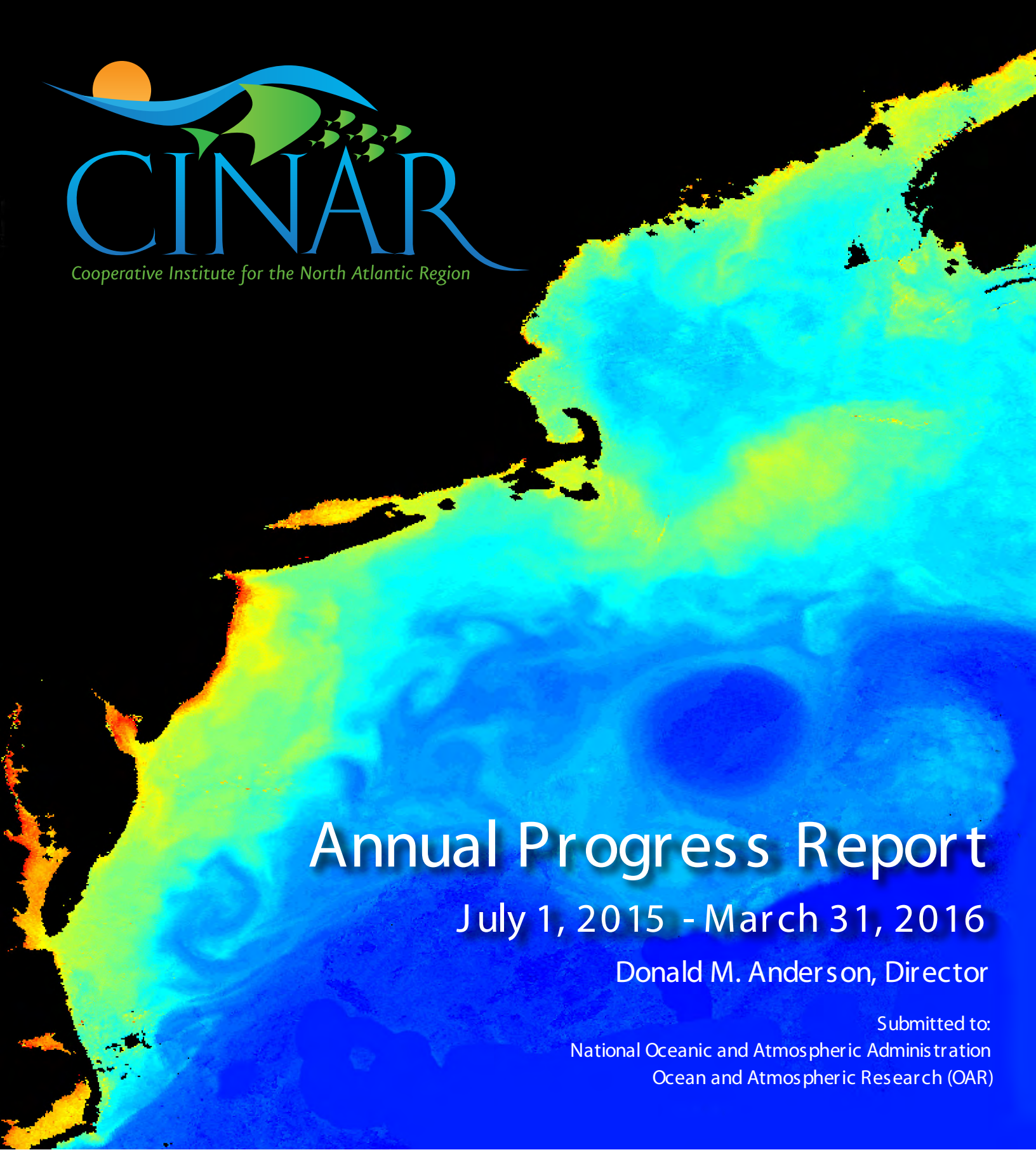
CINAR

Cooperative Institute for the North Atlantic Region



Annual Progress Report

July 1, 2015 - March 31, 2016

Donald M. Anderson, Director

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

Gulf of Maine Research Institute

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University of Maryland CENTER FOR ENVIRONMENTAL SCIENCE

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CINAR
Annual Progress Report

Reporting Period: April 01, 2015 - March 31, 2016

Submitted by:

Donald M. Anderson, Director

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Executive Summary

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

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

Funding:

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

Education and Outreach

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

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

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

CINAR Annual Research Highlights

Donald Anderson – Woods Hole Oceanographic Institution
U.S. National Office for Harmful Algal Blooms

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.

Mark Baumgartner – Woods Hole Oceanographic Institution
Bowhead Whale Feeding in the Western Beaufort Sea Oceanographic Conditions, Whale Prey Distributions, and Whale Feeding and Foraging Behavior

This project was designed to characterize the diving and foraging behavior of bowhead whales on the western Beaufort Sea shelf off Barrow during the late summer. The study employed archival tags to monitor the whales' behavior and proximate oceanographic and zooplankton sampling to characterize oceanographic conditions and the distribution and abundance of the whales' prey. This tagging and fine scale sampling was designed to elucidate (1) the depths of feeding, (2) environmental conditions influencing the depth of prey layers, (3) foraging strategies, and (4) oceanographic processes that may influence the spatial distribution of bowhead whales.

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

The goals of this project are to: (1) develop and evaluate approaches for explicit incorporation of temperature in modeling recruitment dynamics in the length-structured model; (2) evaluate various functions to link temporal variability of shrimp predator abundance with natural mortality; and (3) evaluate impacts of temperature on the growth of shrimp and develop a temperature-dependent growth transition matrix for the length-structured model.

Building on the preliminary study, we plan complete the following tasks: (1) continue analyzing existing information to examine the relationships between temperature and recruitment; (2) quantify the relationships between temperature and growth; (3) develop and evaluate different functional relationships to link predator abundance with shrimp natural mortality; (4) develop and incorporate likelihood functions based on the models developed above in the length-structured model; and (5) evaluate impacts of incorporating temperature and predators on the

quality of the stock assessment in both simulations and the assessment (e.g., retrospective errors and uncertainty).

The incorporation of temperature in modeling recruitment dynamics can greatly improve the quality of stock assessment for northern shrimp, greatly reducing uncertainty. Time steps used in the model is also very important in determining the precision and accuracy of stock assessment results. The incorporation of temperature in life history processes can greatly improve the performance of stock assessment models for northern shrimp.

Enrique Curchitser – Rutgers University
Assessing regional sea ice predictability in the U.S. Arctic: A multi-model approach

Predictability of pan-Arctic sea ice extent and volume has been examined in a number of studies. In comparison, *regional* sea ice predictability is less explored, despite its significance for a suite of stakeholders, including coastal communities, the shipping and oil industry, and marine ecosystem management. *The goal of this study is to assess regional sea ice predictability in the U.S. Arctic*: *the Beaufort Sea, Chukchi Sea, and Bering Sea.* Results from this study are anticipated to improve our understanding of processes controlling regional sea ice predictability in the U.S. Arctic, a necessary step towards developing cross-scale earth system prediction capability. Project highlights include:

- Multi-decadal coupled ocean-sea ice hindcasts were designed and carried out for 20+ years.
- Analysis of model output is ongoing.
- With a stable configuration, we are now embarking on the ensemble of future states.

Scott Gallager – Woods Hole Oceanographic Institution
Operational support for HabcamV4 on 2015 scallop surveys and post-cruise data processing

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 project is in support of six WHOI/NOAA initiatives that directly relate to either further development of this technology or to its application in enhancing stock assessment of sea scallops and ground fish. Key results include:

- Standardized image test sets representing substrate (e.g., mud, sand, gravel, cobble, boulder, and combinations thereof) and biological categories (e.g., epifauna, scallops, yellowtail flounder, etc.) have been developed and distributed to Kitware, Inc and Prasad.
- A geospatially enabled tool set and workflow for the generation of habitat and predicted habitat suitability maps from HabCamV4 and AUV optic and acoustic data has been developed and is running in real-time on the ship as the vehicle is towed.
- A systematic approach to characterizing habitat from all future HabCamV4 surveys and other imaging systems currently in use by NOAA scientists has been developed but further work is necessary to continue to bring disparate data sets together.

Production of visualization tools to better inform scientists, regulators, and the public of habitat value including Google Earth displays have been integrated into the real-time display on the ship and following post-processing on shore.

Jacqueline Grebmeier – University of Maryland Center for Environmental Science
Synthesis activities within the RUSALCA Program, 2014-2015

The Russian-American Long-term Census of the Arctic (RUSALCA) is a NOAA-sponsored program to document the long-term ecosystem health of the Pacific Arctic ecosystem, particularly as changes in various components are observed associated with climate forcing. Three full-scale ecosystem cruises were undertaken in **August 2004,** and August-September 2009 and 2012 in the Chukchi Sea (plus East Siberian Sea in 2009 only). Within the RUSALCA program our project objectives were to evaluate the benthic community structure and carbon cycling in the Pacific-influenced waters in the Amerasian Arctic. Our work was focused on benthic biological communities and associated sediment chemistry. Our findings indicate higher export of carbon in the SE Chukchi Sea in areas of high primary production and in areas around Wrangell Island and on the western side of Herald Canyon. We have also observed decadal changes in organic carbon processing and regional decline in benthic biomass at some time series sites in the SE Chukchi Sea. As part of the RUSALCA effort, we co-authored five publications in the September 2015 special issue of Oceanography with Russian colleagues, with our two lead PI authored articles developed during our trip to Moscow and St. Petersburg, Russia in February 2015.

Shaleen Jain – University of Maine
Nonstationarity in the magnitude and seasonality of extreme precipitation

This research project was conceived with a view to develop methodologies and regional and national scales diagnostic studies to understand the nature and seasonality of extreme precipitation. From the methodological standpoint, the PI and collaborators have developed a nonparametric circular statistical approach to aid characterization of seasonality of hydroclimatic variables. Project highlights include:

- Development of a new daily precipitation dataset for the Asian region, separated based on typhoon and non-typhoon days.
- Completion of a comprehensive study of extreme precipitation nonstationarity over eastern United States. Results show increases in extreme precipitation, and a significant part of the increase can be related to tropical cyclone activity.
- Testing and development of methodology to identify significant time windows within a year related to extreme precipitation (data-based “modes”), and nonstationarity therein. The PI plans to apply both their approach and the SiZeR method to identify temporal changes.

Joel Llopiz – Woods Hole Oceanographic Institution
Is Atlantic cod and haddock recruitment influenced by the planktonic environment and feeding success during the larval stage?

The overall goal of this study is to evaluate whether variability in the larval environment, prey selection and feeding success can explain the contrasting recruitment patterns of the Gulf of Maine and Georges Bank stocks of Atlantic cod and haddock. To accomplish this, we will evaluate concurrently collected larval and zooplankton data, and develop a new dataset on larval feeding from archived ichthyoplankton samples. Specific objectives include:

1. The environmental conditions experienced by fish early life stages can be decoupled from larger regional-scale patterns due to variability in spawning time or location and fine-scale larval distributions. Thus, we will examine inter-annual differences among stocks in the zooplankton communities and temperature environment experienced by the larvae using concurrently collected oceanographic, zooplankton and ichthyoplankton data.
2. We will examine inter-annual, regional, and species-specific differences in both feeding success and diet composition of larval cod and haddock from Georges Bank and the Gulf of Maine, and will relate larval feeding success and diets to physical and biological conditions, including ambient zooplankton abundance and species composition.

This project is testing the hypothesis that the contrasting patterns in recruitment success among the four stocks can be linked to larval feeding success and environmental drivers. If the previous analyses support it, we will then integrate a zooplankton index into the assessment models stock recruitment function.

Henry Mayer – Rutgers University

NOAA Port Tomorrow Proposed Expansion: Resilience of Mid-Atlantic Ports and Surrounding Communities

Recent experiences in the Mid-Atlantic States with severe storms and companion surge, flooding, and high winds have shown that the resiliency of working waterfronts and their adjacent communities can be critical to the minimization of losses and damages to broader regional transportation systems and economies. The research team believes that NOAA's *Port Tomorrow Resilience Planning Tool* (http://www.coast.noaa.gov/port/) has the capacity to address many of these issues, and comprises a web-based platform to provide coastal decision makers with spatially relevant and integrated data, including social and economic data, to support risk analyses, mapping, scenario analyses, adaptation planning, and implementation. Through a pilot study in the Hampton Roads, Virginia area, the research team investigated if and how the tool might be expanded to serve as a tool for multi-stakeholder resilience planning for communities adjacent to or otherwise dependent on working waterfronts. Accomplishments include:

- The project gathered information from critical stakeholder groups, including the Port of Virginia, the Virginia Maritime Association, Hampton Roads Regional Planning District Commission, City of Norfolk, and other participants.
- Data inventory for federal, regional, and local data sources, which the research team used to compile the ESRI StoryMap product for future development.
- Prototype Port Tomorrow website.

Kathy Mills – Gulf of Maine Research Institute
Climate Adaptation in Fishery Ecosystems

As the impacts of climate change and variability become apparent in fishery ecosystems, there is a critical need for strategies that enable climate adaptation in marine fisheries. Advances towards climate adaptation have been less developed for fisheries than for other sectors, such as agriculture, water resources, and coastal management. Our project is developing frameworks for climate adaptation that will enable fishery managers, fishing industry, and fishing communities to plan for future risks and opportunities.

The project will work towards this goal through two specific objectives: (1) Organizing an international working group on Climate Adaptation in Fisheries Ecosystems (CAFE) to compare climate impacts and adaptation approaches with rapidly changing ecosystems with different fisheries and fishery management regimes; and (2) Piloting and refining a social-ecological vulnerability assessment and adaptation planning framework for marine fisheries.

To date, this project has made progress on Objective 1 by organizing and facilitating a workshop on "Moving Towards Climate-Ready Fishery Systems" at the 3rd international symposium on the Effects of Climate Change on the World's Oceans. (The workshop brought together 44 scientists from the US, Australia, New Zealand, Norway, the UK, Canada, Brazil, and Cambodia to compare experiences in climate impacts and adaptation across four fishery ecosystems (eastern Australia, Gulf of Alaska, Gulf of Maine, and Nordic Seas) that are experiencing rapid changes. We reported on this workshop through an article in the summer 2015 issue of PICES Press, and plan to develop a synthesis paper for submission to a peer-reviewed journal that will document case studies presented and key themes of discussion during the workshop.

Michael Moore – WHOI
Effects of Drag from Entanglement in Fishing Gear in Right Whales

Entanglement is the leading cause of death in large whales in the Northwest Atlantic. Entanglement may become protracted when individuals break free and carry a portion of the entangling gear, often for months to years. Sublethal entanglement trauma is close to ubiquitous in North Atlantic right whales: in a recent survey, 83% had been entangled at least once, and 26% acquired new wounds and scars annually. It therefore could be a major concern in terms of population level productivity.

Even following disentanglement of right whales by humans, or self-disentanglement, energy reserves may remain sufficiently impacted so as to lead to death. Combining empirically derived drag estimates with individual life history information from the North Atlantic Right Whale catalog, this project is investigating the energetic impact of 15 specific entanglement cases to determine the predictability of lethality and post-disentanglement survival. This project has: This project has:

- Increased our understanding of the magnitude and variability of drag imposed from different entangling gear scenarios.

- Shown that at a minimum, entanglement doubles the drag experienced by a whale, and doubles the power required to swim.
- Provided formulae from which we can confidently estimate the drag on an entangled whale at the time of detection based on the dimensions of the gear involved
- Reinforced the existing disentanglement practice of reducing trailing lines and the tether to the telemetry buoy to ~20 m.
- Illustrated the extent to which entanglement onset and duration, as well as added energetic burden, come into play when trying to predict the outcome of a given entanglement event.

Robert Pickart – Woods Hole Oceanographic Institution
Climate Adaptation and Mitigation

The overall goal of the Russian-American Long-term Census of the Arctic (RUSALCA) program is to document and understand the ecosystem response of the Pacific sector of the Arctic Ocean to the pronounced recent changes in climatic forcing. The broad-scale component of RUSALCA has included a series of multi-disciplinary cruises sampling the water column and benthos of the Chukchi Sea (and eastern portion of the East Siberian Sea). To date there have been three broad-scale surveys: in August 2004, September 2009, and September 2012. We recently finished the synthesis stage of the program, bringing together the various data sets to understand how this important ecosystem functions – and how it might react to the changing environmental conditions. This culminated in a special issue of *Oceanography* Magazine in September 2015. Our study related the physical drivers on the shelf, including the circulation, atmospheric forcing, and sea-ice concentration, to different components of the biological system, including the benthic community and water column distributions of zooplankton. Project highlights include:

- A flow speed map, constructed using historical acoustic Doppler current profiler (ADCP) data, revealed the major pathways on the shelf. This compared favorably to output from a high-resolution numerical model. It demonstrated that regions of enhanced flow speed are dictated by lateral constrictions—in particular, Bering Strait and Barrow and Herald Canyons—and by sloping topography near coastlines.
- For the most part, benthic epifaunal and macrofaunal suspension feeders are found in high flow regimes, while deposit feeders are located in regions of weaker flow.
- Variations in atmospheric forcing, particularly wind, during the three RUSALCA sampling periods caused significant changes in the lateral and vertical distributions of the summer and winter water masses. These water mass changes, in turn, were reflected in the amounts and species of zooplankton observed throughout the Chukchi shelf.

Robert Weller – Woods Hole Oceanographic Institution
Ocean Climate Observations and Analyses

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. Project highlights include:

- A unique, high quality long time series data set is being provided the Stratus Ocean Reference Station Stratus site, deployed since October 2000 under the marine stratus clouds, in the eastern boundary of the South Pacific. This is a region of very high scientific interest and challenge, as evidenced by biases found there in ocean and climate models and by it being a region of little change in sea surface temperature or even cooling in a world where SST is generally warming. The uniqueness of the Stratus ORS time series stems from their being withheld and independent of the models, their high quality, their provision of coincident surface forcing and ocean variability, and their high vertical and temporal resolution in the upper ocean.
- Weller (2015) has found long-term trends in surface meteorology and air-sea fluxes at the Stratus ORS. Using the firs ten years of Stratus data, statistically significant trends were found in wind speed, wind stress, latent heat flux, and net heat flux. Increases in wind speed, wind stress, and latent heat flux were 0.8 m s^{-1}, 0.022 N m^{-2}, and 20 W m^{-2} or 13, 29, ad 20% of the respective means. The decrease in annual mean net air-sea heat flux was 39 W m^{-2} or 104% of the mean.

Michael Wilberg – University of Maryland Center for Environmental Science
A Management Strategy Evaluation for the Southeastern U.S.

The specific objectives of this project were to develop a Management Strategy Evaluation (MSE) model for red porgy for the Southeastern Region of the U.S. Atlantic Ocean. The goal of the MSE is to test how alternative fishery dependent data collection programs could affect the performance of fishery management for this species and more generally. The MSE involves building a series of simulation models to describe the dynamics of the population, fisheries, data collection, data processing, assessment, and management for red porgy in the U.S. south Atlantic region. Project highlights include:

- Data have been compiled for red porgy distribution and growth.
- The spatial dynamics of the model have been implemented in AD Model Builder.
- All the appropriate agencies have been contacted for red porgy data, and most of the data have already been received.

Riley Young Morse – Gulf of Maine Research Institute
Accessing and visualizing satellite data for use by fisheries managers in the Northeast

In year two of this project, we refined our goals based on work with our stakeholder engagement group and review of preliminary data products produced in the first year.
For both products, we have long-term data sets as well as forecasts. Through this and our "Building tools for applying climate science to fisheries management" effort, we are working closely with fishery stakeholders to ensure that the data views that we develop are intuitive and that the data products we identify are likely to be useful. Project tasks are organized under four

major activities: (1) Data Acquisition and Integration; (2) Spatial Averaging, (3) Build Reference Level (i.e. climatology) for the data; and (4) User interface: Seasonal and Decadal Visualizations. Highlights include:

- Developed automated processes to aggregate and calculate spatial averages from data subsets that map to bounding boxes fisheries management areas.
- Calculated climatology statistics and higher resolution anomalies for subsetted data.
- Modified scripts to automate the process of accessing latest data from SST and SST anomaly time series from OISST services to append to visualizations.

Lisan Yu – Woods Hole Oceanographic Institution
50 Year Global Ocean Surface Heat Flux Analysis

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 producing 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 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. Project highlights include:

- We extended and maintained the project's existing 57-year time series of global ocean evaporation, and turbulent latent and sensible heat fluxes (1958 onward) to meet the demands of the research and operational community.
- We constructed three new sets of high-resolution satellite-based flux products starting from July 1987 onward. These include (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).
- We contributed to NOAA State of Ocean Climate assessment reports on global change of heat/freshwater fluxes and ocean surface winds in 2015.

