosystem and heavily reliant upon 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 Northeast Region
- Hosted and mentored three undergraduates and four high-school students, each working on fish ecology for species within the NE region
- 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.
- Invited workshop participant focused on sand lance on the NE US shelf
- Shared lab’s research with the general public and school-age students through several presentations and lab tours

PUBLICATIONS


CINAR Fellow - Heidi Sosik, WHOI

PROJECT OVERVIEW

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.

PROJECT MILESTONES AND 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 15 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 (June 2018) completed our sixteenth 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 microzooplankton 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).
In 2017 and early 2018, peer-reviewed publications focused on advancing and documenting both IFCB measurement capabilities (Olson et al. 2017, Campbell et al. 2017) and IFCB data analysis and interpretation methods (Kalmbach et al. 2017), as well as casting strategic visions for integration of automated biological sensors into ocean observing systems (Muller-Karger et al. 2017, Boss et al. 2018). New IFCB measurement capabilities include integration of acoustic focusing for non-disruptive concentration of cells as they enter the flow cell (improves counting statistics) and new data analysis approaches embrace state-of-the-art machine learning strategies to extract novel ecologically relevant information from “big data” image time series. Notably, Kalmbach, student first author, received second place in the student presentation award for aspects of this work at the OCEANS ’17 MTS/IEEE conference.

During my fellowship, I led two major efforts to launch new programs in the region. First, 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. Second, I am the scientific lead on a multi-PI program at WHOI to launch an interdisciplinary exploration of mesopelagic ecosystems, the Ocean Twilight Zone (OTZ) project, with initial focus on areas of the northwest Atlantic extending offshore of the NES-LTER region.

The NES-LTER project commenced in fall 2017 with funding for an initial 5 years ($5.6M) and with follow up 6-year renewal cycles pending successful outcomes. Successful field observations under the NES-LTER umbrella have been undertaken in 2017-2018. 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 combines 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?

In April 2018, The OTZ project was announced as one of five recipients for the new Audacious Project initiative designed to replace and scale up the TED Prize. Housed at TED, the Audacious Project is a collaboration between TED and leading philanthropic organizations to support “bold ideas” with high potential to catalyze. With an initial budget of $35 million over a 6-year scope, the OTZ project reflects the largest philanthropic donation in WHOI’s history. The project will embrace a high level of science integration, a portfolio of new ocean technologies, and a new approach to societal engagement.
The scientific goals are to deepen understanding of the distribution of biomass and biodiversity, food web linkages within the twilight zone and among the twilight zone and other ocean realms, the life histories and behaviors of twilight zone animals, and the role of the twilight zone and its inhabitants in the global carbon cycle. A overriding vision is to promote channels for rapid and effective translation of scientific knowledge for management and policy making, including in relation to promoting sustainable fishing and other human interactions.

Education and outreach activities during my CINAR fellowship include (1) numerous conference proceedings related to the research described above (including a now widely viewed TED Talk presented at the official TED2018 conference); (2) community-level and political engagement (e.g., presentations to local volunteers; ecosystem-science focused briefings to visiting dignitaries, etc.); and (3) participation in graduate education (e.g., advisee Emily Brownlee defended her PhD dissertation; on-going graduate advisees Kevin Archibald and Bethany Fowler conducting NES-LTER research; 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 16th successful Imaging FlowCytobot deployment on NOAA surveys of the Northeast US shelf, continuous underway operation has produced ~10 million plankton images in >163 days at sea (surveys during 2013-2018).
- 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).
- 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.
- Led successful effort to launch the Ocean Twilight Zone (OTZ) project, with an unprecedented $35 million philanthropic donation through the Audacious Project initiative housed at TED; the OTZ project is focused on promoting deep understanding of mesopelagic ecology and developing channels for communicating knowledge that can be used for sustainable management and harvesting policies.
- Delivered TED Talk on the ocean’s twilight zone at the official TED2018 conference (now online: https://www.ted.com/talks/heidi_m_sosik_what_if_we_explored_the_ocean_s_twilight_zone
EDUCATION AND OUTREACH ACTIVITIES