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

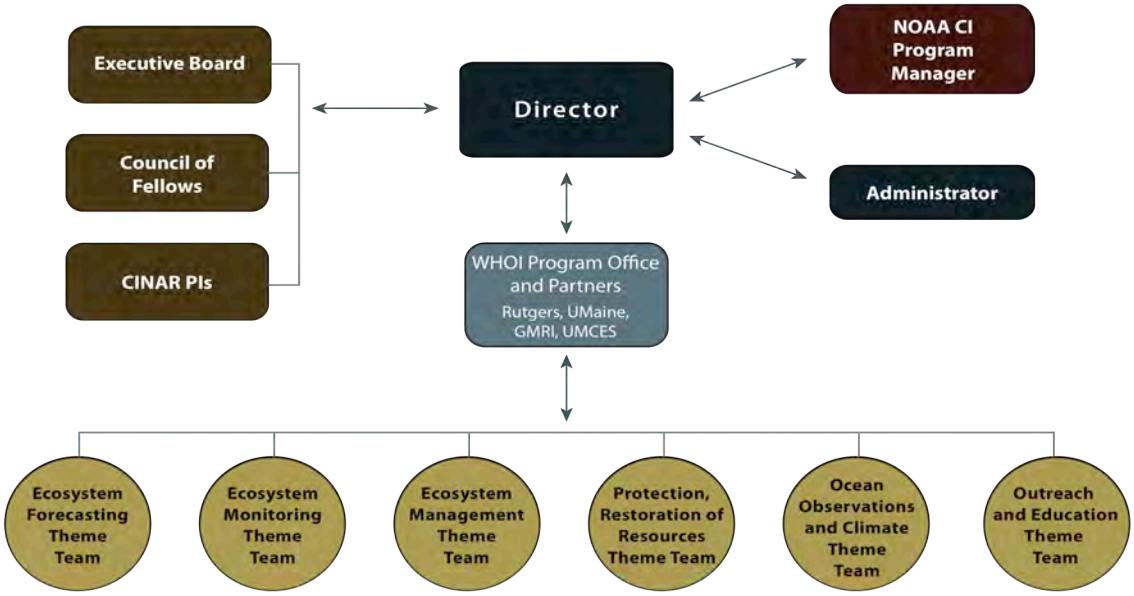


Figure 1. Organizational structure of CINAR.

CINAR PIs

The CINAR PIs include Donald M. Anderson, *CINAR Director, Woods Hole Oceanographic Institution*; Mark Miller, *Professor, Environmental Science, Rutgers University*; Michael Roman, *Director, Horn Point Laboratory, University of Maryland Center for Environmental Science*; Fei Chai, *Director, School of Marine Sciences, University of Maine*; and Andrew Pershing, *Chief Scientific Officer, Gulf of Maine Research Institute*. The CINAR PIs meet frequently 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:

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

CINAR Council of Fellows

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

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

The CINAR Council of Fellows members are:

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

CINAR Theme Leaders

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

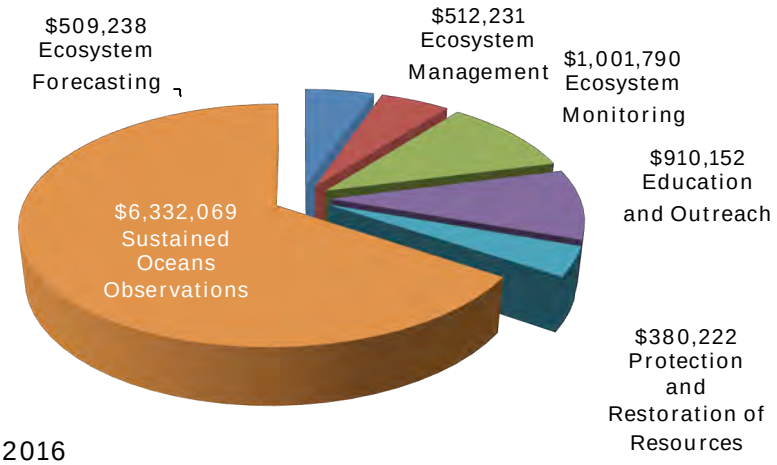
CINAR Research and Administrative staff

WHOI and the partner institutions provide the administrative staff for grants and contracts management, human resource management, systems administration, procurement, and all necessary support staff roles for CINAR activities. CINAR uses the services of researchers through an appropriate combination of tenured or tenure-track faculty in academic departments, and non-tenure track faculty. Each institution is responsible for appropriate oversight of faculty research activities. CINAR actively promotes undergraduate and graduate education through internships, cooperative experiences, graduate assistantships, and fellowships. During the past year, CINAR Administrator Judy Kleindinst retired after 40 years of service to WHOI. Her role has been filled by Mindy Richlen, a research specialist in Donald Anderson's lab, and Ann Stone.

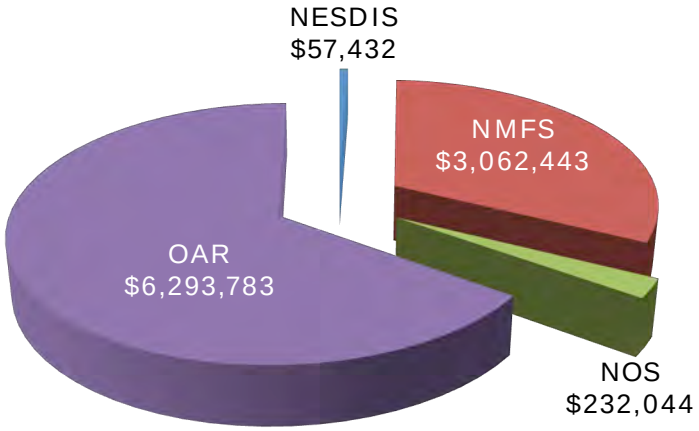
CINAR Program Office

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

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

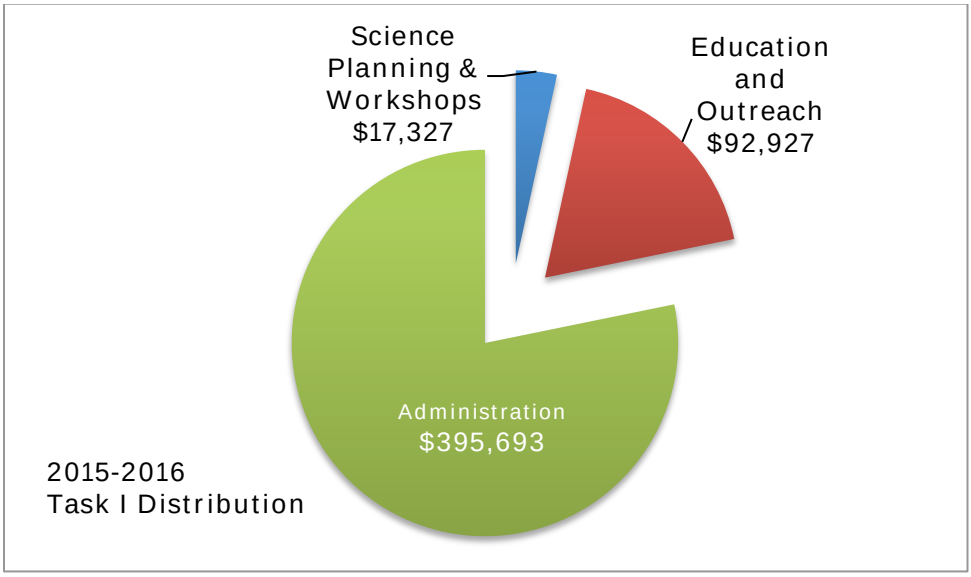


2015-2016
Funded amounts by Theme



2015-2016
Funded amounts by Line Office

Task I Activities with Distribution of Funding



Task I funding received from NOAA during this period totaled $505,947. WHOI provided $145,693 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

Postdoctoral Scholar program: Through WHOI cost-sharing support for CINAR, each year we appoint an 18-month Postdoctoral Scholar. Postdocs are selected from a national competition at WHOI of very strong applicants in all fields of oceanography. The CINAR Director convenes an ad hoc committee each year of CINAR investigators from each scientific department at WHOI to review the top 25 applicants and make recommendations for which ones CINAR is interested in supporting. Currently we have 1 remaining CINAR Postdoctoral Scholar – Andrew Jones. His progress report begins on the following page.

Undergraduate student training: CINAR continued its Minority Traineeship program in 2015, 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 2016.

WHOI-NEFSC Special Seminar Series on Fisheries and Ecosystems Acoustics: This seminar series continued through 2015-2016, sponsored jointly by NEFSC, CINAR, and the WHOI Biology and Applied Ocean Physics and Engineering Departments and co-convened by CINAR Fellow Gareth Lawson, Andone Lavery, and Tim Stanton of WHOI, together with Michael Jech of NEFSC. The series focuses on bio-acoustics, both passive and active, emphasizing applications and technological developments relevant to fisheries and ecosystem research and management as well as protected species conservation. The intent is to promote interactions between WHOI and NEFSC personnel on these topics and in general. In order to maximize attendance from both institutions, the seminars take place in the NEFSC Clark Conference Room and occur as a special seminar during the regular AOPE time slot. The talks are also distributed live as a webinar, via the OneNOAA Science Seminar series.

The seminar series has convened approximately every two months and has been very well received. The presentations have covered a variety of topics, including how soundscapes can be used to identify differences in the composition of coral reef communities (T. Aran Mooney, WHOI), the use of sonar technologies to estimate eel abundance, determine distribution, and describe behavior (ChristopherW.D. Gurshin, Normandeau Associates, Inc.), and the use of broadband acoustic techniques to classify swimbladder-bearing fish (Timothy Stanton, 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.

2015 CINAR Postdoctoral Scholar Progress Report

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 - March 31, 2016

Postdoctoral Scholar – Andrew Jones, WHOI

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

The overall goal of this work related to two main research themes: 1) work on the conservation, management, and basic biology of diadromous fishes, and 2) exploring the trophic ecology of marine fishes from northeast U.S. continental shelf.

ACCOMPLISHMENTS

A significant portion of time in the spring, summer, and fall of 2015 was dedicated to conducting research on the biology of diadromous fishes; specifically, conducting fieldwork for two distinct projects that were both focused on river herring. The first of these projects was an exploration of the factors that affect growth of larvae in their freshwater habitats. This project was led by Joel Llopiz and funded by Woods Hole Sea Grant. While this project is still ongoing, preliminary results were recently presented at a national conference. The second of these projects was an investigation of the movement patterns of river herring in the local Coonamessett River watershed. This project was a collaborative effort with researchers from the Marine Biological Laboratory and local volunteer groups, and generated high-quality information on the timing and duration of migration of both species of river herring. These topics are poorly understood and of great importance in management and restoration efforts. Results from this project have been the subject of numerous local interest stories, and have been presented at local, regional, and national conferences.

Dr. Jones was also involved in a collaborative project with researchers from NMFS and the North Carolina Museum of Science to explore dietary patterns in marine fishes from the northeast U.S. continental shelf; specifically, assessing dietary variation below the species level. Despite historically being largely overlooked, there is growing evidence that variation below the species level can have a large effect on the ecological interactions of a species, thus warranting investigation in this valuable ecosystem. Work from this project was presented at a national meeting and has progressed to the stage of a draft manuscript. These efforts have also laid the groundwork for future work on the importance of trophic intraspecific trophic variation in this ecosystem.

HIGHLIGHTS

1) Generation of a novel dataset on herring growth and survival.
2) Generation of a novel dataset on herring migration.
3) Novel analysis of existing finfish diet data from the northeast continental shelf ecosystem.

SOCIETAL BENEFITS

Like the subject matter of this project, the benefits of this work are diverse. Perhaps the most value will come from an increased understanding of basic river herring biology. Despite our proximity to these migratory fish, our understanding of their basic biology is limited, and this has negative impacts on our ability to manage these ecologically important species.

EDUCATION AND OUTREACH ACTIVITIES

Outside of these core projects, Dr. Jones has been involved in many grant applications and outreach activities. He has served on the board of two local non-profits and on the advisory committee of a third. Dr. Jones has also given lectures to a diverse set of audiences and served as the co-instructor for a college level Biology of Fishes course run by the Marine Studies Consortium.

CINAR Research Summaries

The following pages provide research summaries of the CINAR proejcts funded through the period April 1, 2015 through June 30, 2016. The projects are organized by theme.

Theme I. Ecosystem Forecasting

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

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

Hongshen Bi, UMCES*: Estimating Early Mortality for Reference Points for the Atlantic Menhaden Stock*

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

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

Theme II. Ecosystem Monitoring

Heather Benway, WHOI: *Publication of a Special Issue of Oceanography Magazine on Emerging Themes in Ocean Acidification Science*

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

Genevieve Nesslage, UMCES: *Support for updating stock assessments in the Southeastern U.S.*

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

Hanumant Singh, WHOI: *Field Experimentation to Determine Catchability of Advanced Technologies*

Rhian Waller, GMRI: *Investigating Coral Communities in the Gulf of Maine*

Theme III. Ecosystem Management

Scott Gallager, WHOI: *Operational Support for HabcamV4 on 2015 Scallop Surveys and Post-cruise Data Processing*

Michael Wilberg, *UMCES: Development and Testing of a New Method for Selecting Among Stock Assessment Models*

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

Theme IV. Protection and Restoration of Resources

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

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

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

Shaleen Jain, UMaine: *Nonstationarity in the Magnitude and Seasonality of Extreme Precipitation*

Joel Llopiz, WHOI: *Is Atlantic Cod and Haddock Recruitment Influenced by the Planktonic Environment and Feeding Success during the Larval Stage?*

Henry Mayer, Rutgers: *Addressing Coastal Hazards in the Mid-Atlantic*

Henry Mayer, Rutgers: *NOAA Port Tomorrow Proposed Expansion: Resilience of Mid-Atlantic Ports and Surrounding Communities*

Kathy Mills, GMRI: *Climate Adaptation in Fishery Ecosystems*

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

Michael Moore, WHOI: *Effects of Drag from Entanglement in Fishing Gear in Right Whales*

Michael Moore, WHOI: *Assessing the Pathogenesis and Host Susceptibility to Dolphin Morbillivirus in Cetaceans*

Grace Saba, Rutgers: *Physiological Ecology and Habitat Suitability: Combining Experiments and Surveys to Inform Stock Assessments*

Timothy Shank, WHOI: *Deep-Sea Coral and Sponge Habitats in the Northeast and Mid-Atlantic Canyons: Integrative Imaging and Mapping of Unknown Canyon Environments and Ecosystems*

Theme V. Sustained Ocean and Observations and Climate

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

Carin Ashjian, WHOI: *An Eye in the Ocean: Exploration of High-Resolution Vertical Distributions of Plankton and Particles and Coincident Hydrography in the Western Chukchi Sea Data Synthesis*

Carin Ashjian, WHOI: *Bowhead Whale Feeding in the Western Beaufort Sea Oceanographic Conditions Whale Prey Distributions and Whale Feeding and Foraging Behavior*

Jacqueline Grebmeier, UMCES: *Pacific Group (PAG) Secretariat Office III, 2015-2016*

Jacqueline Grebmeier, UMCES: *Synthesis Activities within the RUSALCA Program, 2015-2016*

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

Daniel McCorkle, WHOI: *An Experimental Study of the Impact of Ocean Acidification on the Early Life Stages of Sea Scallops, including the Interactive Effects of Feeding*

Robert Pickart, WHOI: *The Western Chukchi Sea: Physical Drivers and Biological and Geochemical Responses*

Robert Pickart, WHOI: *Synthesis of Physical Measurements from the Pacific Arctic Group: Flux of Pacific Water through Barrow Canyon, Chukchi Sea*

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

Albert Plueddemann, WHOI: *Ocean Climate Observations and Analyses - NTAS*

Albert Plueddemann, WHOI: *Supplement to: Ocean Climate Observations and Analyses*

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

Robert Weller, WHOI: *Supplement Ocean Climate Observations*

Robert Weller, WHOI: *Ocean Climate Observations and Analyses*

Riley Young Morse, GMRI: *Building Tools for Applying Climate Science to Fisheries Management*

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

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

Theme VI. Education and Outreach

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

CINAR Fellow: Porter Hoagland, WHOI
CINAR Fellow: Rubao Ji, WHOI
CINAR Fellow: Gareth Lawson, WHOI
SMAST Faculty, Gavin Fay

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

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

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

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

Gayle Zydlewski, UMaine: *UMaine Cooperative Education*

THEME I. ECOSYSTEM FORECASTING

Gulf of Maine Annual Cyst Cruise and Sample Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
July 1, 2015-March 31, 2016

CINAR Investigator: Donald Anderson, WHOI

NOAA Sponsor: Richard Stumpf, NOS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

PROJECT OVERVIEW

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

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

ACCOMPLISHMENTS

Approximately 90 stations were occupied during the cruise. At each station, a Craib corer was deployed and a relatively undisturbed surface sediment core was collected. The core was extruded onboard and sectioned into two layers; the top 0-1 cm and the underlying 1-3 cm layers.

The sediment samples were processed onboard using standard cyst techniques that are routine in the Anderson lab but were transitioned to NOAA personnel that served on cruise EX-14-05. That processing included protocols for dilution of the raw sediment, sonifying and sieving the sample to yield a 20-100 µm particulate fraction that was initially preserved in 2% formalin and exchanged onboard into 100% methanol for long term storage until counting began.

In addition to this processing, a portion of each sediment layer was subsampled for analysis using a qPCR assay for *Alexandrium* cysts. This work evaluated qPCR as an objective alternative to cyst enumeration using fluorescence in situ hybridization (FISH) and microscopy, which could reduce the labor required to obtain these important datasets. As part of the transition of the cyst cruise to NOAA for long-term operations of this program, comparisons were also made between counts made by WHOI and NOAA personnel. Linear regression showed excellent agreement between the NOAA/WHOI FISH datasets (Fig. 1; R2=0.96), demonstrating the efficacy of our training approach and the counting method in general.

Samples analyzed by qPCR assay were first treated with freshwater to remove extracellular DNA debris and heat to improve cyst lysis and increase DNA yield. Additionally, newly designed primers provided by W. Litaker (NOAA Southeast Fisheries Science Center) were used to increase the qPCR assay sensitivity. Data from the qPCR assay was then compared to cyst abundances generated by primulin-staining and enumeration using fluorescence microscopy. Linear regression showed a significant relationship between both methods (R2=0.4, $p<0.05$); however, qPCR generally underestimated cyst abundance, particularly for samples with low cyst concentrations (Fig 2). We are currently preparing a detailed report of the methods employed in these analyses that also takes into account the cost, time requirements, and technical skills required for each approach.

Cyst concentrations obtained using traditional counting methods were provided to Dr. Dennis McGillicuddy (WHOI) for preparation of contour plots and cyst abundance calculations for each layer and sub-regions within the GOM (Fig. 3), and to McGillicuddy, Ruoying He (NCSU), and Rick Stumpf (NOAA) for *Alexandrium* GOM model simulations under a separately funded project.

HIGHLIGHTS

- Cyst abundance in 2015 indicated a decrease in abundance from the previous year (2014)
- Model simulations based on the 2015 cyst abundance were completed during winter, 2016 with the bloom prediction released (https://coastalscience.noaa.gov/news/habs/gulf-maine-red-tide-forecast-predicts-small-bloom-2016/).
- Linear regression showed excellent agreement between the NOAA/WHOI datasets, demonstrating the efficacy of our training approach and the fluorescence microscopy counting method.
- qPCR generally underestimated cyst abundance, particularly for samples with low cyst concentrations; a detailed report detailing the methods and data is currently underway.
- 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 (HABs) 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

Two Northeastern University cooperative program (undergraduate) students participated in the project and cruise receiving training in Alexandrium cyst identification and enumeration as well as training in sampling techniques.

Results of the cruise were discussed at a meeting of academic researchers, regional stakeholders Results of the cruise were discussed at a meeting of academic researchers, regional stakeholders (ME, NH, and ME shellfish resource managers), and NOAA managers as part of the 2016 seasonal PSP forecast discussion.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

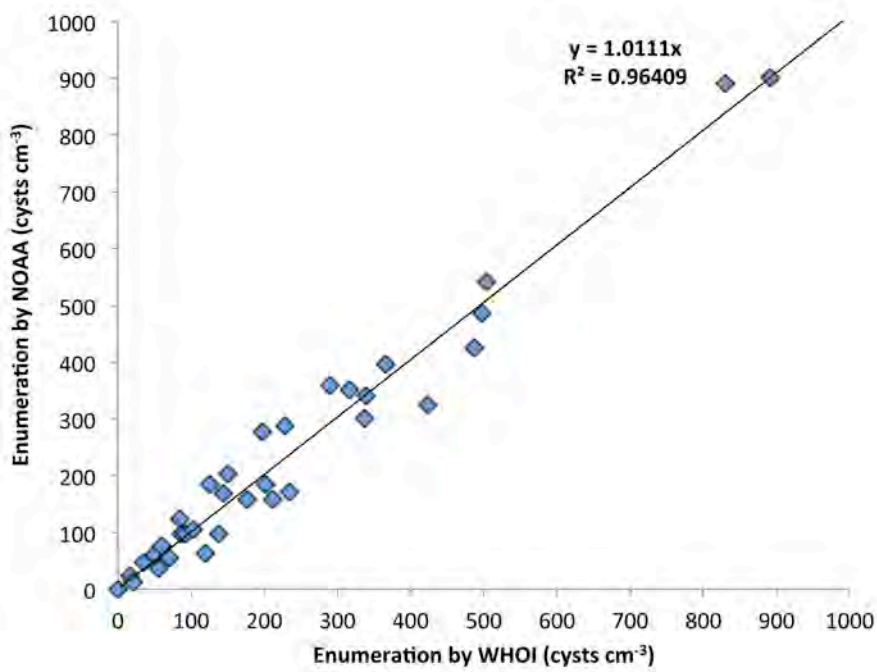


Figure 1. Linear regression comparing cyst abundances quantified by NOAA versus WHOI personnel, showing excellent agreement between the datasets.

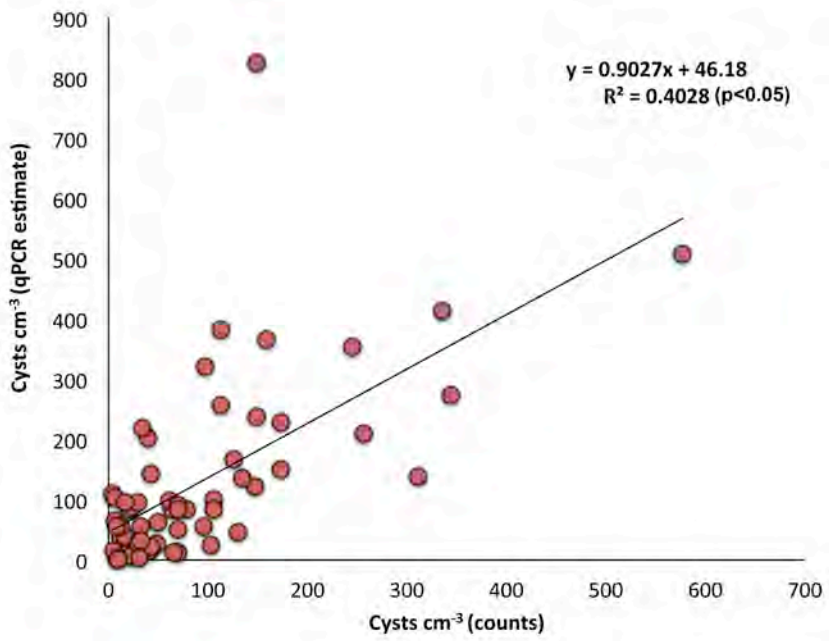


Figure 2. Linear regression comparing the cyst abundances quantified using fluorescence microscopy and qPCR. In general, qPCR underestimated cyst abundance quantified via enumeration using microscopy; however, values were within one order of magnitude.

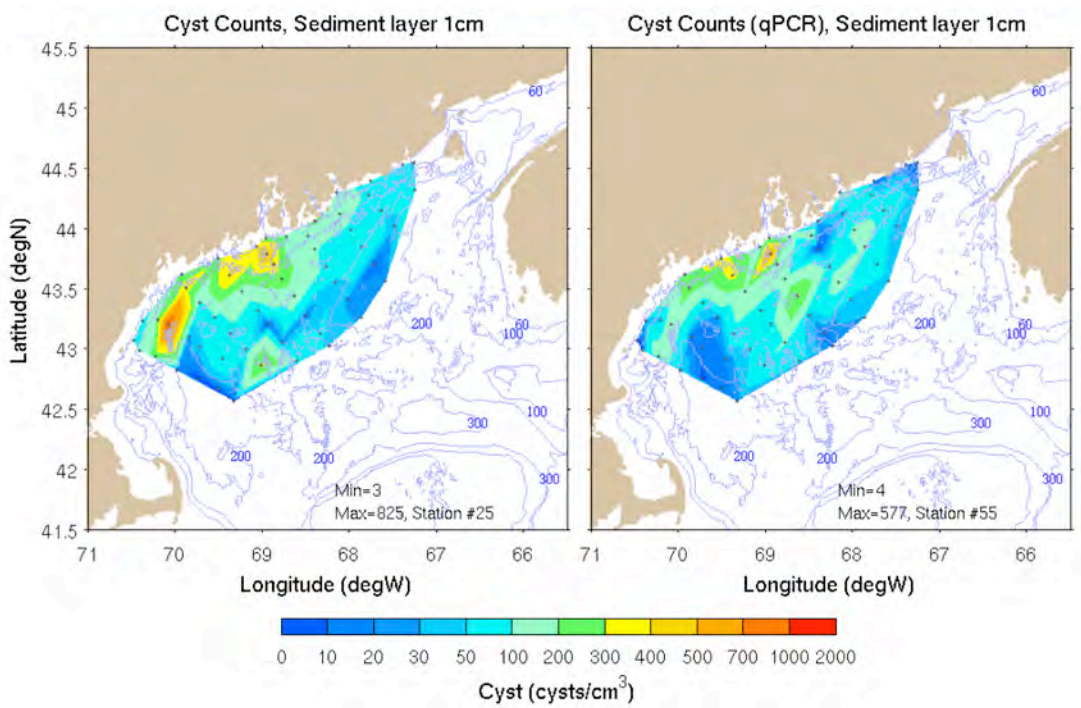


Figure 3. Cyst survey maps generated using traditional counting methods (left panel) and qPCR estimates (right panel). The cyst seedbed map is used in forecasting models to determine the intensity of future blooms in the region.

Technical Support and Improvement of FVCOM for NOAA Modeling Activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 - March 31, 2016

CINAR Investigator: Robert Beardsley, WHOI

NOAA Sponsor: Eugene Wei, OAR

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

PROJECT OVERVIEW

The objectives of this project are to: 1) hold an FVCOM workshop at the 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 U.S. Northeast Coastal Ocean Forecast System (NECOFS). FVCOM teams will provide updated examples of techniques used for NECOFS to support the NOAA modeling activities.

ACCOMPLISHMENTS

- CSDL-WHOI-UMASSD organized a FVCOM workshop at CSDL on September 3-4, 2015. Robert Beardsley (WHOI) and Changsheng Chen (UMASSD) gave one joint presentation entitled *FVCOM: Development, Improvement and Applications*. During the workshop, Beardsley and Chen addressed 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 gave several reports on the FVCOM forecast system development in the Gulf of Mexico shelf, San Francisco Bay, and Great Lakes. The workshop was very productive and many questions were addressed and solved by the open discussion.
- We have been upgrading FVCOM by implementing a) a new vector matrix approach in the surface wave iteration, b) ice embedding process, and c) current-wave-sediment interactions with inclusion of cohesive sediment processes as well as re-constructing the offline ecosystem model codes.
- We arranged several conference calls with CSDL and GLERL scientists to help them solve several code issues. The conference calls were made using the following approach. First,

CSDL collected all questions from NOAA FVCOM users and delivered them to us. Second, we reviewed the questions and provided our answers and explanations, either on the conference calls or via written texts.

- We helped debugged the FVCOM code when the Fortran compiler was upgraded, including find the initialization issues for variable pointers of NetCDF input forcing, resolving NaN output issues, etc.
- We helped CSDL scientists to set up the PROJ library on the NOAA supercomputer. This work was done in collaboration with IT staff in NOAA.
- We added a new module to include latitude and longitude in the NetCDF output for time series output at selected stations.
- We modified the time attributes for the station output to be consistent with the field output.
- We shared the results of the NOAA-UMASS-WHOI collaboration in FVCOM improvement with the FVCOM users at the *2015 FVCOM User Workshop* at Bedford Institute of Oceanography, Halifax, October 20-22, 2015.

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.
- Shared the water quality and ecosystem modules with NOAA CSDL and GLERL.
- 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

- Shared the FVCOM development with public users, which facilitated the utilization and application of FVCOM to other coastal regions in the world.
- The development of the FVCOM forecast system provided the NWS, USCG, and the public with real time surface weather and ocean environmental conditions for navigation, ocean rescue planning, storm-induced coastal inundation, and other applied and public uses.
- Updated the existing NOAA forecast system to a new technical level with better resolution of coastal geometry.

EDUCATION AND OUTREACH ACTIVITIES

- Helped train the new generation of modelers in NOAA labs, especially in using the unstructured grid models.

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

PUBLICATIONS

We are working on updating the FVCOM version 4.0 User Manual by adding all new modules developed for the NOAA forecast operation.

Estimating Early Mortality for Reference Points for the Atlantic Menhaden Stock

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Hongshen Bi, UMCES

NOAA Sponsor: Jonathan Hare, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

PROJECT OVERVIEW

- In the past two decades, Atlantic menhaden (*Brevoortia tyrannus*) has experienced a notable decline in recruitment to the Chesapeake Bay. The primary objective of this study is to examine the coast-wide larval menhaden abundance and identify possible causes for the observed decline.
- Larval data were obtained from two major ichthyoplankton surveys conducted by the NOAA Northeast Fisheries Science Center, MARMAP, and ECOMON. MARMAP, the Marine Resources Monitoring, Assessment, and Prediction Program, was conducted from 1977-1987, and ECOMON, the Ecosystem Monitoring Program, was conducted from 1992-present.
- The goal of this project is to understand the relationship between larval menhaden abundance and recruitment. Using data on larval abundance and size, we developed a larval abundance index. This index was used to examine changes in larval abundance over time, and was also incorporated into a survival model to examine how environmental conditions affect interannual variation in early life survival.

ACCOMPLISHMENTS

- We used the larval index paired with the juvenile abundance index constructed for the 2015 Atlantic Menhaden stock assessment to estimate relative early life survival (Fig. 1), and then fit our survival model with environmental variables.
- We were interested in examining the effects of large-scale ocean variability, temperature, wind, and freshwater flow on Atlantic Menhaden early survival. To examine long-term environmental effects, we collected data sets that spanned the entire span of the study, beginning in 1977. We used surface temperature information collected with larval observations during the ECOMON and MARMAP surveys. We also used temperature data collected from the Patuxent River in the Chesapeake Bay by the Chesapeake Biological Lab as an index of nursery temperature conditions. Wind and flow data were collected for the Chesapeake Bay as well. We used AMO (the Atlantic Multidecadal Oscillation index) to characterize changes in large-scale ocean conditions (Fig. 2).

- We used AIC selection and found the best fit model estimates of survival from larval abundance, coastal temperature, wind speed, and wind direction. Southeastward wind appeared to be coincidental with higher survival.
- We also identified several interesting spatial patterns: highest larval abundance was observed near the coast (within ~25 km) and in the southern portion of the survey off the coast of North Carolina. Larvae were, on average, also largest near the coast and in the central portion of the survey, between the Chesapeake and Delaware Bays.
- Future analysis will focus on these spatial trends as well as the fine-scale analysis of environmental variables that affect larval abundance and survival.

HIGHLIGHTS

- We observed a declining trend in larval survival.
- Interesting patterns related to the effects of wind and temperature on survival were observed; in particular, strong southeastward winds were associated with higher survival.
- Larvae were larger and in higher abundance near the coast.

SOCIETAL BENEFITS

Atlantic menhaden support the largest fishery on the U.S. east coast. This analysis provides a fishery independent index of Atlantic menhaden abundance with broad spatial and temporal coverage. Modeling the changes in larval mortality improves the scientific information used to manage this stock by incorporating environmental processes into stock assessments and the determination of stock status.

EDUCATION AND OUTREACH ACTIVITIES

- Bi, H., C. Simpson, M. Wilberge, A. Schueller, G. Nesslage, H. Walsh, 2015, Estimating early mortality for reference points for the Atlantic menhaden stock, FATE annual meeting, San Diego, CA

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

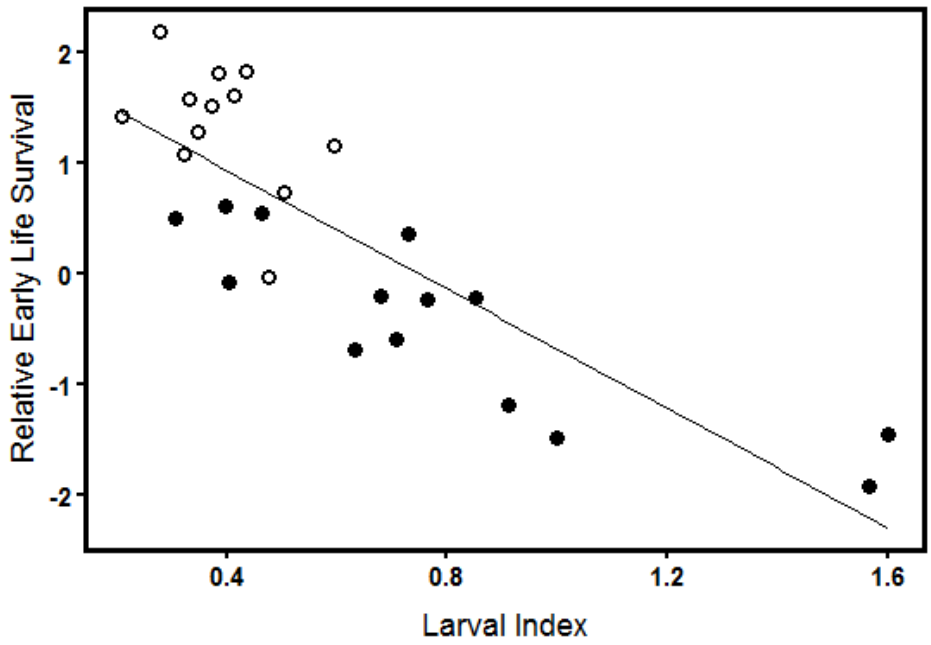


Figure 1. Relative early survival and larval index with solid black dots indicating ECOMON period, and open circles indicating MARMAP period.

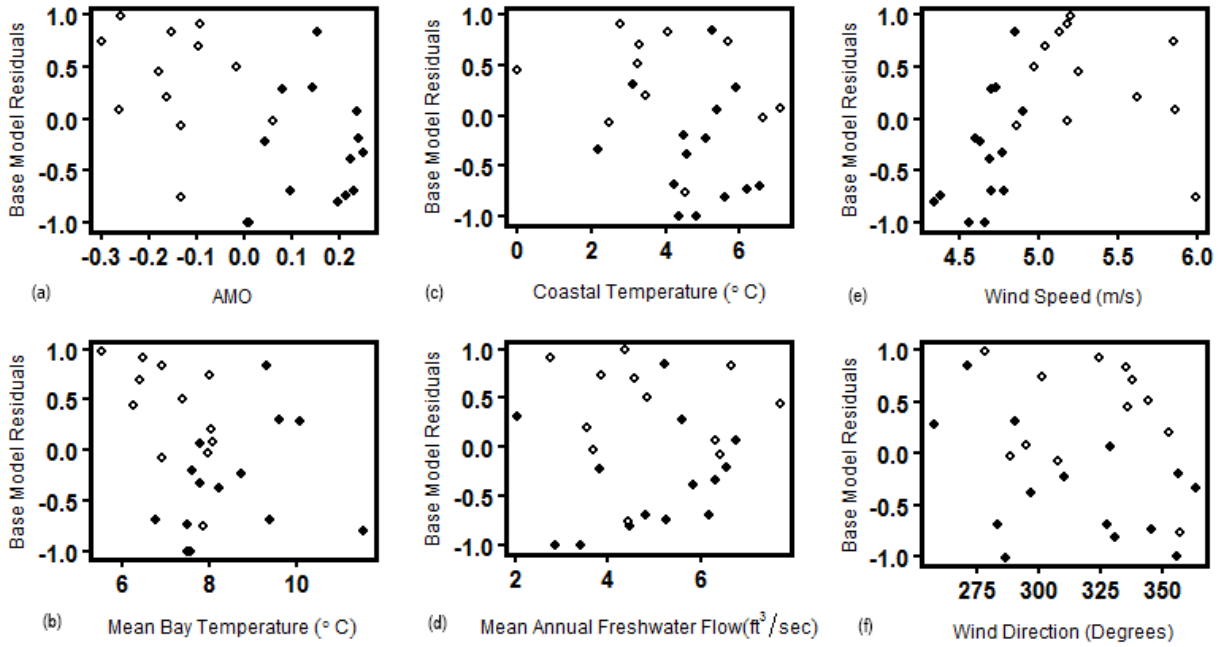


Figure 2. Scatter plots showing base model residuals from Figure 1 and environmental variables: (a) Atlantic multi-decadal oscillation (AMO), (b) coastal surface temperature from field data, (c) wind speed at Chesapeake Bay mouth, (d) temperature in the Chesapeake Bay, (e) mean annual freshwater flow to the Chesapeake Bay, and (f) wind direction at the Chesapeake Bay mouth.

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

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Yong Chen, UMaine

NOAA Sponsor: Anne Richards, NMFS, NEFSC

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

PROJECT OVERVIEW

The goals of this project are to: (1) develop and evaluate approaches for explicit incorporation of temperature in modeling recruitment dynamics in the length-structured model; (2) evaluate various functions to link temporal variability of shrimp predator abundance with natural mortality; and (3) evaluate impacts of temperature on the growth of shrimp and develop a temperature-dependent growth transition matrix for the length-structured model.

Building on the preliminary study, we plan complete the following tasks: (1) continue analyzing existing information to examine the relationships between temperature and recruitment; (2) quantify the relationships between temperature and growth; (3) develop and evaluate different functional relationships to link predator abundance with shrimp natural mortality; (4) develop and incorporate likelihood functions based on the models developed above in the length-structured model; and (5) evaluate impacts of incorporating temperature and predators on the quality of the stock assessment in both simulations and the assessment (e.g., retrospective errors and uncertainty).
We have accomplished tasks 1-5 for temperature, and will focus on the predator and natural mortality during the second year of the project. We are ahead of the scheduled research plan.

ACCOMPLISHMENTS

We have updated the model and relevant codes as follows:

- The seasonal time step model was developed and tested based on simulation and the model works correctly (and can be operated in both annual and time step).
- Added functions to incorporate environmental effects on recruitment dynamics (thus environmental information can be used to help estimate of recruitment).
- Likelihood of recruitment deviations were added to the total likelihood.
- The newest model, which is able to account for environmental effects on recruitment, was tested based on simulations and it works correctly.
- An operating model was developed for simulating the population dynamics of shrimp, including environmental effects on recruitment.
- Simulation studies were conducted to evaluate the performance of the new model.

Specifically, we developed various simulation scenarios regarding seasonality in the fishery, including growth and environmentally-driven recruitment dynamics. We demonstrated how the new model can improve the assessment through comparisons with the model that ignores seasonal variation and/or environmentally-driven recruitment dynamics.

- Various configurations of the model (application in Maine shrimp using real data) have been investigated, including rebinning the size class, adding temperature data to estimate the recruitment, reweighting survey data, etc. However, none of them improves the residual pattern significantly, and we are continuing to work at this issue. We have completed the simulation study to evaluate the performance of models with and without incorporation of temperature in the stock assessment.

HIGHLIGHTS

The incorporation of temperature in modeling recruitment dynamics can greatly improve the quality of stock assessment for northern shrimp, greatly reducing uncertainty. Time steps used in the model is also very important in determining the precision and accuracy of stock assessment results. The incorporation of temperature in life history processes can greatly improve the performance of stock assessment models for northern shrimp.

SOCIETAL BENEFITS

Northern shrimp provide unique fishing opportunities for fishermen around of the Gulf of Maine during the winter season, when other fishing opportunities are limited. Temperature and predation mortality are critical in determining the dynamics of northern shrimp stock in the Gulf of Maine. The improved stock assessment, which incorporates these environmental variables, improves the stock assessment quality, thus reducing the likelihood of overexploitation of this stock.

EDUCATION AND OUTREACH ACTIVITIES

One postdoc is fully funded by this project. We have met with the Atlantic States Marine Fisheries Commission Northern Shrimp Stock Assessment Committee and Technical Committee to provide updates on our progress in developing this new model and in model testing. Relevant information has been sent to these two committees. They have informed us that the improved model will be used in the next benchmark stock assessment for northern shrimp in the Gulf of Maine.

We have also updated relevant scientists and managers in the Maine Department of Marine Resources and NOAA Northeast Fisheries Science Center on our research progress. They have provided us with all relevant data needed for this project.

PUBLICATIONS

Cao, J., Y. Chen, and A. Richard. 2016. Improving assessment of *Pandalus* stocks using a

seasonal, size-structured assessment model with environmental variables: Part I: Model description and application. *Canadian Journal of Fisheries and Aquatic Sciences* (under revison)

Cao, J., Y. Chen, and A. Richard. 2016. Improving assessment of *Pandalus* stocks using a seasonal, size-structured assessment model with environmental variables: Part II: Model evaluation and simulation. *Canadian Journal of Fisheries and Aquatic Sciences* (under revison)

Cao, J., J. Thorson, A. Richard, Y. Chen. 2016. Geostatistical index standardization improves the performance of stock assessment model: an application to northern shrimp in the Gulf of Maine. *Canadian Journal of Fisheries and Aquatic Sciences* (submitted).

Nutrient Dynamics on the NE Continental Shelf: Sample Analyses

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31,2016

CINAR Investigator: David W. Townsend, UMaine

NOAA Sponsor: Jonathan Hare, NMFS

Related Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Forecasting

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. Our analyses of hydrographic and nutrient data back to the 1960s have revealed that deep water layers in the Gulf (>100m) have become fresher and cooler, with lower nitrate but higher and more variable silicate concentrations, but that those proportions of nutrients in the Gulf 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 better understand the nature of water mass variability in the Gulf of Maine its influence on the nutrient field, which is of fundamental importance to our understanding of basic biological phenomena from red tides to changing fish abundances and distributions.

We report here progress made on our CINAR-funded project to analyze samples collected as part of the ***NOAA Northeast Fishery Science Center's Ecosystem Monitoring Program*** (ECOMON Program) in collaboration with Dr. Jon Hare. The ECOMON Program conducts survey cruises approximately four times each year in shelf and slope waters of the Gulf of Maine – Georges

Bank – Mid-Atlantic Bight. As part of their standard sampling, they perform a CTD cast at each station and, when possible (given constraints for water sample allocation) they collect water samples for nutrient analyses. Samples are filtered and frozen at sea and then delivered by overnight courier to the University of Maine where they are analyzed for nitrate plus nitrite, silicate, phosphate and ammonium using standard autoanalyzer techniques. Those data are delivered to NOAA following each cruise.