• Presented at TED2018 Conference, Vancouver, Canada, 10-13 April 2018
• Presented at 2018 Ocean Sciences Meeting, Portland, OR, 11-16 February 2018
• Presented keynote address at International Ocean Colour Science Meeting, Lisbon, Portugal, 15-18 May 2017
• Presented at 2017 Annual Meeting of the Society for Integrative and Comparative Biology, 1 Jan 2017
• 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/
• 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
• 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
• 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
  o http://www.whoi.edu/news-release/NES-LTER
  o http://www.whoi.edu/news-release/audacious-project
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°C (triangles), 9°C (circles), 12°C (stars), or 15°C (squares). (B) *Synechococcus* cell concentration. Markers indicate the day in each year when cell concentration exceeds $8 \times 10^3$ (triangles), $1.6 \times 10^4$ (circles), $4.8 \times 10^4$ (stars), or $9.6 \times 10^4$ (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.
APPENDIX 1: CINAR Personnel Summary

NA14OAR4320158
April 01, 2017– March 31, 2018

Task 1 Support

Employees Appt. Dates

Don Anderson, CINAR Director                  7/01/09 - present
Mindy Richlen, CINAR Associate Director                6/01/15- present
Ann Stone, CINAR Administrative Professional         9/26/09 - present
## Appendix 2. CINAR Personnel Summary Chart

**NA14OAR4320158**  
April 01, 2017 – March 31, 2018

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<th>M.S</th>
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### Appendix 3: Other Agency Awards

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<td>Danielle Cholewiak</td>
<td>NA17OAR4320158A</td>
<td>$20,122</td>
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<td>A. Mooney</td>
<td>Behavioral effects of sound sources from offshore renewable energy construction on the black sea bass (<em>Centropristis striata</em>) and longfin inshore squid (<em>Doryteuthis pealeii</em>)</td>
<td>Sofie Van Parijis</td>
<td>NA17OAR4320158B</td>
<td>$101,828</td>
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</table>
DTAG Support: Tagging Beaked Whales in the North Atlantic

CINAR Investigator – Alessandro Bocconcelli, WHOI

NOAA Sponsor – Danielle Cholewiak, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

Award Number: NA17OAR4320158A

Amount funded: $20,122

PROJECT OVERVIEW

Abstract: The goal of the project is to study the behavior of beaked whales in the North Atlantic offshore the U.S. coast. The proposed work takes advantage of the digital acoustic recording tag (DTAG) developed at Woods Hole Oceanographic Institution (WHOI) for studying the behavior of marine mammals in the wild. The National Oceanic and Atmospheric Administration (NOAA) Northeast Fisheries Science Center’s (NEFSC’s) Passive Acoustic Research Group will be conducting the field component of this project. The recording tag is attached non-invasively to the back of the whales using suction cups. Once released, the tag floats to the surface and it is recovered using radio-tracking. A large memory array on the tag stores raw sensor data.

Project Description: This proposal covers the preparation of four (4) DTAGs (version 3) at WHOI for the planned field effort (July 24 to August 9, 2017). The WHOI DTAG lab will supply the tagging equipment and the radio-tracking equipment. This includes four (4) DTAGv3, supplies for preparation and maintenance of the tags, several spares including suction cups and releases, and the DTAG data download gear (data cables and one DTAG laptop). The radio gear will include one (1) four-element Yagi antenna with coaxial cables, four (4) handheld antennas, four (4) R1000 receivers, and one (1) RDF “black box” plus a spare. WHOI will be responsible for the preparation, calibration, and bench testing of the DTAGs and related equipment. The data collected during this research cruise will be analyzed by members of Dr. Danielle Cholewiak’s research team at NOAA NEFSC.