ACCOMPLISHMENTS

As of this writing (June 2016) have received and processed samples from the ECOMON cruises shown in Table 1 below, with stations 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 and profile plots are then sent to NOAA Narragansett (c/o Dr. Jon Hare). We plan to continue to study – with our NOAA a

nd Woods Hole Oceanographic Institution colleagues – the hydrographic and nutrient data collected on future ECOMON cruises, as the data density becomes suitable for more in depth analysis. As with all of our nutrient data processed in our laboratory, we are incorporating them into our regional nutrient and hydrographic database (Rebuck et al., 2009).

HIGHLIGHTS

- Fall 2014 samples collected in Jordan Basin in the eastern offshore Gulf of Maine captured the fall phytoplankton bloom, showing how *in situ* chlorophyll was elevated in waters above a rather deep pycnocline. With accompanying nutrient data, this is a first: I am unaware of any other account of a fall phytoplankton bloom in the Gulf of Maine, apart from satellite images. With these data, we have a first-of-its-kind snapshot of the bloom.

SOCIETAL BENEFITS

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

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Fogarty, M.J., **D.W. Townsend** and E. Klein. 2012. Advances in understanding ecosystem structure and function in the Gulf of Maine. pp. 261-272, *In:* Stephenson, R.L., J.H. Annala, J.A. Runge and M. Hall-Arber, (Eds). Advancing an Ecosystem Approach in the Gulf of Maine. *American Fisheries Society, Symposium 79,* Bethesda, MD. 415 pp.

McGillicuddy, D.J., Jr., **D.W. Townsend**, B.A. Keafer, M.A. Thomas and D.M. Anderson. 2013. Georges Bank: A leaky incubator of *Alexandrium fundyense* blooms. *Deep-Sea Research II* http:// dx.doi.org/10.1016/j.dsr2.2012.11.002

Gettings, R.M., **D.W. Townsend**, M.A. Thomas, L. Karp-Boss. 2013. Dynamics of late spring and summer phytoplankton communities on Georges Bank, with emphasis on diatoms, *Alexandrium* spp., and other dinoflagellates. *Deep Sea Research II* http://dx.doi.org/10.1016/j.dsr2.2013.05.012

McGillicuddy, D.J., Jr., M.L. Brosnahan, D.A. Couture, R. He, B.A. Keafer, J.P. Manning, J.L. Martin, C.H. Pilskaln, **D.W. Townsend**, D.M. Anderson. 2013. A red tide *of Alexandrium fundyense* in the Gulf of Maine. *Deep Sea Research II.* http://dx.doi.org/10.1016/j.dsr2.2013.05.011

Townsend, D.W., M.A. Thomas, D.J. McGillicuddy, N.R. Rebuck. 2014. Nutrients and water masses in the Gulf of Maine - Georges Bank region: Variability and importance to blooms of the toxic dinoflagellate *Alexandrium fundyense. Deep Sea Res. II* 103: 238-263. http://dx.doi.org/10.1016/j.dsr2.2013.08.003

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Townsend, D.W., N.R. Pettigrew, M.A. Thomas, M.G. Neary, D.J. McGillicuddy, Jr. and J. O'Donnell. 2015. Water masses and nutrient sources to the Gulf of Maine. *Journal of Marine Research 73:* 93–122.

PUBLICATIONS

Townsend, D.W., N.R. Pettigrew, M.A. Thomas, M.G. Neary, D.J. McGillicuddy, Jr. and J. O'Donnell. 2015. Water masses and nutrient sources to the Gulf of Maine. *Journal of Marine Research 73:* 93–122.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Date	Number of Stations	Number of Nutrient Samples Analyzed
Nov. 2009	26	88
Feb. 2010	19	64
Nov. 2010	25	94
Feb. 2011	1	11
Jun-11	38	182
Nov. 2011	13	65
Feb. 2012	22	130
Jun-12	19	100
Aug. 2012	63	300
Nov. 2012	34	210
Feb. 2013	41	170
Jun-13	27	194
Jul-13	14	138
Aug. 2013	15	108
Nov. 2013	23	135
Mar. 2014	19	115
Jul-14	3	19
Nov. 2014	36	225
Jun-15	35	244
Oct. 2015	24	180

Table 1. Samples collected during ECOMON cruises.

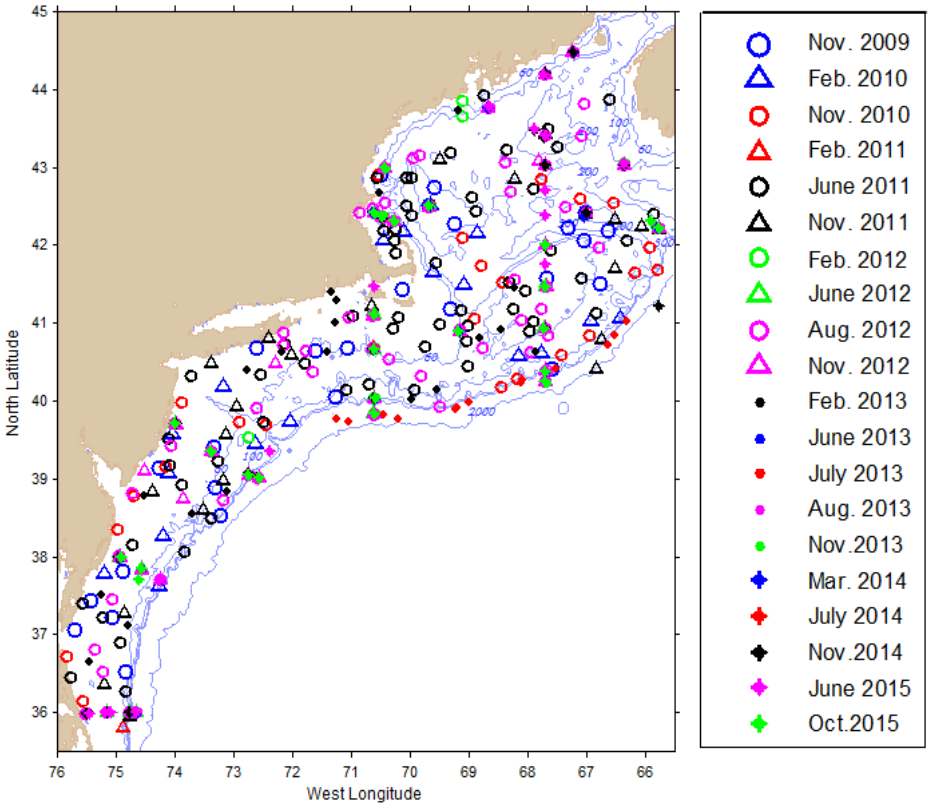

Figure 1. Station Map: NOAA ECOMON Surveys 2009 to Summer 2016.

THEME II. ECOSYSTEM MONITORING

Publication of a Special Issue of Oceanography Magazine on Emerging Themes in Ocean Acidification Science

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Heather Benway, WHOI

NOAA Sponsor: Libby Jewett, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW

NOAA funds were used to publish a special issue of *Oceanography* magazine in June 2015 entitled "*Emerging Themes in Ocean Acidification Science*." The proposed issue contained peer-reviewed articles that 1) synthesized the outcomes from breakout discussion sessions at the 2013 Ocean Acidification Principal Investigators' (OAPI) Meeting, and 2) reviewed subtopics of ocean acidification science that were not deeply explored at the OAPI meeting, yet are of broad interdisciplinary interest.

ACCOMPLISHMENTS

The special issue was published in June 2015 and all articles are available at: http://www.tos.org/oceanography/issue/volume-28-issue-02

The special issue has been broadly advertised and hard copies have been distributed in the U.S. and abroad (OA International Coordination Center).

SOCIETAL BENEFITS

This special issue of *Oceanography* magazine (http://www.tos.org/oceanography) provided a summary of the state of ocean acidification knowledge and research activities that is readily understandable to the lay public, undergraduate and graduate students, and a wide range of scientists and policy makers.

PUBLICATIONS

FULL SPECIAL ISSUE AVAILABLE AT: http://www.tos.org/oceanography/issue/volume-28-issue-02

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

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Yong Chen, UMaine

NOAA Sponsor: John Hoey, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW

The Eastern Gulf of Maine Sentinel Survey/Fishery is a groundfish survey conducted in the summer from the western edge of Penobscot Bay to the eastern border with Canada. The survey consists of stratified random stations that are sampled with both demersal longline gear and jigging gear. A portion of the stations is also allocated for fishermen to select where they want to fish based on their knowledge of historic fishing grounds and suitable habitat. The primary objective of the survey is to provide an annual index of abundance as well as habitat preference information for groundfish species (including Atlantic cod, cusk, white hake and Atlantic halibut) in an area that was traditionally important for the commercial groundfish fishery but is not currently well covered by either commercial fisheries or other bottom-trawl –based monitoring programs. This report focuses on the most recent year of the sentinel survey/fishery in 2015, but also includes an analysis of all the survey/fishery catch data since the inception, from the sentinel survey/fishery in 2010 to the most recent year 2015.

In 2015, the overall allocation of sampling effort was divided into longline and jig components that were stratified by depth. Within these two gear types, random longline stations (LL) and fishermen's choice longline stations (LF) comprised the longline portion, while jigging at jigging only stations (JJ) comprised the jig portion. Due to gear and weather-related logistical constraints, the number of random stratified fishermen's choice longline stations was decreased compared to 2014. While there were 30 LL stations selected for sampling in 2015, just 24 of these stations were sampled by longline gear. The stations were stratified by three separate depths (50-80m, 80-150m, and 150m+). Additionally, although 16 LF stations were planned for 2015, only 9 of these stations were sampled. A total of 47 JJ stations were sampled in 2015 (Figure 1). The JJ stations were also stratified by depth, and consisted of 35 JJ at stratum 0 (0-50m) stations and 12 JJ at strata 1-3 (50-80m, 80-150m, and 150m+). Each LL and LF station also had a jigging component (JL and JF, respectively) included to continue modifications made in 2013, as suggested by the Northeast Fisheries Science Center. Due to gear constraints, only 29 out of the 30 random longline stations (LL) were sampled with jig gear (JL), meaning there were 29 jigging at random longline stations (JL). Furthermore, because only 9 fishermen's choice longline stations were sampled, there were 9 jigging at fishermen's choice (JF) stations sampled. The JL stations were stratified by depth like the random longline stations, all falling into strata 1-

3. Including a jigging component at each random LL and LF station allowed for an additional 38 stations to be sampled with jigging gear, resulting in a total of 85 stations sampled by jig gear. Atlantic cod were the only targeted groundfish species for the JJ, JL, and JF, although other species including pollock and mackerel were also caught. There is no LL station in Stratum 0 (0-50 m) because of a large number of fixed gear present in Maine coastal waters during the summer.

Due to financial restraints and logistical concerns, the overall sampling allocation for 2016 will include 36 randomly selected stations to be sampled with jig gear only, and will be in the shallowest depth strata (0-50 m). Data collected from these sites will be directly comparable to jig data collected previously (2012-2015) for this strata.

ACCOMPLISHMENTS

In 2015, Atlantic cod were caught by longline at 8.3% of stratified random stations (LL); by longline at 33.3% of fishermen's choice stations (LF); by jig at 31.9% of random jig stations (JJ); by jig at 6.9% of random longline stations (JL); and by jig at 44.4% of fishermen's choice stations. Cusk were caught by longline at 12.5% of LL stations and by longline at 22.2% of LF stations. White hake were caught by longline at 62.5% of LL stations and 55.5% of LF stations. Atlantic halibut were caught by longline at 33.3% of LL stations and 22.2% of LF stations. Finally, spiny dogfish were caught by longline at 45.8% of LL stations and 55.5% of LF stations.

In 2014 Atlantic cod were caught by longline at 16.7% of LL stations; by longline at 31.2% of LF stations; by jig at 29.8% of JJ stations; by jig at 10.0% of JL stations; and by jig at 25.0% of JF stations. Cusk were caught at 6.7% of LL survey stations, and at 31.2% of LF stations. White hake were caught at 63.3% of LL survey stations and at 43.8% of LF stations. Halibut were caught at 56.7% of LL survey stations and 37.5% of LF stations. Dogfish were caught at 43.3% of LL survey stations and 37.5% of LF stations.

In 2015 Atlantic cod were caught at a lower percentage of random longline stations than in 2014, but still higher than 2013. Additionally, Atlantic cod were caught at a higher percentage of fishermen's choice longline stations in 2015 than in both 2014 and 2013. However, Atlantic halibut were caught at a lower percentage of both random longline stations and fishermen's choice longline stations in 2015 compared to 2014, although still greater than in 2013.

The stratified random survey was only conducted between 2012 and 2015. Thus we have four years of survey abundance indices for longline and jigging. Each abundance index was calculated per station type. For longline (LL), the mean abundance index of cod increased from 2012 to 2013, decreased from 2013 to 2014, and decreased from 2014 to 2015. The estimates of all four years had large CVs, making the interpretation of between-year difference difficult. The mean abundance of cusk at LL stations decreased from 2012 to 2013, decreased from 2013 to 2014, and increased from 2014 to 2015. All four years had large CVs. Mean abundance of white hake decreased from 2012 to 2013, decreased again from 2013 to 2014, and further decreased from 2014 to 2015. The CV in 2012 was large, slightly decreased in 2013, and then greatly decreased in 2014-2015. The mean abundance of Atlantic halibut at LL stations decreased from 2012 to 2013, but then more than doubled from 2013 to 2014. In 2015, the mean abundance for

halibut decreased. All CVs for halibut were very small. The CVs for jigging were much smaller than those for the longline.

Analysis for jigging stations in 2015 involved separating the inshore jigging (JJ at stratum 0) stations from offshore jigging at strata 1-3 (JJO). Mean abundance and CV was calculated for each. Mean abundance of cod at all random jig stations (JJ) decreased from 2013 to 2014, but increased from 2014-2015. The CV for cod at JJ stations decreased by a large amount from 2013 to 2014, but increased from 2014 to 2015. The random jigging stations were then divided into inshore and offshore components for analysis. The JJ stations at stratum 0 sites were referred to as inshore stations, while JJ stations in strata 1-3 were referred to as offshore stations (JJO). The JJO and jigging at the random longline stations (JL) were combined because they both encapsulated strata 1-3, and combining the two station types increased sample size of Atlantic cod. Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, then sharply increased from 2013 to 2014. In 2015, the mean abundance of Atlantic cod increased slightly from 2014. While the CV was large in 2012, it decreased dramatically in 2013, 2014, and 2015.

To analyze the mean abundance of species at fishermen's choice (LF) stations, we used standardized catch per unit effort (CPUE). Our fishermen were asked to choose LF stations that targeted Atlantic cod; stations could be chosen anywhere within the allotted sampling region for 2015. Trends in standardized CPUE of fishermen’s choice stations between 2010 and 2015 show a slight increase for white hake from 2010 to 2012, but a slight decrease from 2012 to 2013, followed by a decrease from 2013 to 2014 and a decrease from 2014 to 2015. There was a small decrease from 2010 to 2012, a large decrease from 2012 to 2013, and a large increase from 2013 to 2014, and a large increase from 2014 to 2015 for Atlantic halibut. Standardized CPUE for cusk showed a decrease from 2010 to 2012 followed by an increase in 2013, a slight increase in 2014, and a minute decrease in 2015. Finally, there was an increase from 2010 to 2012, a decrease in 2013, a large increase in 2014, and almost equally as large decrease in 2015 for Atlantic cod. Large standard errors were associated with most standardized CPUEs.

HIGHLIGHTS

- The mean abundance index of cod at random longline stations increased from 2012 to 2013, decreased from 2013 to 2014, and decreased from 2014 to 2015.
- The mean abundance of cusk at LL stations decreased from 2012 to 2013, decreased from 2013 to 2014, and increased from 2014 to 2015.
- Mean abundance of white hake decreased from 2012 to 2013, decreased again from 2013 to 2014, and further decreased from 2014-2015.
- The mean abundance of Atlantic halibut at LL stations decreased from 2012 to 2013, but then more than doubled from 2013 to 2014. In 2015, the mean abundance for halibut decreased.
- Mean abundance of cod at JJ Stratum 0 decreased from 2012-2013, then sharply increased from 2013-2014. In 2015, the mean abundance of Atlantic cod increased slightly from 2014. Overall an increasing trend is shown with coupled decreasing CVs.
- Trends in standardized CPUE of fishermen’s choice longline stations between 2010 and 2015 show a slight increase for white hake from 2010 to 2012, but a slight decrease from 2012 to 2013, followed by a decrease from 2013 to 2014 and a decrease from 2014 to 2015.
- Trends in standardized CPUE of fishermen's choice longline stations show a small decrease

from 2010 to 2012, a large decrease from 2012 to 2013, and a large increase from 2013 to 2014, and a large increase from 2014 to 2015 for Atlantic halibut.

- Trends in standardized CPUE of fishermen's choice longline stations show a decrease from 2010 to 2012 followed by an increase in 2013, a slight increase in 2014, and a minute decrease in 2015 for cusk.
- Trends in standardized CPUE of fishermen's choice longline stations show there was an increase from 2010 to 2012, a decrease in 2013, a large increase in 2014, and almost equally as large decrease in 2015 for Atlantic cod.

SOCIETAL BENEFITS

The eastern Gulf of Maine Sentinel Longline/Jig Survey-Fishery is a fine-scale fisheries-independent survey that was designed to be a cooperative research program in an area not well covered by existing monitoring programs. Fishermen are involved in both the design process and data collection, and the surrounding communities they are from in eastern Maine can benefit from direct catch and also from information shared about species in the area. Cooperation and knowledge-sharing among fishermen, managers, scientists, and other community members can help improve resilience of coastal fishing communities.

EDUCATION AND OUTREACH ACTIVITIES

- Rodrigue, Mattie and Yong Chen. Developing a Sentinel Longline/Jig Survey for Estimating Abundance and Distribution of Groundfish in the eastern Gulf of Maine. RARGOM: Portsmouth, NH, October 14, 2015.
- Rodrigue, Mattie and Yong Chen. 2015. Estimating Abundance and Distribution of Groundfish Species in the eastern Gulf of Maine Using a Sentinel Longline Survey-Fishery. Maine Fisherman's Forum March 5-7, 2015; collaboration with Penobscot East Resource Center.
- Rodrigue, Mattie, Chen, Y. and James Wilson. Developing a Sentinel Longline/Jig Survey for Estimating Abundance and Distribution of Groundfish in the eastern Gulf of Maine. Midcoast Regional Planning Commission Meeting, 2016.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Table 1. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2015 survey.

			Stations where species present									
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	**24**	**20.1**	**2**	**8.3**	**3**	**12.5**	**15**	**62.5**	**8**	**33.3**	**11**	**45.8**
Stratum1 (50-80)	4	3.4	0	0	0	0	0	0.0	3	12.5	1	4.2
Stratum2 (80-150)	10	8.4	1	10.0	2	20.0	5	50.0	5	50.0	3	30.0
Stratum3 (150+)	10	8.4	1	10.0	1	10.0	10	100.0	0	0.00	7	70.0
Fishermen's Choice (LF)	**9**	**7.6**	**3**	**33.3**	**2**	**22.2**	**5**	**55.5**	**2**	**22.2**	**5**	**55.5**
Jigging at jigging only station(JJ)	**47**	**39.5**	**15**	**31.9**								
Stratum 0 (0-50)	35	29.4	14	41.2								
Stratum1 (50-80)	5	4.2	1	20.0								
Stratum2 (80-150)	3	2.5	0	0								
Stratum3 (150+)	4	3.4	0	0								
Jigging at random longline (JL)	**30**	**25.2**	**2**	**6.9**								
Jigging at fisherman's choice(JF)	**9**	**7.6**	**4**	**44.4**								
All (cod/other species)	119/33	100.0	26	22.2	5	15.2	20	60.6	10	30.3	16	48.5

Table 2. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2014 survey.

			Stations where species present									
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	30	22.1	5	16.7	2	6.7	19	63.3	17	56.7	13	43.3
Stratum1 (50-80)	9	6.5	0	0.0	0	0.0	0	0.0	4	44.0	0	0.0
Stratum2 (80-150)	10	7.2	2	20.0	1	10.0	7	70.0	10	100.0	3	30.0
Stratum3 (150+)	11	7.9	3	27.2	1	9.0	10	90.9	1	9.09	10	90.9
Fishermen's Choice (LF)	16	11.5	5	31.2	5	31.20	7	43.8	6	37.5	6	37.5
Jigging at jigging only station(JJ)	47	33.8	14	29.8								
Stratum 0 (0-50)	36	25.9	14	38.9								
Stratum1 (50-80)	4	2.9	0	0								
Stratum2 (80-150)	4	2.9	0	0								
Stratum3 (150+)	3	2.2	0	0								
Jigging at random longline (JL)	30	21.6	3	10.0								
Jigging at fisherman's choice(JF)	16	11.5	4	25.0								
All (cod/other species)	139/44	100.0	31	22.3	7	5.03	26	18.7	23	16.5	19	41.3

Table 3. Breakdown of station allocations and number of stations where groundfish species of interest were caught in the 2013 survey.

			Stations where species present									
Station Type	Stations		Cod		Cusk		White Hake		Halibut		Dogfish	
	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Random longline (LL)	30	22.1	2	6.7	2	6.7	17	56.7	11	36.7	22	73.3
Stratum1 (50-80)	5	3.7	0	0.0	0	0.0	0	0.0	4	80.0	2	40.0
Stratum2 (80-150)	12	8.8	0	0.0	2	16.7	4	33.3	5	41.7	7	58.3
Stratum3 (150+)	13	9.6	2	15.4	0	0.0	13	100.0	2	15.4	13	100.0
Fishermen's Choice (LF)	14	10.3	2	14.3	4	28.6	6	42.9	2	14.3	6	42.9
Jigging at jigging only station(JJ)	48	35.3	9	19								
Stratum 0 (0-50)	36	26.5	8	22								
Stratum1 (50-80)	4	2.9	0	0								
Stratum2 (80-150)	4	2.9	1	25								
Stratum3 (150+)	4	2.9	0	0								
Jigging at random longlme (JL)	30	22.1	2	6.7								
Jigging at fisherman's choice(JF)	14	10.3	0	0								
All (cod/other species)	136/44	100.0	15	11.0	6	13.6	23	52.3	13	29.5	28	63.6

Table 4. Mean abundance and coefficient of variation (CV) of groundfish species of interest.

Year/Station Type	Species							
	Cod		Cusk		White Hake		Halibut	
	mean	CV	mean	CV	mean	CV	mean	CV
2012 LL	0.11	0.17	0.56	0.19	39.00	0.14	3.90	0.095
2013 LL	0.35	0.78	0.07	0.19	32.28	0.11	1.05	0.090
2014 LL	0.20	0.24	0.04	0.96	16.01	0.09	2.30	0.097
2015 LL	0.08	0.89	0.18	0.26	4.37	0.06	1.8	0.09
2013 JJ	0.34	0.71						
2014 JJ	0.14	0.04						
2015 JJ	0.22	0.33						
2012 JJ Stratum 0	0.50	0.27						
2013 JJ Stratum 0	0.44	0.06						
2014 JJ Stratum 0	0.64	0.06						
2015 JJ Stratum 0	0.65	0.03						
2013 JJO+JL	0.21	0.57						
2014 JJO+JL	0.04	0.36						
2015 JJO+JL	0.16	0.16						
2013 JJ+JJO+JL	0.23	0.45						
2014 JJ+JJO+JL	0.11	0.13						
2015 JJ+JJO+JL	0.22	0.16						

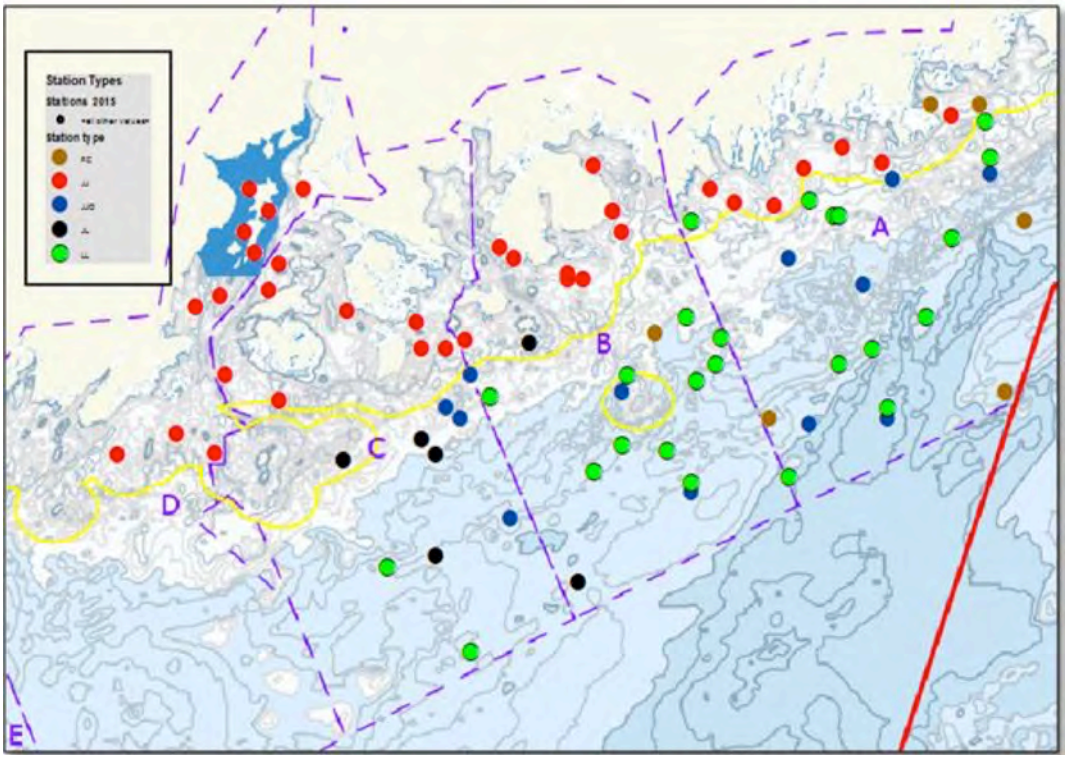

Figure 1. Survey area, including 2015 sampling locations.

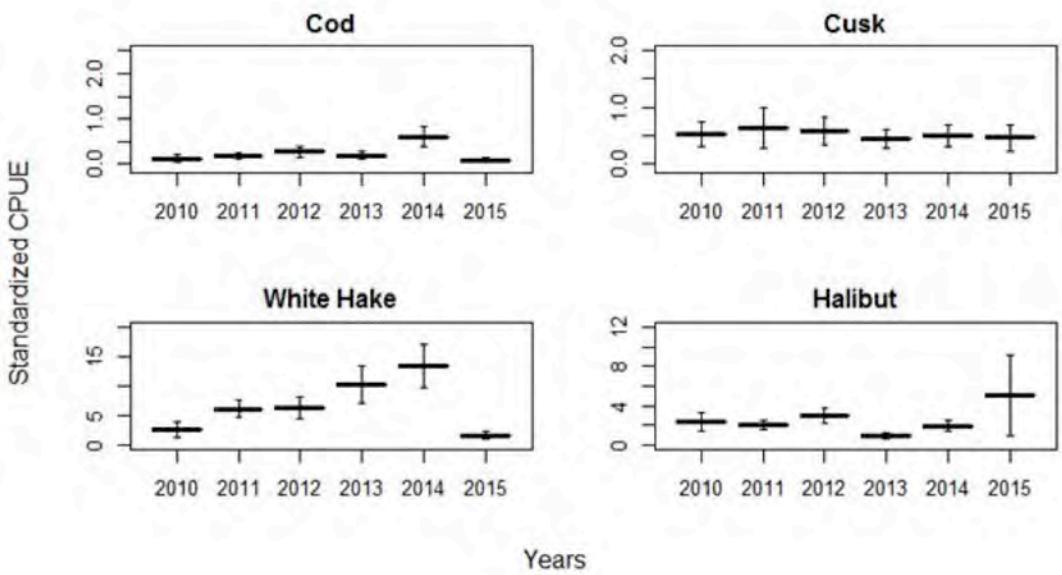

Figure 2. Standardized CPUE for groundfish species of interest between 2010-2015.

Support for updating stock assessments in the Southeastern U.S.

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Genevieve Nesslage, UMCES

NOAA Sponsor: Erik Williams, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW

Stock assessments involve the development of statistical and mathematical models that produce quantitative predictions about the response of fish stocks to exploitation. Assessments are the primary tool NOAA uses to address its strategic goal of maintaining healthy oceans through the implementation of strategies that rebuild and sustainably manage natural fish stocks. In order to effectively manage fish stocks, NOAA regularly updates its stock assessments with the most recent catch statistics, survey data, and life history information available. The primary aim of this project was to assist in data preparation, analysis, programming, and modeling work needed to support stock assessment updates being conducted by the SEFSC Beaufort Laboratory. The stock prioritized for this project was golden tilefish (*Lopholatilus chamaeleonticeps*). This project had the following objectives:

Objective 1: Provide programming and data analyses work to assist in the timely delivery of fish stocks assessment updates conducted by the SEFSC Beaufort Laboratory.

Objective 2: Support timely management of fish stocks and help ensure sustainability of our nation's fisheries.

The previous benchmark assessment of golden tilefish was updated with recent data and new stock projections were conducted as outlined in the Terms of Reference provided by the South Atlantic Fishery Management Council.

ACCOMPLISHMENTS

A stock assessment for golden tilefish (*Lopholatilus chamaeleonticeps*) was completed in a timely manner such that sustainable fishery management measures can be established for the upcoming 2017 fishing season. A final report entitled "Stock Assessment of Golden Tilefish off the Southeastern United States 2016 SEDAR Update Assessment" and a supplemental report entitled "Supplement to the Stock Assessment of Golden Tilefish off the Southeastern United States 2016 SEDAR Update Assessment" were produced and submitted to the South Atlantic Fishery Management Council.
The time period for this assessment was 1962-2014. Available data on this stock included indices

of abundance, landings, and samples of annual length and age compositions from fishery dependent and independent sources. Two indices of abundance were fitted by the model: one from the commercial longline fleet, and one from a fishery-independent survey. Data on landings were available from commercial and recreational fleets.
The primary model updated for this project was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure. Median values from the uncertainty analysis were also provided. Stock status was evaluated by measuring the 2014 spawning biomass against the minimum stock size threshold (MSST). The current definition of MSST is MSST = 75%SSBMSY.

Spawning stock declined in the 1980s, remained low but stable from the mid-1990s to the mid-2000s, then increased over the last decade, rising above MSST in the last seven years of the assessment (Figure 1). The terminal (2014) base-run estimate of spawning stock biomass was above MSST (base: SSB2014=MSST =1.13; median of MCBs: SSB2014=MSST =1.04), but below SSBMSY (base: SSB2014=SSBMSY =0.85; median of MCBs: SSB2014=SSBMSY =0.83).

Estimated fishing mortality rates began increasing in the early 1980s, peaked in the early 1990s, displayed another smaller peak around 2000, then declined steadily until 2012 when rates began to increase again (Figure 1). The base run estimate of fishing mortality (F), represented by the geometric mean of the last three years (2012-2014), exceeded the MFMT (F2012-2014=FMSY = 1:22), as did the median of the MCB estimates (F2012-2014=FMSY = 1:43). Thus, this assessment finds that the stock is experiencing overfishing, but is not overfished.

The MCB analysis indicated that estimates of stock and fishery status were robust, but also revealed some quantitative uncertainty in the results (Figure 2). Among all MCB runs, 53% are in qualitative agreement that the stock is not overfished (SSB2014=MSST > 1:0), and 66% are in qualitative agreement that the stock is experiencing overfishing (F2012-2014=FMSY > 1:0). Over 47% of MCB runs indicated that the stock was both overfished and that overfishing was occurring.

The estimated trends of this SEDAR-25-Update assessment are similar to those from the SEDAR-25 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Of those modifications, the use of a robust multinomial likelihood function to fit age and length composition data had the greatest effect. Compared to the SEDAR-25 benchmark, this assessment suggests lower values of SSBMSY and MSY, and a higher value of FMSY.

HIGHLIGHTS

- A stock assessment for golden tilefish (*Lopholatilus chamaeleonticeps*) was completed and summary reports submitted to the South Atlantic Fishery Management Council in a timely manner such that sustainable fishery management measures can be established for the

upcoming 2017 fishing season.

- The update assessment for golden tilefish finds that the stock is experiencing overfishing, but is not overfished.

SOCIETAL BENEFITS

An update stock assessment for golden tilefish (*Lopholatilus chamaeleonticeps*) was completed and reports submitted to the South Atlantic Fishery Management Council in a timely manner such that sustainable fishery management measures can be established for the upcoming 2017 fishing season.

EDUCATION AND OUTREACH ACTIVITIES

Provided a presentation in May 2016 on the golden tilefish update stock assessment methods and results to the South Atlantic Fishery Management Council's Scientific and Statistical Committee (SSC). Additional model projections were conducted at the SSC's request and a supplemental report was submitted to the Council. Upon review, the SSC recommended the work be used to set sustainable fishery quotas for the upcoming 2017 fishing season.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

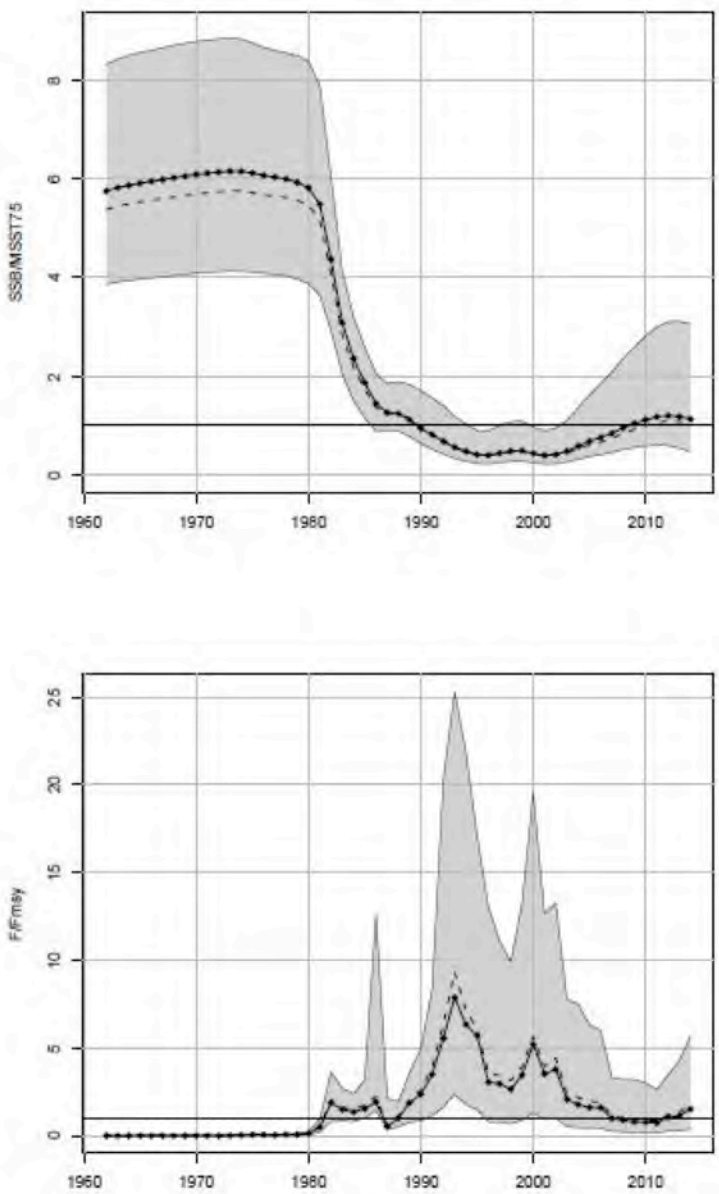

Figure 1. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. Top panel: spawning biomass (SSB) relative to the minimum stock size threshold (MSST). Bottom panel: Fishing mortality (F) relative to FMSY.

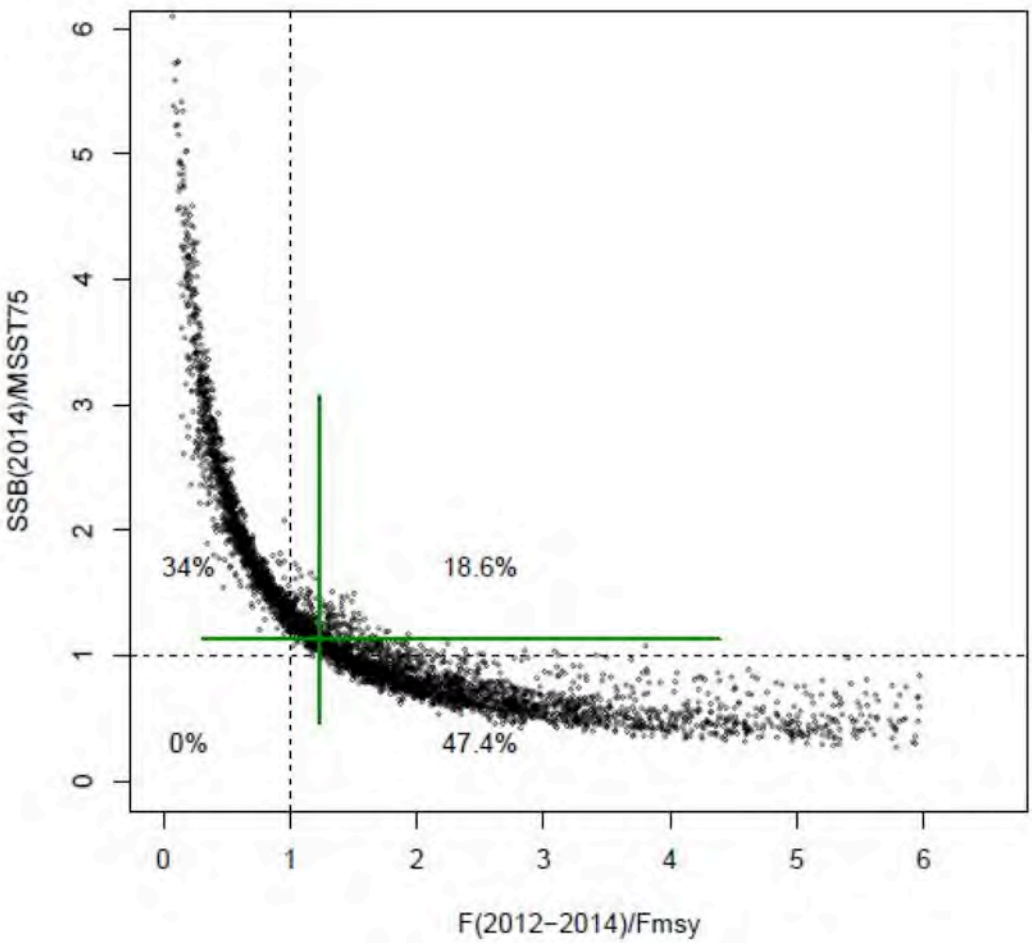

Figure 2. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5th and 95th percentiles.

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

NOAA Cooperative Agreement NA14OAR43201588
April 01, 2015- March 31, 2016

CINAR Investigator: Donald Peters, WHOI

NOAA Sponsor: Julie Mocklin, NMFS

Related Strategic Plan Goals: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW AND ACCOMPLISHMENTS

Due to unavailability of vessels, the 2015 deployment of the marine mammal detection mooring was not conducted. A no-cost extension was requested and granted, and the deployment is currently planned for this summer.

Field Experimentation to Determine Catchability of Advanced Technologies

NOAA Cooperative Agreement NA14OAR43201588
April 01, 2015- March 31, 2016

CINAR Investigator: Hanumant Singh, WHOI

NOAA Sponsor: Elizabeth Clarke, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW

The Untrawlable Habitat Strategic Initiative has decided to conduct a multiplatform survey of a single site to look at the avoidance and attraction issues associated with different species. This experiment will be conducted at the middle grounds off the coast of Florida in water depths of 20-30m. As part of the experiment we deployed three fixed stereo camera systems on the seafloor spaced 50m apart. We than ran the AUV, ROV, and Towed Vehicles through the line of sight of the camera systems. By comparing fish seen in the cameras with those observed by the different platforms, we hope to be able to quantify both the avoidance and attraction issues for each platform.

ACCOMPLISHMENTS

Our role in this multi PI cross NOAA experiment was to instrument the fixed platforms as well as the NWFSC AUV with a navigation system so that we could validate the results. By navigating the towed ROV and AUV platforms we could quantify fish avoidance and attraction behavior. The experiment was extremely successful in collecting data. We collected several Terabytes of data and decided for the sake of expediency to focus in only on sections where we could see the towed vehicle (ROV or AUV) in the fixed stereo camera systems. The efforts to analyze this data are continuing under Dr M Campbell of the SEFSC and Dr. Clarke at the NWFSC. Buoyed by our successes in this experiment, the next experiment is now being planned for much deeper water in Southern California.

HIGHLIGHTS

- We have developed methodology to test fish avoidance and attraction to robotic underwater vehicles.
- We tested our methodology as part of a large scale NOAA wide strategic initiative.
- Our initial results are encouraging, and we are now moving on to addressing challenges in using such a methodology in deeper waters

SOCIETAL BENEFITS

Fisheries independent stock assessment has the potential to revolutionize the manner in which we conduct stock assessment surveys for a variety of commercially important fish species.