Relationship to NOAA goals: NOAA's mission includes monitoring the distribution and abundance of cetaceans occurring within the U.S. Exclusive Economic Zone, with the NEFSC responsible for surveying waters in the western North Atlantic. NOAA achieves these goals by using a combination of visual survey effort and passive acoustic monitoring (PAM). Key components to effective visual and acoustic surveying include developing a better understanding of the dive behavior and acoustic characteristics of cryptic species, such as beaked whales. Employing technology such as DTAGs enables NOAA to collect critical information on species that are difficult to study using other methodologies. These data will inform estimates of availability for visual surveys and provide
acoustic characters of echolocation clicks for PAM.

Additional Resources – Data Sharing: The work described in this proposal comprises the preparation of tagging and tracking equipment. As noted above, WHOI personnel will not be involved in the field operations, tagging, and/or handling of marine mammals; thus, no data will be generated by the activities proposed herein.

PROJECT MILESTONES AND ACCOMPLISHMENTS

Four non-invasive, suction cup-mounted digital tags (DTAG version 3) were prepared for this project. The tags were equipped with new custom-made suction cups and releases. The tags were bench tested at WHOI prior to delivery.

A complete array for tag radio-tracking was delivered to Newport, RI, and installed on the R/V *Bigelow*. All the tag delivery gear (carbon fiber poles, robot arms, etc.) was tested and also loaded onto the R/V *Bigelow*.

The array was connected to a new, custom-made Horten RDF box (fabricated in Norway for WHOI) and tested. All the gear and radio-tracking array had to be removed from the R/V *Bigelow* as the project was cancelled due to major failure of the main engine(s) of the vessel. The gear was re-packed and stored at WHOI. The same procedure was repeated later in the summer when a substitute vessel was found.

HIGHLIGHTS

- New collaboration established between WHOI and NEFSC staff to study poorly known species.
- NEFSC staff and colleagues surveyed approximately 800 km during daytime hours between 8 – 17 September, 2017. Multiple groups of beaked whales, including both Cuvier’s (*Ziphius cavirostris*) and True’s (*Mesoplodon mirus*) were located.
- Weather conditions allowed for attempted deployment of DTAGs on 3 survey days. While no DTAGs were deployed, focal follows of several groups of True’s beaked whales facilitated collection of visual and passive acoustic data, including data on dive intervals.
Figure 1. DTAG deployment attempt with True’s beaked whale (*Mesoplodon mirus*), conducted by NEFSC staff during NEFSC shipboard survey. (*Photo credit: S. Cerchio*)
Behavioral effects of sound sources from offshore renewable energy construction on the black sea bass (Centropristis striata) and longfin inshore squid (Doryteuthis pealeii)

CINAR Investigator - T. Aran Mooney, WHOI

NOAA Sponsor - Sofie Van Parijs, NMFS

Related NOAA Strategic Plan Goal: Resilient Coastal Communities and Economics

CINAR Theme: Ecosystem Management

Award Number: NA17OAR4320158B

Amount funded: $ 101,828

PROJECT OVERVIEW

The overarching goal of this project is to assess how two commercially important species, black sea bass (Centropristis striata) and longfin squid (Doryteuthis pealeii), are behaviorally impacted by exposure to marine pile driving sounds from the construction of renewable offshore energy platforms. This is a joint project between our lab (WHOI) and the Northeast Fisheries Science Center (CoPis Stanley et al.). Our portion focuses on the squid work but because this is a joint project summaries and progress of both experiments are presented here. Concern exists that exposure to pile driving sounds may lead to adverse behavioral impacts on marine fauna, including spatial avoidance of feeding and reproductive areas (and fishing areas), and may interfere with ecologically important behaviors such as conspecific communication and schooling (Bailey et al., 2014; Dahl et al., 2015; Hawkins et al., 2014). D. However, there are no published studies on effects of pile driving sounds on our study species. For this project we are utilizing pile driving sounds previously recorded from the construction of the Block Island Wind Farm, 0.5 km away from the construction site (Miller et al., 2017). Particular attention will be given to characterizing the particle motion component of water-borne sound, as squid are likely only sensitive to particle motion and not the sound pressure component, and black seabass likely utilize particle motion in addition to sound pressure for hearing. Thus for both species we are reporting and testing for the effects of both sound components.