PUBLICATIONS

Yogesh Girdhar, Walter Cho, Matthew Campbell, Jesus Pineda, Elizabeth Clarke, Hanumant Singh (2016), "Anomaly Detection in Unstructured Environments using Bayesian Nonparametric Scene Modeling", Proceedings of the 2016 IEEE International Conference on Robotics and Automation, pg 2651-2656.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

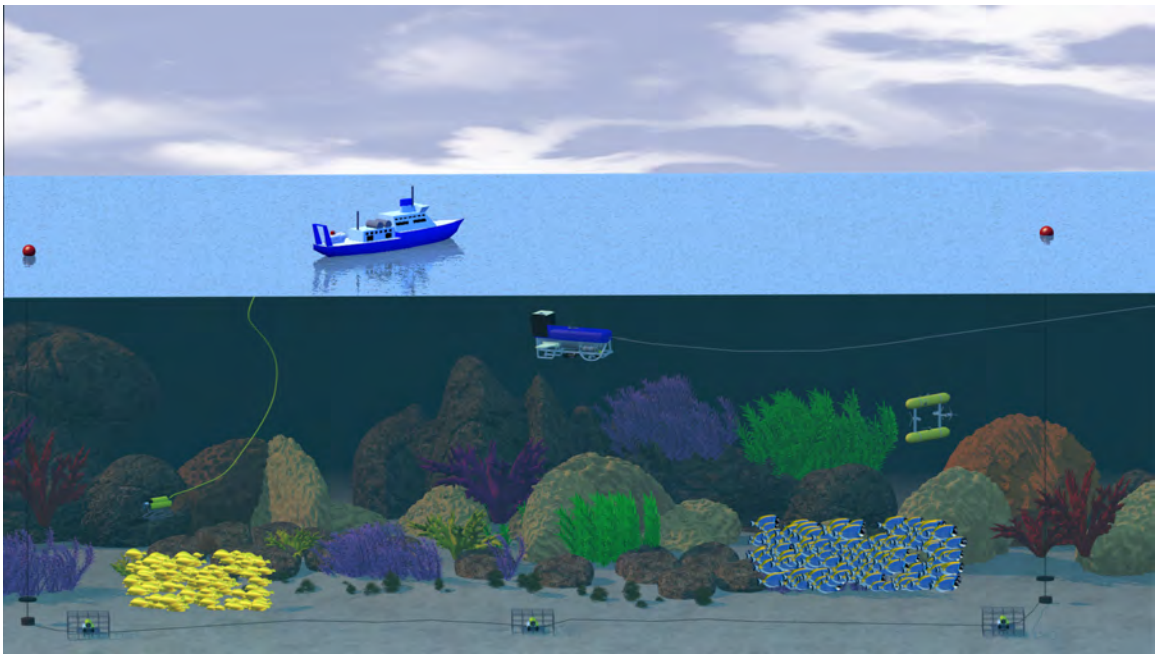

Figure 1. The concept behind the Florida Middle Grounds UHSI experiment. Fixed camera platforms are placed on the seafloor to help document fish avoidance and attraction behaviors in the presence of towed, ROV and AUV mapping efforts.

Investigating Coral Communities in the Gulf of Maine

NOAA Cooperative Agreement NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Rhian Waller, GMRI

NOAA Sponsor: Martha Nizinski, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Monitoring

PROJECT OVERVIEW

1. Characterize the deep-sea coral and sponge ecosystems and determine the distribution, abundance, and diversity of deep-sea corals/sponges in select areas of the Gulf of Maine where major structure-forming corals/sponges may or are known to occur. Establish the spatial extent of corals/sponges in these areas, their scales of patchiness, and correlation with substrate features.
2. Use the deep-sea coral/sponge distribution data to refine the next iterations of the Northeast's deep-sea coral habitat suitability model; conversely, the model will assist in choosing survey sites and thus be continuously "field tested."
3. Refine methods for deep-sea coral/sponge image and video analyses through collaboration and consultation with the NEFSC James J. Howard Marine Sciences Laboratory Image Analysis Group (IMAG).

The cruises for this research are now complete and data analysis are underway. Unfortunately the graduate student hired for this work had to leave school because of a family emergency. Waller is currently interviewing new candidates for the graduate student position, but this will delay findings from this research. Work to establish the species associations/interactions with these deep-sea corals/sponges was started by the previous graduate student and will be taken up by a new student incoming in Fall 2016.

We also plant to determine if the common sea pen (*Pennatula aculeata*) in the Gulf of Maine is being utilized as shelter by fish larvae, perhaps by those of redfish (*Sebastes* spp.) as has been recently found in Canada, by collecting specimens for analyses. No collections were able to be made in 2015, as a towed camera was used for this years fieldwork; however, we did visualize several areas of sea pens during that research cruise.

This project also seeks to improve knowledge of the taxonomy, ecology, growth and connectivity of the corals, sea pens and sponges in this region through collections. Specimens from 2014 are in curation at the University of Connecticut, and will be measured and dated by the incoming graduate student. This student will also examine reproductive ecology of the corals within the Gulf of Maine, though a 2016 summer intern is starting to process those samples.

ACCOMPLISHMENTS

- Planned, coordinated and conducted a cruise to Gulf of Maine in summer 2015 sing the ISIS 2 camera platform and RV Connecticut. This cruise included a goal of spatially bounding existing coral sites and confirming new sites based on historic and habitat model outputs. Produced geo-referenced data on camera transect locations and site level classification for target faunas of coral (octocorals and scleractinians), sponge and sea pen.
- The surveys in the summer of 2015 to the target areas were again highly successful and added a new area in Georges Basin to the list of major sites within the Gulf. Deep sea corals were present at 7 stations, sea pens at 11 stations and sponge fauna at 12 stations.
- Copied and archived at NMFS dive video from 2002-03 cruises in order to complete the archival set of imagery.
- Presented cumulative results of Gulf of Maine deep coral cruises (2002-03 and 2013-15) to NEFMC Habitat PDT as a precis to continued development of alternatives for Deep Coral Amendment.
- Provided data sets of dive site locations from cruises (2002-03 and 2013-15) with classification of coral status at the site level (i.e., coral garden, sparse coral and no coral). Status based on ICES definition of coral garden habitat. Auster and Packer both serve on the Habitat PDT and will continue to contribute directly to development of the amendment.
- Caren Martins completed her MSc thesis with analysis of 8 transects from 2013 cruise: Martins, C.J.E. 2015. Distribution of Octocorals in Jordan Basin, Gulf of Maine NW Atlantic. Master of Science in Marine Biodiversity and Conservation Within the ERASMUS MUNDUS Master Program EMBC+. University of Ghent, Belgium.
- Initiated collection of coral size class data from 2014 ROV video (joint UMaine-UConn grad student). This effort includes measuring size from video and comportment with corals collected for size validation. Coral collections (Paramuricea - as held at UConn) will be measured in January and bases excised for direct aging in support of growth and recruitment model development.
- Submitted abstract to 13th ICRS re Gulf of Maine work (session on Mesophotic and Deep Coral Reefs) with plans to submit a paper for the proceedings: Auster, P.J., D.B. Packer, R.G. Waller, L. Watling, M.S. Nizinski, C.J.E. Martins, D.L. Johnson and J.P. Pessutti. 2016. Identifying spatially rare deep sea coral communities in the Gulf of Maine (NW Atlantic), 13TH International Coral Reef Symposium, 19–24 June 2016, Honolulu, HI.
- Working on Gulf of Maine deep-sea coral "story map" documenting three years of fieldwork and discoveries (Dave Packer, Donna Johnson, Renee King). Will be hosted on NEFSC and DSCRTP website home pages. Early draft completed and being formatted for web.
- Frame grabs from videos completed for all 2013 tows. For the non-priority tows, there were 4618 images. There were 8 priority tows for Caren's thesis, with 1647 frame grabs analyzed, but only 1616 annotated. She also analyzed 838 photos from the still camera, and annotated 500 of them.
- Frame grabs from videos for 2014: 13 dives completed, 2 dives in progress, 3-5 dives yet to be done; 4256 images captured thus far.
- Working on habitat-dive characterization summary document for use by Council in the model of the SEDESC report and based on DSCRTP guidelines. Culled over 150 still images thus far

for 2013. Station location maps have been created. Tow profiles are in progress, and ancillary data for each tow/station is being put into tables and graphs.

HIGHLIGHTS

Produced geo-referenced data on camera transect locations and site level classification for target faunas of coral (octocorals and scleractinians), sponge and sea pen. The surveys in the summer of 2015 to the target areas were again highly successful and added a new area in Georges Basin to the list of major sites within the Gulf. Deep sea corals were present at 7 stations, sea pens at 11 stations and sponge fauna at 12 stations.

Presented cumulative results of Gulf of Maine deep coral cruises (2002-03 and 2013-15) to NEFMC Habitat PDT as a precis to continued development of alternatives for Deep Coral Amendment.

SOCIETAL BENEFITS

This research brings to light both new populations of cold-water corals and visualizes for the first time populations that have been known to be present for decades in the Gulf of Maine - an area traditionally thought to be deporporate in coral fauna. These corals form vital habitat for multiple fisheries species within the Gulf of Maine so information gained by this research will help inform fisheries management decisions and protections in the region.

EDUCATION AND OUTREACH ACTIVITIES

Submitting abstracts to 6th International Symposium on Deep Sea Corals on (1) our characterization of deep coral communities in the Gulf of Maine, (2) ecology of sea pens, and (3) how coral data are being used to develop management alternatives for a Deep Sea Coral Amendment at the New England Fisheries Management Council. Multiple talks on this research have been done in public settings (e.g., Belfast Free Library).

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

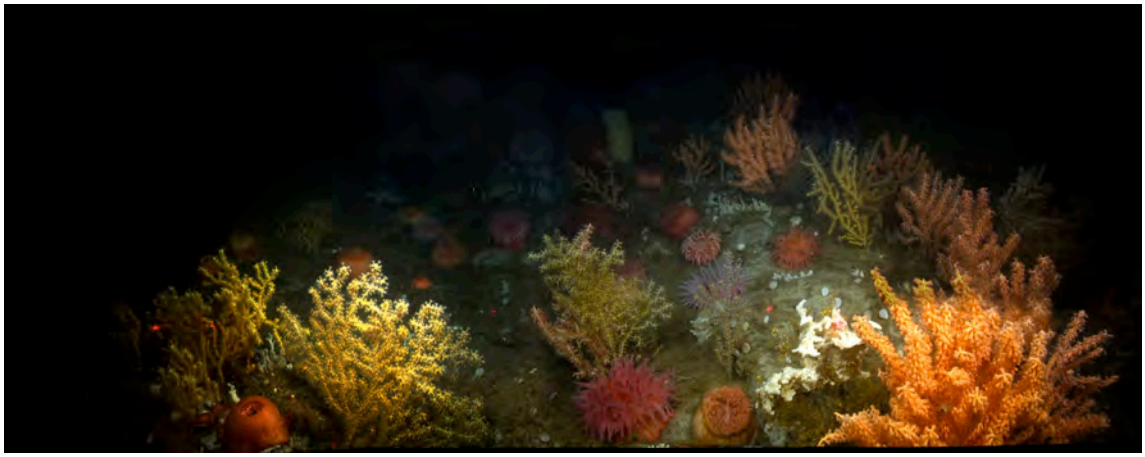

Figure 1. Coral landscape from the Gulf of Maine.

THEME III. ECOSYSTEM MANAGEMENT

CINAR

Cooperative Institute for the North Atlantic Region

Operational Support for HabcamV4 on 2015 Scallop Surveys and Post-cruise Data Processing

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Scott Gallager, WHOI

NOAA Sponsor: Robert Johnston, NMFS

Related NOAA Strategic Plan Goals: Healthy Oceans

CINAR Theme: Ecosystem Management

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 project is in support of six WHOI/NOAA initiatives that directly relate to either further development of this technology or to its application in enhancing stock assessment of sea scallops and ground fish.
Project Tasks include:

- WHOI's participation in the annual 2015 scallop survey and post cruise data processing.
- WHOI's participation in the development of habitat characterization methods and data products using data from HabCamV4.
- Support for development and testing of image processing and machine vision tools for segmentation and classification of yellowtail flounder and other difficult targets (in collaboration with Lakshman Prasad, Los Alamos National Laboratory).
- Support for RPI/WHOI student Peter Honig for developing machine vision tools for classifying substrate, scallops, and other targets.

HIGHLIGHTS

Highlights relate to the following objectives: 1) WHOI participation in the annual scallop survey and post cruise data processing; and 2) WHOI participation in the development of habitat characterization methods and data products using data from HabCamV4.

Key results include:

- Standardized image test sets representing substrate (e.g., mud, sand, gravel, cobble, boulder, and combinations thereof) and biological categories (e.g., epifauna, scallops, yellowtail flounder, etc.) have been developed and distributed to Kitware, Inc and Prasad.
- A geospatially enabled tool set and workflow for the generation of habitat and predicted habitat suitability maps from HabCamV4 and AUV optic and acoustic data has been

developed and is running in real-time on the ship as the vehicle is towed.
- A systematic approach to characterizing habitat from all future HabCamV4 surveys and other imaging systems currently in use by NOAA scientists has been developed but further work is necessary to continue to bring disparate data sets together.
- Production of visualization tools to better inform scientists, regulators, and the public of habitat value including Google Earth displays have been integrated into the real-time display on the ship and following post-processing on shore.

SOCIETAL BENEFITS

With the initiation of habitat characterization in the HabCam-based scallop resource survey in the northwest Atlantic, this research project is having immediate and practical applicability to population assessments of additional target species while demonstrating the applicability of assessing benthic living marine resources within the Northeast as well as other regions that fall under NOAA's jurisdiction.

EDUCATION AND OUTREACH ACTIVITIES

We have sponsored and continue to sponsor several NOAA PEP students who are also Guest Students at WHOI. Gallager has made many presentations at NOAA NMFS conferences, at ICES Habitat Committee, and at the New England Fisheries management Council on the importance of understanding habitat and the use of habitat suitability modeling to predict community structure under climate change scenarios.

PUBLICATIONS

In preparation:
- "HabCamV4: A towed optical and acoustic platform for characterization of benthic and pelagic habitat and stock assessment of fish and shellfish". To: J. Oceanographic Technology
- "Habitat suitability modeling to characterize Essential Fish Habitat using data from HabCamV4"

Submitted:
"The importance of *Didemnum vexillum* on benthic community structure and sea scallop populations on the northeast continental shelf". To: Marine Ecology Progr. Ser.

Development and testing of a new method for selecting among stock assessment models

NOAA Cooperative Agreement NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Michael Wilberg, UMCES

NOAA Sponsor: Brian Linton

Related NOAA Strategic Plan Goals: Healthy Oceans

CINAR Theme: Ecosystem Management

PROJECT OVERVIEW

Selecting among competing models remains an important problem in the fisheries stock assessment field. Models with different parameterizations of biological and fishery processes often are developed over the course of an assessment, with no a priori reason to choose one model over another. These differences in model structure can have a large effect on estimates of key management quantities (e.g., spawning stock biomass and fishing mortality). Therefore, objective methods to select among models are necessary.

We used a simulation-evaluation framework to test several methods of stock assessment model selection: retrospective pattern characterized by Mohn's rho, Akaike's Information Criterion, and a new method we have called the Predictive Accuracy Statistic (PAS). We simulated data sets assuming a wide variety of time-varying conditions and fitted 3-5 assessment models to each set of time series. We then applied each of the model selection methods to the set of models and determined the predictive accuracy of important quantities from the stock assessment including fishing mortality in the terminal year, spawning stock biomass in the terminal year, and stock status in the terminal year. We compared the model selection methods to the strategies of randomly selecting a model and to always selecting a single model.

ACCOMPLISHMENTS

Three versions of our Predictive Accuracy Statistic (PAS) were developed and tested. The first version evaluates the accuracy of a candidate model's terminal year predictions. The second version evaluates the accuracy of a candidate model's short term forecasts. The third version evaluates the accuracy of both a candidate model's terminal year predictions and short term forecasts. Three estimation models were fit to data sets produced by a data generating model in 90+ scenarios. The scenarios explored different forms and levels of variation in fishery selectivity, survey catchability, and natural mortality. Model selection by PAS was compared to model selection by AIC, Mohn's rho, always selecting the same estimation model, randomly selecting one of the estimation models, and averaging the three estimation models. PAS shows promise as a model selection method. PAS generally outperformed always selecting the same estimation model, when that estimation model was misspecified. PAS generally outperformed

randomly selecting an estimation model. PAS generally performed as well as or, in some cases, better than AIC.

HIGHLIGHTS

- Three versions of our Predictive Accuracy Statistic (PAS) were developed and tested. The first version evaluates the accuracy of a candidate model's terminal year predictions. The second version evaluates the accuracy of a candidate model's short term forecasts. The third version evaluates the accuracy of both a candidate model's terminal year predictions and short term forecasts.
- Three estimation models were fit to data sets produced by a data generating model in 90+ scenarios. The scenarios explored different forms and levels of variation in fishery selectivity, survey catchability, and natural mortality.
- Model selection by PAS was compared to model selection by AIC, Mohn's rho, always selecting the same estimation model, randomly selecting one of the estimation models, and averaging the three estimation models.
- PAS shows promise as a model selection method. PAS generally outperformed always selecting the same estimation model, when that estimation model was misspecified. PAS generally outperformed randomly selecting an estimation model. PAS generally performed as well as or, in some cases, better than AIC.

SOCIETAL BENEFITS

This project will help improve the quality of scientific advice used to manage fisheries through stock assessments. By developing more objective ways to choose among assessment models, the uncertainty the quantification of uncertainty in stock assessment estimates will be improved.

PUBLICATIONS

Two manuscripts are currently in preparation.

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

NOAA Cooperative Agreement NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: John Wilkin, Rutgers

NOAA Sponsor: Aijun Zhang, NMFS

Related NOAA Strategic Plan Goals: Healthy Oceans

CINAR Theme: Ecosystem Management

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.

ACCOMPLISHMENTS

On April 19-20, 2016, the Rutgers project team met with NOS scientists in Silver Spring to present an overview of recent enhancements to the ROMS modeling system. These are primarily 2-way synchronous downscaling nesting capabilities that have matured and are being adopted by the general ROMS user community for science applications. NOS were given an overview of the real-time U.S. East Coast forecast system (called "*doppio*") being developed by Rutgers University and MARACOOS that uses four-dimensional variational (4DVAR) data assimilation

to combine satellite temperature and sea-level data, HF-radar surface currents, and all IOOS *in situ* observations in a regional hydrodynamic model for Cape Hatteras to Cape Cod. The system is in pre-operational status and undergoing skill assessment. The data assimilation techniques demonstrate the capabilities that the Rutgers team recommends are useful for the NOS West Coast Operational Forecast System (WCOFS).

Following discussion with senior NOS staff, the Rutgers team are exploring opportunities to create instructional opportunities in the form a small workshops or exchange visits during 2017 to develop 4DVAR system knowledge within the NOS group for future operational systems.

RU described the prototype code of the COMT estuarine hypoxia prediction model for Chesapeake Bay, and an agreed acceptance test regime was established. NOS confirmed acceptance of the "red tide" Gulf of Maine HAB forecast system implemented by RU in 2014, and therefore that code will be installed in the public branch of the ROMS code later this year in preparation of its incorporation into the GOM OFS.

SOCIETAL BENEFITS

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

THEME IV. PROTECTION AND RESTORATION OF RESOURCES

Passive Acoustic Monitoring from Autonomous Platforms

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Mark Baumgartner, WHOI

NOAA Sponsor: Sofie Van Parijs, NEFSC

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

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 (GOM) and conduct proximate visual surveys from the Mount Desert Rock lighthouse during summer 2015 and 2016.
    - Deploy a Slocum glider in the Great South Channel of the southwestern GOM and conduct proximate visual surveys from the NOAA Ship *Gordon Gunter* during spring 2015 and 2016.
    - Deploy a wave glider in the GOM to do broadscale surveys and coordinate visual surveys with the NOAA aerial survey team.

2. Persistent real-time detection, classification, and reporting of baleen whales near a Coast Guard gunnery range (*Nomans Land moored buoy*).

- Deploy a moored buoy near Nomans Land Island and report real-time detections to the Coast Guard to help them minimize impacts to whales during gunnery exercises in the area.

3. Passive acoustic surveys for Atlantic cod in the Stellwagen Bank National Marine Sanctuary (*Cod glider surveys*).

   - Deploy two gliders (jointly funded by NOAA/CINAR and The Nature Conservancy) in Stellwagen Basin during December 2014 and 2015 to acoustically survey for Atlantic cod.

4. Real-time passive acoustic surveys for baleen whales in the GOM (*GOM glider surveys*).

   - Conduct Slocum glider surveys in areas of ecological or conservation importance to baleen whales in the GOM.

5. Real-time passive acoustic surveys for baleen whales in the New York Bight (*NYB wave glider surveys*).

   - Deploy a wave glider in the New York Bight during 2015 and 2016 to survey for baleen whales.

6. Development of improved detection and classification software (*DCS development*).

   - Support use of the desktop LFDCS by NEFSC and other users.
   - Modify DMON/LFDCS as needed to improve performance.
   - Develop wide-band detection and classification system to monitor sounds from blue whales to dolphin whistles.

ACCOMPLISHMENTS

1) *ESTCP demonstration and evaluation:* During the reporting period, a new Slocum G2 glider and wave glider were procured, and all platforms (Slocum glider, wave glider, and moored buoy) were prepared for deployment in spring 2015. Baumgartner participated in the preparation of the Demonstration Plan for the Department of Defense, and attended an ESTCP In-Progress Review meeting in preparation for fieldwork.

2) *Nomans Land moored buoy:* The moored buoy was prepared for deployment, including fabrication of a new DMON faired housing for the multi-function node (MFN) bottom mooring. Improvements in the electronics to warehouse DMON data and transmit these via Iridium satellite were completed. The buoy was deployed on March 24, 2015, and detection data for fin, sei, right, and humpback whales are being reviewed in near real time.

3) *Cod glider surveys:* Two G1 Slocum gliders were outfitted with two DMONs each, including an internally mounted DMON (the same setup as was used in past years) that

transmitted detection data in near real time via Iridium, and an externally mounted DMON that recorded both low- and mid-frequency audio. Each glider was also equipped with a Vemco VR2W acoustic receiver to detect tagged cod, and sensors to measure temperature, conductivity (from which salinity is derived), chlorophyll fluorescence, and optical backscatter. The gliders were deployed in Stellwagen Basin on December 1, 2014, and they operated for three weeks (recovered on December 22, 2014). Glider data has been disseminated to all project participants.

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:* A wave glider was procured, modified with noise abatement mechanisms, and outfitted with a DMON. Testing has been conducted on the wave glider to reduce platform noise and verify expected operation. Baumgartner attended wave glider pilot training in Hawaii during February 2015 in preparation for wave glider surveys.

6) *DCS development:* An LFDCS wiki (online manual) was developed and implemented during the reporting period (http://dcs.whoi.edu/mediawiki/index.php/Main_Page). A three-day training course on both the LFDCS and DMON/LFDCS was held for NEFSC personnel as well as participants from NAVFAC Atlantic, Dalhousie University, and DFO Canada during March 2015. Improvements in the LFDCS have been made to accommodate virtually any filename convention. Conceptual work has been conducted on the wide-band detection and classification system (WBDCS), including comparisons of wavelet versus constant-Q implementations of log-frequency spectrograms.

HIGHLIGHTS

- Deployment of the Nomans Land moored buoy for incorporating near real-time whale acoustic detections in Coast Guard gunnery exercise scheduling to reduce impacts to endangered baleen whales.
- Passive acoustic detection of Atlantic cod, baleen whales, and dolphins from two Slocum gliders in Stellwagen Basin, with simultaneous detection of tagged Atlantic cod and measurement of oceanographic conditions for three weeks.
- Implementation of near real-time passive acoustic monitoring capability from wave gliders.

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. Only one conference presentation has been made:

Baumgartner, M.F. 2015. Real-time passive acoustic monitoring of marine mammals from autonomous vehicles and moored platforms: development and applications. William Watkins Memorial Bioacoustic Symposium, New Bedford, MA, March 27-29, 2015.

Assessing Regional Sea Ice Predictability in the U.S. Arctic: A Multi-Model Approach

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015–March 31, 2016

CINAR Investigator: Enrique Curchitser, Rutgers

NOAA Sponsor: Jessie Carma, OAR

NOAA Related Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

Predictability of pan-Arctic sea ice extent and volume has been examined in a number of studies. In comparison, *regional* sea ice predictability is less explored, despite its significance for a suite of stakeholders, including coastal communities, the shipping and oil industry, and marine ecosystem management. *The goal of this study is to assess regional sea ice predictability in the U.S. Arctic*: *the Beaufort Sea, Chukchi Sea, and Bering Sea.* This effort is in part motivated by the PMEL/EcoFOCI (Ecosystem and Fishery Oceanography Coordinated Investigations) group's *in situ* knowledge of the role of sea ice on the regional oceanography and marine ecosystem. To assess predictability, we will utilize existing output from the NCAR CESM Large Ensemble simulations and the NOAA CFSv2 forecast system. In addition, we will carry out ocean-sea ice experiments using a pan-Arctic grid of the Regional Ocean Modeling System (ROMS) at nominal 10-km horizontal resolution, driven by these global models. We will analyze both diagnostic (lagged correlation) and prognostic (from initialization ensemble runs) sea ice predictability on regional scales. For the latter, root-mean-square error, anomaly correlation coefficient, and potential prognostic predictability will be calculated. We will begin our analyses on the regional sea ice area and thickness, and time permitting, expand to other properties such as ice edge locations and spring retreat timing. Moreover, we will examine cross-model differences in regional predictability and assess what factors (e.g., spatial resolution and coupling) and physical mechanisms contribute to such differences. Results from this study are anticipated to improve our understanding of processes controlling regional sea ice predictability in the U.S. Arctic, a necessary step towards developing cross-scale earth system prediction capability. This effort will be in close coordination with scientists working on the ESPC Arctic sea ice focus project, directly contributing to the goals of the latter.

ACCOMPLISHMENTS

During the first year of this effort, we implemented a high-resolution regional model for the Arctic and sub-Arctic regions. The initial resolution of the model was 10 km. We determined that higher-resolution was desirable and we are now running at model that telescopes to 5 km resolution in our regions of interest--the Chuckchi and Beaufort Shelf. The coupled ice-ocean model is first being implemented in a pure hindcast mode to test the model setup and

parameters.

We have started analyzing sea ice predictability in the regional seas of the Arctic (Bering and Chukchi Seas) using the NCAR CESM large ensemble runs output. Seasonal ice area persistency is examined through lagged autocorrelations, and the seasonal persistency in the regional seas is compared to that of the Arctic. During the freezing season ice area persistency in the regional seas is generally lower than that of the entire Arctic, but there are also regional variations. For example, the Bering Sea autocorrelations starting in January and March closely follow their Arctic counterparts until sea ice melts away at the end of spring. Meanwhile, ice areas in the Chukchi and Beaufort Seas show a faster drop in their autocorrelations than ice areas in the Arctic and Bering Sea. In comparison, in the spring and fall seasons, the Arctic and regional ice areas show similar magnitude of autocorrelation until lag 4 months. We will continue examining the mechanisms that contribute to such regional and seasonal differences in the ice area autocorrelation, and the implications on regional sea ice predictions.

HIGHLIGHTS

- Multi-decadal coupled ocean-sea ice hindcasts were designed and carried out for 20+ years.
- Analysis of model output is ongoing.
- With a stable configuration, we are now embarking on the ensemble of future states.

SOCIETAL BENEFITS

The goal of this study is to assess regional sea ice predictability in the U.S. Arctic: the Beaufort Sea, Chukchi Sea, and Bering Sea. This work is of societal significance for a suite of stakeholders — coastal communities, shipping and oil industry, and marine ecosystem management.

PUBLICATIONS

One publication is being prepared on the analysis of the Pan-Arctic model simulations.

Construction and testing of a plankton imaging and identification system in gliders and drifters for use in low-cost plankton observing systems

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31, 2016

CINAR Investigator: Cabell Davis, WHOI

NOAA Sponsor: Jonathan Hare, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

Rationale: Understanding plankton distributions and abundance is fundamental to understanding marine ecosystems. Recruitment success in marine fish populations is linked to the timing of spawning in relation to spring phytoplankton blooms. Zooplankton serve as the critical link between primary producers and higher trophic levels including exploited fish and protected marine mammals. Marine snow represents the downward flux of matter that feeds the benthos. A fundamental limitation to our understanding of plankton and marine snow dynamics is sparseness of data. Traditional sample collection and processing methods are arduous, destructive to ubiquitous fragile forms, and grossly undersample submesoscale patches, where the bulk of productivity and predator-prey interactions occur. The time consuming nature (and coupled expense) limits the amount of data that can be generated to inform assessments. Objective: We are designing and building a modular, low power, compact plankton imager incorporating it into a glider for ocean observations of plankton taxonomic and size composition together with environmental variables. We are using low-power image acquisition and processing hardware and satellite telemetry of processed plankton data together with CTD and navigation data.

ACCOMPLISHMENTS

During the first year, we designed the imaging system and its incorporation into the glider, and we selected components (Figs. 1, 2). The glider itself is capable of 300m depth profiling with an along-axis speed of 25cm/s and a glide angle of 25 degrees. On-board batteries will enable 2 months operation at sea. We decided to base the imaging system on our low-power digital holographic system (Loomis et al., 2007; Loomis, 2011). This holographic imaging system has a large image volume and is stealthy, thus minimizing avoidance by zooplankton. This imaging system uses a monochromatic red laser (658nm wavelength) ,which is not visible to zooplankton. In addition, the relatively large separation distance between the camera and laser housings (16cm) reduces flow disturbance that can trigger escape response in zooplankton. The in-line holographic imaging method used allows for reconstruction of in-focus images with 5.5 micron/pixel and resolution of 100 microns along the optical axis. This method thus gives an effective image volume of 20 ml per hologram and 1 liter per vertical meter traversed by the

glider. This image volume is over 10x greater than the VPR per vertical meter and the image resolution is 2x higher. The battery pack will include 14 DD cells configured for 7.8 V, 210 Ah.

We have had several team meetings to discuss the new system design and build criteria. Seascan has developed drawings of the component assemblies. We conducted background research into the use of LEDs and shadow imaging methods. We concluded that to maximize image volume, image resolution and quality, and minimize power requirements, our digital holographic imaging approach is the best method. This method uses a low power fiber-coupled diode laser, a collimating lens, and a lens-less digital camera back. The existing Holocam design was modified to obtain a 16 cm x 1.1 cm x 1.1 cm image volume, which as mentioned above is an order of magnitude larger than our current VPR image volume at the same magnification. The modification of Holocam design required a change in the collimating lens diameter and position and use of an imaging sensor with mobile architecture. Our existing image processing methods for extracting regions of interest from the holograms will be ported to a mobile platform.

HIGHLIGHTS

- A small modular low-power imaging system is being designed and built for incorporation into a low-cost glider
- The imaging design is based on in-line digital holographic imaging.
- This imaging system has a large image volume and minimizes plankton avoidance behavior.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

Davis gave lectures on plankton imaging systems including the new holographic method to the WestPac, China-Thailand Summer school for young scientists from Asia and Africa.

FIGURES/PHOTOS/ILLUSTRATIONS

Figure 1. Seascan glider.

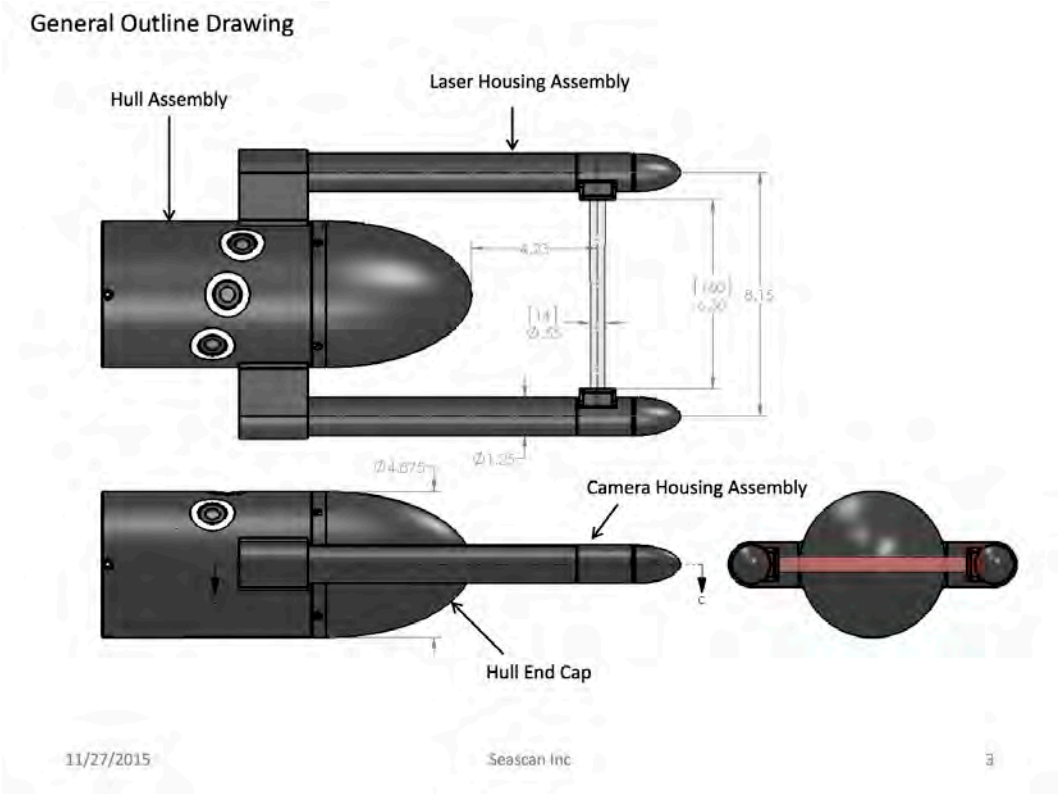

Figure 2. Drawing of Seascan glider with plankton imager (black)

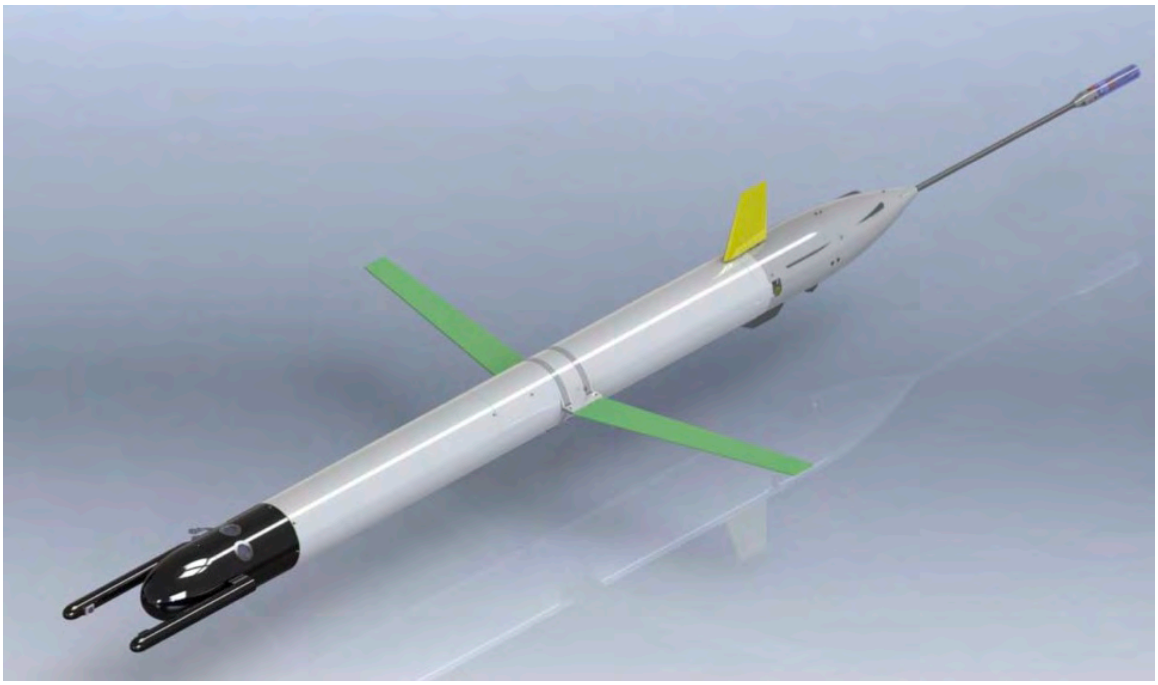

Figure 3. Drawing of plankton imager design for glider.

Nonstationarity in the Magnitude and Seasonality of Extreme Precipitation

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31, 2016

CINAR Investigator: Shaleen Jain, UMaine

NOAA Sponsor: Marty Hoerly, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

This research project was conceived with a view to develop methodologies and regional and national scales diagnostic studies to understand the nature and seasonality of extreme precipitation. From the methodological standpoint, the PI and collaborators have developed a nonparametric circular statistical approach to aid characterization of seasonality of hydroclimatic variables (Dhakal *et al.*, 2015). Project research over the past year focused on the following:

- Development and testing of methodology to separate daily precipitation conditioned upon the tropical cyclone within a select radius. Two regional datasets were used: eastern United States and Asian monsoon region.
- Precipitation (in particular the extremes) show multimodality, and there is a need for flexible approaches to not only aid the estimation of empirical probability density functions, but also the identification of significant seasonality, as well as temporal changes over time. While the PI's work crafted a relatively robust approach (Dhakal et al., 2015), a particular focus during the project period was to investigate the effectiveness of zero crossing of derivatives approach, SiZeR, as proposed by Chaudhuri and Marron (1999).
- Nonstationarity in precipitation extremes was examined in detail for the eastern United States region, based first on educing spatial dimensions, and then examining the relative stability of spatial patterns (as evidenced via Principal Component Analysis). The temporal changes and linkages to the tropical cyclone activity was examined using moving window correlation and partial correlation approaches.
- Preliminary work towards applying the above-noted approach to a 30-member ensemble simulation of NCAR CCSM model was also completed. A goal of this work would be to provide global assessment of the changes in the seasonality of precipitation extremes under anthropogenic climate change scenarios.

References cited:

Chaudhuri P., J. S. Marron (1999), SiZer for Exploration of Structures in Curves, Journal of the American Statistical Association, 94 (447), 807-823.

Dhakal, N., S. Jain, A. Gray, M. Dandy, and E. Stancioff (2015), Nonstationarity in seasonality of extreme precipitation: A nonparametric circular statistical approach and its application, Water Resources Research, 51, 6, 4499–4515. doi:10.1002/2014WR016399.

ACCOMPLISHMENTS

- Separation of daily precipitation for the gridded Asian dataset (APRHRODITE: https://goo.gl/aRWco7) and eastern United States (780 GHCN stations) was completed. This results in new datasets for the Asian region, wherein typhoon and non-typhoon related daily precipitation is available (URL: https://goo.gl/HCx2Fz).
- SiZeR approach was rigorously tested against the resampling approach of Dhakal et al., to understand the relative similarities and variances between the two approaches. We found the Dhaka approach to be competitive, and plan to test it further for different probability density function specification. We are tailoring the available computer codes, and an implementation by Oliveira to be applied to observational and modeled precipitation datasets.
- Analysis of nonstationarity in extreme precipitation for the eastern United States was completed. The results show not only changes in the patterns of extreme precipitation, the spatial signature show interesting variations. A modest link between the tropical cyclone activity (measured using Accumulated Cyclone Energy Index) and increases in extreme precipitation were diagnosed. Furthermore, station-by-station analysis of the relative preponderance of cyclone-related extremes shows a moderate trend towards increases over the 1950-2010 period. A manuscript reporting this work is under preparation.
- In October 2015, NOAA collaborators shared a 30-member ensemble simulation from the NCAR CCSM model. The PI has worked with a student to further process the data for analysis, and completed preliminary testing of the precipitation extremes, and plans to pursue a detailed analysis over 2016 Summer. As the analyses progress, the PI will work closely with NOAA collaborators to complete the U.S. scale assessment of climate-related nonstationarity.

HIGHLIGHTS

- Development of a new daily precipitation dataset for the Asian region, separated based on typhoon and non-typhoon days.
- Completion of a comprehensive study of extreme precipitation nonstationarity over eastern United States. Results show increases in extreme precipitation, and a significant part of the increase can be related to tropical cyclone activity.
- Testing and development of methodology to identify significant time windows within a year related to extreme precipitation (data-based “modes”), and nonstationarity therein. The PI plans to apply both their approach and the SiZeR method to identify temporal changes.

SOCIETAL BENEFITS

An improved understanding extreme precipitation variability and changes ties directly to public safety, ecosystem health and economic well-being. A range of decisions are tied to the seasonality of precipitation extremes; and, as a less well-studied topic, there is a general lack of knowledge in this important area with links to climate vulnerability, and potential to inform adaptation.

EDUCATION AND OUTREACH ACTIVITIES

Jain, S. and N. Dhakal, Seasonality of extreme precipitation events in a changing climate: A nonparametric statistical approach and critical considerations for climate change studies. International Conference on Advances in Extreme Value Analysis and Application to Natural Hazards (EVAN2015), Santander, Spain, 16-18 September 2015.

PUBLICATIONS

Dhakal, N. and S. Jain, Mixed-population of daily precipitation extremes over eastern United States: Variability and change stemming from north Atlantic hurricanes. To be submitted to Water Resources Research.

Is Atlantic Cod and Haddock Recruitment Influenced by the Planktonic Environment and Feeding Success during the Larval Stage?

NOAA Cooperative Agreement No. NA14OAR4320158
July 1, 2015-March 31, 2016

CINAR Investigator: Joel Llopiz, WHOI

NOAA Sponsor: David Richardson, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Ecosystem Management

PROJECT OVERVIEW

The overall goal of this study is to evaluate whether variability in the larval environment, prey selection and feeding success can explain the contrasting recruitment patterns of the Gulf of Maine and Georges Bank stocks of Atlantic cod and haddock. To accomplish this, we will evaluate concurrently collected larval and zooplankton data, and develop a new dataset on larval feeding from archived ichthyoplankton samples.

Specific objectives include:

3. The environmental conditions experienced by fish early life stages can be decoupled from larger regional-scale patterns due to variability in spawning time or location and fine-scale larval distributions. Thus, we will examine inter-annual differences among stocks in the zooplankton communities and temperature environment experienced by the larvae using concurrently collected oceanographic, zooplankton and ichthyoplankton data.
4. We will examine inter-annual, regional, and species-specific differences in both feeding success and diet composition of larval cod and haddock from Georges Bank and the Gulf of Maine, and will relate larval feeding success and diets to physical and biological conditions, including ambient zooplankton abundance and species composition.

We will test the hypothesis that the contrasting patterns in recruitment success among the four stocks can be linked to larval feeding success and environmental drivers. If the previous analyses support it, we will then integrate a zooplankton index into the assessment models stock recruitment function.