Our first specific objective is to measure the hearing thresholds of C. striata, which is vital in determining the ecological significance of these fishes’ exposure to pile driving sounds. Hearing thresholds have been published for D. pealeii (Mooney et al., 2010), but currently no published literature exists on the hearing sensitivity of C. striata. Using Auditory Evoked Potential methods following Mooney et al. (2010), electrophysiological audiograms are being constructed for C. striata.

Second, we are quantifying initial behavioral effects of offshore pile driving sound on sexually mature black sea bass and longfin squid. This work is occurring concurrently in two different, confined and well controlled laboratory environments, with black sea bass being tested in Sandy
Hook, NJ, and longfin squid being tested at Woods Hole Oceanographic Institution, MA. Small groups of both species will be exposed to both pressure and particle motion components from sound sources involved in the construction of offshore wind farms. We will investigate changes during this sound exposure in multiple behaviors of *C. striata* and *D. pealeii*, including intraspecific communication by visual and acoustic means for *C. striata* and by visual signaling for *D. pealeii*, spatial avoidance of the sound source, swimming speed and startle responses, and schooling and shoaling behaviors (e.g. cohesion). Additionally, we plan to investigate physiological effects of noise exposure by analyzing stress hormone levels (e.g. blood cortisol, lactate, and glucose) in *C. striata*. We further plan to simulate pile driving sound exposure at various distances from the source, dependent on the ability to reproduce realistic sound intensity and spectral levels in a controlled, restricted field environment. These studies will be conducted during critical behavioral windows in order to determine if the responses vary between these periods. Specifically, we will test for differences in behavior in the presence of pile driving sound during spawning and non-spawning periods for *C. striata*, and during mating and feeding activities for *D. pealeii*.

**PROJECT MILESTONES AND ACCOMPLISHMENTS**

**Milestone 1: Baseline hearing sensitivities of black sea bass:**
Electrophysiological experiments were conducted to attain baseline audiograms of *C. striata*. The acoustic pressure sensitivity of 13 individual black seabass was tested. 10 mature individuals (~190 mm total length when mature) and three juvenile individuals were tested. Interestingly, the juveniles exhibited increased hearing sensitivities (i.e. decreased hearing thresholds) across all tested frequencies (Fig. 1). Further experiments will be run on juvenile individuals and individuals >380 mm in total length to determine ontogenetic changes in hearing sensitivities in this species. These larger sizes may also be more relevant to commercially targeted sizes. No fish responded to 2 kHz tones at any point during the trials.

**Milestone 2: Alarm responses of individual longfin squid to pile driving noise playbacks:**
Three pile driving sound tracks of similar amplitude and with inter-pulse-intervals ranging from 1.5-2.3 s were prepared for playbacks. Prior to experiments the exposure tank was calibrated in 10 cm increments in both sound pressure and acoustic particle motion. Initial experiments were then conducted. Individual longfin squid (n=14) were exposed to 15 min periods of pile driving sound playback from an underwater loudspeaker in a 1.2 m diameter, 0.5 m deep circular tank (Day 1 trials). A subset of animals (n=9) received a second sound exposure after a 24 h rest period (Day 2 trials). Control squid (n=4) were placed in the tank under the same procedure, except a silent file was played through the speaker instead, to account for effects of electrical noise from the powered playback system. Squids’ received peak sound pressure levels and peak particle acceleration levels were estimated based on a detailed spatial calibration in the tank and the squids’ present location in the tank during each pile driving sound impulse. These peak levels were about 165 dB re 1 μPa and 15 dB re 1 m s⁻² for sound pressure and particle acceleration, respectively. The sound pressure levels in the experiment represented those typically present in the water column 2-4 km away from the pile (Collett et al., 2016; Miller et al., 2017; Tetra Tech & JASCO, 2016). Particle motion levels reflected those modeled at the seabed (not the water column) within 400 m away from a simulated offshore pile driving sound source (Miller et al., 2016).
Squid behavior was recorded with overhead video for the full duration of all trials, and the following alarm behaviors were quantified: inking, jetting, locomotor startle responses, and body pattern changes (i.e. changes in coloration and patterns in the skin). All squid in experimental trials exhibited at least one of these recorded alarm behaviors during the first 30 pile driving noise impulses (which amounted to 45-69 s of playback, depending on the inter-pulse-interval). In contrast, none of the control squid exhibited any of these behaviors during the first minute of silent playback. Inking and jetting behaviors were confined entirely to the first 18 impulses, i.e. up to about 40 s of playback, and the majority of recorded behaviors occurred during the first 8 impulses (Fig. 2a). The greatest proportion of each alarm response type occurred at the first impulse and responses quickly diminished with successive impulses, suggesting rapid habituation to the pile driving sound. There were no significant differences in proportions of any alarm behavior between Day 1 and Day 2 trials in any of the first 30 impulse time bins ($P > 0.05$; Fisher’s exact test), suggesting squid re-sensitized to the pile driving sound after the 24 h rest period. Pooling Day 1 and Day 2 groups, there were significant differences in the proportions for all behaviors between the minute immediately before the start of noise exposure and the period of the first 30 noise impulses ($P < 0.05$; Fisher’s exact test). Regression models predicted that first inking behavior, followed by startle responses, then jetting, extinguished before the 30th pile driving noise impulse, and predicted near-extinction of alarm-type body pattern changes by this point (Fig. 2b).

We plan to run several more trials with individual in May and June of 2018 under this same experimental setup and procedure, in order to attain a more robust sample size prior to submitting this work for publication.

References:


**HIGHLIGHTS**

- Preliminary results of neurophysiological hearing thresholds of black sea bass indicate that hearing sensitivities drop off above 1000 Hz, and highest sensitivities occur around 150 Hz. Out of the individuals tested thus far, juveniles have higher hearing sensitivities across tested frequencies compared to adults.
- Individual longfin squid consistently responded at the onset of pile driving sound playback with at least one of the following alarm responses: inking, jetting, locomotor startle movements, and body pattern changes. Such responses are naturally employed by these squid to evade and defend against predators.
- Individual longfin squid rapidly habituated to pile driving noise in terms of their behavioral alarm responses, with all recorded alarm behaviors but body pattern changes being extinguished within the first minute of pile driving noise playback.

**EDUCATION AND OUTREACH ACTIVITIES**

- One WHOI-MIT Joint Program student is involved in the project. This project will be part of his dissertation. He is learning experimental design, hypothesis development, calibrations, data analyses and scientific writing.
- A WHOI guest student (undergraduate) was also involved in this work. She similarly learning experimental design, hypothesis development, calibrations, data analyses and scientific writing, as well as science presentation/communication.
• We provided several tours of the facility to students and invited members of the public including an animal behavior class from Boston University.

**PUBLICATIONS**

There are not yet any publications or submitted manuscripts for this project. However, a manuscript has been drafted for our work investigating behavioral alarm responses of *D. pealeii* individuals to pile driving noise playbacks.
Figure 1. Auditory thresholds (± S.D.) of 13 black seabass presented in dB re 1 μPa determined by visual inspection of waveform traces. Frequency values shown are in Hz.
**Figure 2.** Proportions (A) and number (B) of trials with squid that responded with inking, jetting, startle, and body pattern change behaviors in given pile impulse time bins. Day 1 and Day 2 trials are shown separately in A, and combined in B. Regression lines in B shown for each behavior were obtained from log link, Poisson Generalized Linear Models, with the following pseudo R² values: Inking R² = 0.8521; Jetting R² = 0.8803, Startle R² = 0.9238, Pattern Change R² = 0.7683.
Appendix 4: CINAR Publications for Reporting Period

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Publications