ACCOMPLISHMENTS

This two year project is in its early stages, and efforts thus far have been focused on data gathering and organization, and sorting and selecting the fish larvae to be examined for diet analyses from the thousands of plankton samples available. We have also written some code that produces the average zooplankton community experienced by a larval fish, which is basically a weighted (by larval abundance) mean abundance of each zooplankton taxon. This will be used to examine how the zooplankton community experienced by cod and haddock larvae changes

through time and space. Larval diet analyses, which will begin in summer 2016, will be used in conjunction with observed environmental conditions to understand the influence of prey availability and variability on feeding success and prey preferences.

SOCIETAL BENEFITS

The review panel for the Gulf of Maine cod assessment update in the summer of 2014 "*spent a considerable amount of time discussing the potential that Gulf of Maine cod is responding to a regime shift in the environment.*" This discussion was in part driven by the recent severe downward trend in recruitment that coincided with a substantial warming trend in the Gulf of Maine. The review panel expressed an interest in seeing an assessment model that included this environmental variability, however previous assessment working groups have concluded that the available analyses were inadequately developed for use in the assessment model. This project is intended to address these concerns.

EDUCATION AND OUTREACH ACTIVITIES

Workshop presentation: "Larval cod feeding and food availability from periods of contrasting recruitment levels" Christina Hernandez, Joel Llopiz, and David Richardson, Workshop on Cod and the Gulf of Maine Ecosystem, Boston, 16-17 November 2015

Addressing Coastal Hazards in the Mid-Atlantic

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Henry Mayer, Rutgers

NOAA Sponsor: Darlene Finch, OAR

Related NOAA Strategic Plan Goal: Resilient Coastal Communities

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

The Addressing Coastal Hazards in the Mid-Atlantic project includes three different research and engagement tasks:

1. Nuisance Flooding in Hampton Roads Area: Reducing Impacts through Better Information.
2. Identification of Demographic, Environmental and Economic Trends that will shape the Mid-Atlantic Coastal Landscape in the Future.
3. Assessing Priorities for NOAA's Coastal Storms Program in New York and New Jersey in a Post-Sandy Context.

In order to address flooding in Virginia, the researchers collaborated with NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) to conduct interviews and a participatory mapping workshop. The object of the workshop was to use Participatory GIS software tools to gather data that would allow the research team to develop recommendations for improvements to mapping products to enhance users' understanding of historical, real-time, and projected future information on recurrent flooding in the Hampton Roads area. The research team also gathered users' perceptions of economic impacts as part of the PGIS exercise, discussing flood impacts (both current and future) on transportation, commerce, emergency response and the regional economy. The research team is currently completing the final analysis and recommendations to deliver to NOAA.

In producing "*Identification of Demographic, Environmental, and Economic Trends that will Shape the Mid-Atlantic in the Future"* the research team helped NOAA's Office of Coastal Management catalog future coastal management challenges in the Mid-Atlantic. Researchers performed a literature review to identify demographic, environmental, and economic trends, and developed an accompanying database of projections at the national, regional, and local scales relevant to the Mid-Atlantic. Additionally, the report identified gaps for further investigation where important trends have not yet be been documented for the region, but still merit future investigation. The identification of areas for further investigation will help NOAA OCM target its ongoing efforts to helping leaders, citizens, and coastal managers to build resilient coastal communities, sustainable economies, and healthy coastal ecosystems.

The NOAA Coastal Storms Program (CSP) did not receive any funding under the FY16 Omnibus budget. Therefore, the JC NERR research team worked with NOAA to reevaluate priorities for the region and performed several critical tasks to enhance regional resilience. The team is currently working to develop a workshop for enhancing users' capabilities to work with NOAA flooding products. Researchers will schedule the workshop for the end of summer 2016. Additionally, JC NERR is working with Wetlands Watch and the Concursive Corporation to test the Wetlands Watch Flood App (v1.0) in the New York and New Jersey region. This project is also improving the utility and delivery of NOAA's coastal flooding products by convening NOAA flooding product developers to understand current products and future directions, and engaging with external users to improve communication about these products. Lastly, the JC NERR team developed a workshop to bring together researchers funded through Hurricane Sandy CREST grants in order to share lessons learned from their grants, and to discuss a sustainable method for communicating and engaging with one another for future resilience efforts.

ACCOMPLISHMENTS

- The Hampton Roads research team facilitated a participatory mapping workshop with 25 individuals representing the City of Norfolk and regional emergency management and planning institutions. Because of this engagement, the project team expects to deliver a final report to NOAA detailing recommendations to improve the use of flood data products for local and regional land use and emergency management planning. Additionally, the project team will deliver data and other analyses to the City of Norfolk for its continued use in other planning processes.
- A final report, *Identification of Demographic, Environmental, and Economic Trends that will Shape the Mid-Atlantic in the Future*, was submitted to the NOAA Office of Coastal Management in December 2015.
- JC NERR has successfully repurposed funding toward several worthwhile projects. To date, JCNERR held the CREST grant participant workshop, which has resulted in an agreement to draft a charter for a sustainable organization following the project. The research team has also developed workplans to execute pilot testing of the Wetlands Watch App, and for holding a workshop to test and brainstorm alternative approaches for utilizing NOAA's published coastal flooding products.

HIGHLIGHTS

- Facilitated a participatory mapping workshop with representatives from the City of Norfolk and regional emergency management and planning institutions.
- Issued final report *"Identification of Demographic, Environmental, and Economic Trends that will Shape the Mid-Atlantic in the Future"* to the NOAA Office of Coastal Management in December 2015.
- Agreement to draft a partnership charter for municipal coordination to advance resilience among the Sandy CREST grant participants.

SOCIETAL BENEFITS

The projects conducted under this grant will assist NOAA in the development and dissemination of data products and community engagement tools. Based on work products that have been delivered already, and those to come, communities will have access to more informative resources for planning in the coastal zone.

EDUCATION AND OUTREACH ACTIVITIES

- The Bloustein School team facilitated a participatory mapping workshop with representatives from the City of Norfolk and regional emergency management and planning institutions.
- JCNERR held the CREST grant participant workshop, which has resulted in an agreement to draft a charter for a sustainable organization following the project.

NOAA Port Tomorrow Proposed Expansion: Resilience of Mid-Atlantic Ports and Surrounding Communities

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Henry Mayer, Rutgers

NOAA Sponsor: Darlene Finch, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

Recent experiences in the Mid-Atlantic States with severe storms and companion surge, flooding, and high winds have shown that the resiliency of working waterfronts and their adjacent communities can be critical to the minimization of losses and damages to broader regional transportation systems and economies. The research team believes that NOAA's *Port Tomorrow Resilience Planning Tool* (http://www.coast.noaa.gov/port/) has the capacity to address many of these issues, and comprises a web-based platform to provide coastal decision makers with spatially relevant and integrated data, including social and economic data, to support risk analyses, mapping, scenario analyses, adaptation planning, and implementation. Through a pilot study in the Hampton Roads, Virginia area, the research team investigated if and how the tool might be expanded to serve as a tool for multi-stakeholder resilience planning for communities adjacent to or otherwise dependent on working waterfronts.

The research team began the project by gathering data and information available through the prior version of Port Tomorrow and reviewing those data for updates, changes, or locally improved comparable data sets to integrate into the planning tools. Once the research team reviewed the current tools, they sought feedback from local Hampton Roads stakeholders by providing a guided walk through of the tools, and gathering feedback from the participants during the session and afterward. The team was also able to integrate data from local representatives in Hampton Roads into the tool. After making modifications based on user feedback and integrating local data, the research team provided both webinar and in-person presentations of the revised Port Tomorrow tool for comment and revision. The project resulted in findings and recommendations that led to additional efforts in the Hampton Roads region to expand the scope of the Port Tomorrow tool to include other water dependent uses to enhance the planning and resilience of the broader group of waterfront development stakeholders (e.g. commercial fishermen, tourists, etc.).

ACCOMPLISHMENTS

- The project gathered information from critical stakeholder groups, including the Port of

Virginia, the Virginia Maritime Association, Hampton Roads Regional Planning District Commission, City of Norfolk, and other participants.
- Data inventory for federal, regional, and local data sources, which the research team used to compile the ESRI StoryMap product for future development.
- Prototype Port Tomorrow website.

HIGHLIGHTS

- Prototype Port Tomorrow Website.
- Support for future development of tools to support resilience planning processes that encompass a broader set of water dependent users.
- Research efforts cited in port commerce and resilience briefings to Virginia Governor's office.

SOCIETAL BENEFITS

The work conducted under this grant gathered feedback from several user groups to help configure maps, data, and tools that could be more helpful in maritime stakeholders' planning efforts to enhance resilience. Improved resilience planning for port stakeholders can enhance the resilience of the Hampton Roads region and the critical supply chains that pass through the region.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

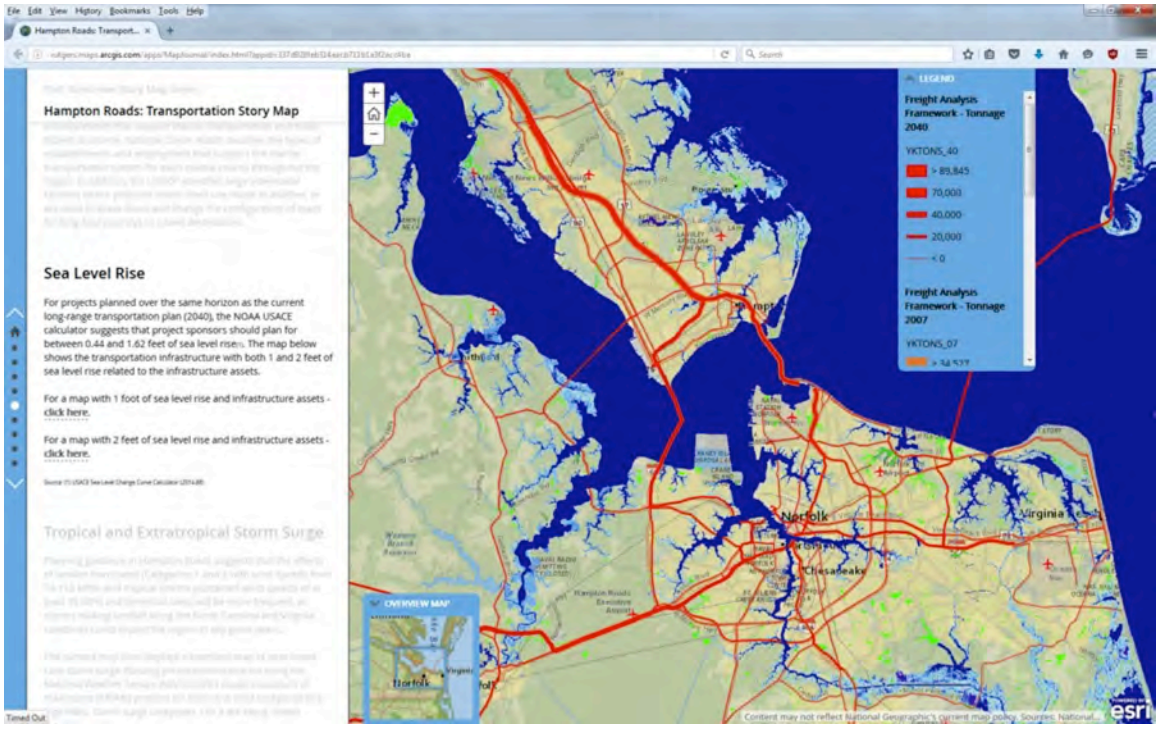

Figure 1. A screenshot of the Prototype Port Tomorrow tool presented to regional port stakeholders.

Climate Adaptation in Fishery Ecosystems

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Kathy Mills, GMRI

NOAA Sponsor: Roger Griffis, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

As the impacts of climate change and variability become apparent in fishery ecosystems, there is a critical need for strategies that enable climate adaptation in marine fisheries. Advances towards climate adaptation have been less developed for fisheries than for other sectors, such as agriculture, water resources, and coastal management. Our project is developing frameworks for climate adaptation that will enable fishery managers, fishing industry, and fishing communities to plan for future risks and opportunities.

The project will work towards this goal through two specific objectives:

1. Organizing an international working group on Climate Adaptation in Fisheries Ecosystems (CAFE) to compare climate impacts and adaptation approaches with rapidly changing ecosystems with different fisheries and fishery management regimes.
2. Piloting and refining a social-ecological vulnerability assessment and adaptation planning framework for marine fisheries.

Since the last project report, we completed reporting on the workshop that we held during the 3rd International Symposium on the Effects of Climate Change on the World's Oceans, which was a large step towards Objective 1. A summary of the workshop and key points raised was published in summer 2015 issue of PICES Press. We are working towards a synthesis paper to be published in a peer-reviewed journal that will capture key themes and case studies presented during this workshop. Plans for Objective 2 of this project are currently being re-scoped with the NOAA collaborator to align with current priorities and lower funding levels for this project.

ACCOMPLISHMENTS

To date, this project has made progress on Objective 1 by organizing and facilitating a workshop on "Moving Towards Climate-Ready Fishery Systems" at the 3rd international symposium on the Effects of Climate Change on the World's Oceans (March 21-22, 2015). The workshop brought together 44 scientists from the US, Australia, New Zealand, Norway, the UK, Canada, Brazil, and Cambodia to compare experiences in climate impacts and adaptation across four fishery ecosystems (eastern Australia, Gulf of Alaska, Gulf of Maine, and Nordic Seas) that are experiencing rapid changes.

Specifically, discussions identified:

- Key elements of climate change adaptation,
- How these elements as well as other contextual factors shape adaptation approaches in different situations and at different scales, and
- Advances that are needed to support climate adaptation in marine fisheries.

We reported on this workshop through an article in the summer 2015 issue of PICES Press, and plan to develop a synthesis paper for submission to a peer-reviewed journal that will document case studies presented and key themes of discussion during the workshop.

HIGHLIGHTS

- Report on workshop on "Moving Towards Climate-Ready Fishery Systems" held at the 3rd international symposium on the Effects of Climate Change on the World's Oceans published in PICES Press.
- Workshop synthesis paper in development.

SOCIETAL BENEFITS

This project will advance our capacity to understand climate-related risks and adaptation strategies for marine fisheries. Our work to date has developed a global perspective on approaches to climate adaptation in marine fisheries and advances that are needed to support further adaptation and preparedness. We will now apply these global insights locally to enable fishery managers, industry participants, and fishing communities in the Northeast to understand climate-related risks and to plan for how they will respond to climate impacts.

EDUCATION AND OUTREACH ACTIVITIES

Key themes from the workshop were integrated into a synthesis paper and presentation for the Northeast Regional Planning Body to convey how environmental variability and climate change are affecting commercial fisheries in the Northeast U.S .and how adaptation to climate change may intersect with spatial planning in the future.

Mills, K. E. and A. J. Pershing. 2015. The influence of environmental variability and climate change on marine fisheries in the Northeast United States: a synthesis of scientific knowledge and forward-looking considerations. Prepared for Northeast Regional Ocean Council and Northeast Regional Planning Body. Gulf of Maine Research Institute, Portland, ME.

Mills, K. E. 2015. Impacts of climate variability and change on the Northeast United States marine ecosystem. Invited presentation to Northeast Regional Planning Body. November 16, 2015.

PUBLICATIONS

Mills, K. E., R. Griffis, A. Haynie, G. Pecl, and A. Pershing. 2015. 2015 Santos Workshop on "Moving towards climate-ready fishery systems: Regional comparisons of climate adaptation in marine fisheries." PICES Press 23(2): 14-16.

Impacts of a changing ecosystem on Atlantic salmon marine productivity

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Kathy Mills, GMRI

NOAA Sponsor: Timothy Sheehan, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

This study is evaluating the hypothesis that Atlantic salmon marine growth provides a mechanism that links changing ecosystem conditions to Atlantic salmon survival and productivity. Statistical analyses and modeling are being used to investigate: (1) how changes in marine survival and productivity are related to changes in marine growth of Atlantic salmon; and (2) how changes in marine growth are related to ecosystem conditions that affect salmon marine energetic requirements and energetic resources available via salmon prey.

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.

In years 1 and 2, our plans focused on analyzing changes in growth of Atlantic salmon from the Penobscot River, relationships between growth and survival ,and relationships between growth and ecosystem conditions. In addition, we planned to hire a postdoc and run a workshop to identify commonalities in ecosystem change and fish population changes across the North Atlantic. Our progress towards these goals has been re-organized for several reasons. First, we are still filling data gaps in scales from the Penobscot fish. Second, a funding shortfall in year 2 caused us to shift the timeline for hiring a postdoc. However, progress towards all of these project activities is underway.

ACCOMPLISHMENTS

To date, we have obtained archived scales of Atlantic salmon that returned to the Penobscot River from ME Department of Marine Resources, and NMFS has read scales to measure circuli and seasonal growth increments from 1SW and 2SW in three clusters of smolt years (1978-1980, 1986-1988, and 1998-2000) that align with periods of high, medium, and low marine survival. Our initial plan had been to have samples sizes of 50 scales from each sea age/smolt

year combination. However, due to unreadable scales in the initial target and back-up sets, some years have fallen as much as 20% below the target sample size. We are currently making a final attempt to identify readable scales from those that remain in the archive and reading those to collect growth data.
An intern was hired during the summer of 2015 to set up R code that will be used for standard data processing needs in this project. The intern developed quality assurance processes to determine rates of difference between human-read and computer-calculated marks on the scales. In addition, he set up code for calling to different temperature and oceanographic data sets as well as wrapper functions so that standard inputs (e.g., latitude-longitude boundaries of areas of interest) can be used to define data that are retrieved from those data sets; this effort will simplify ecosystem data collection and processing throughout this project.

Tim Sheehan and Kathy Mills proposed a session for the 2016 ICES Annual Science Conference, which has been accepted. This session will address a project goal to broadly evaluate how changing ecosystem conditions are affecting Atlantic salmon growth and survival across the North Atlantic, not just in North America. We have expanded the focus of the session to facilitate comparisons of how climate and ecosystem changes are affecting diadromous as well as marine fish population productivity, with a goal of being able to broadly synthesize commonalities in climate-ecosystem-fish population linkages across the North Atlantic basin.

Finally, we have completed the interview process for postdoctoral research associates and plan to issue an offer in a few days. The postdoc will play a major role in all modeling associated with this project (primarily Objective 3).

HIGHLIGHTS

- Growth data have been obtained from Atlantic salmon from the Penobscot River, and current data gaps are in the process of being filled.
- R codes have been written for quality assuring the biological data and for facilitating retrieval of climate and ecosystem data from global data sources (e.g., SST data).
- ICES session proposal has been accepted and organizing is underway to bring together diverse experts and contributions to shape a basinwide understanding and framework for how climate and ecosystem changes are affecting fish population productivity.
- Postdoctoral hire for the project is imminent.

SOCIETAL BENEFITS

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

Effects of Drag from Entanglement in Fishing Gear in Right Whales

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Michael Moore, WHOI

NOAA Sponsor: Peter Corkeron, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

Entanglement is the leading cause of death in large whales in the Northwest Atlantic. Entanglement may become protracted when individuals break free and carry a portion of the entangling gear, often for months to years. Emaciation is common in entanglement mortalities: drag-induced increases in energetic costs, and reduced mobility and foraging ability significantly alter energy balance. Sublethal entanglement trauma is close to ubiquitous in North Atlantic right whales: in a recent survey, 83% had been entangled at least once, and 26% acquired new wounds and scars annually. It therefore could be a major concern in terms of population level productivity.

Energetic consequences associated with drag from towing entangling gear have only recently begun to be quantified. Evidence acquired so far from one right whale entanglement case has suggested that entanglement imposes significant energy drain, requiring 70 to 102% more power to maintain a preferred swimming speed. Quantifying drag imposed by entangling gear is critical, and the potential for survival or recovery. Such an exercise assists predictive efforts to estimate the drag imposed by gear towed by free-swimming individuals at the time of their detection.

Even following disentanglement of right whales by humans, or self-disentanglement, energy reserves may remain sufficiently impacted so as to lead to death. Combining empirically derived drag estimates with individual life history information from the North Atlantic Right Whale catalog, we will investigate the energetic impact of 15 specific entanglement cases to determine the predictability of lethality and post-disentanglement survival.

Research Objectives

1. Assess the energetic impact of specific North Atlantic right whale entanglements to determine the predictability of lethality or post-disentanglement survival.
2. Quantify the incremental energetic gains achieved by partial disentanglement.
3. Compare measured vs. estimated drag from gear sets, to enable a predictive capacity to estimate drag for free-swimming entangled individuals at their time of detection

ACCOMPLISHMENTS

As previously reported in this study we quantified the amount of drag at different speeds and depths measured from fishing gear removed from entangled whales. We examined how these factors changed with different gear configurations (Figure 1). We established predictive relationships between drag and (1) the weight of a gear set and (2) the length of a gear set, and whether or not it includes buoys or floats (Figure 1). We found that on average, entanglement doubles the drag on a swimming whale, and hence the propulsion required for a given speed. We also examined the reduction of drag achieved by partial gear removal, which is particularly beneficial at slow swim speeds.

We have provided an additional method by which to assess the drag on an entangled whale at the time of entanglement detection, by comparing drag forces measured with a tensiometer and those estimated from theory (Figure 1), and suggest a critical entanglement duration that may be more likely to lead to death. We suggest that this method be incorporated into the current definitions and criteria for Serious Injury, at least for right whales.

We have also used these data to place the energetic cost of entanglement within a broader context of right whale life history. We used two separate approaches that yield comparable estimates of the energetics associated with increased drag from entanglement. These, in combination with individual history data have allowed us to show that: propulsive requirements increase on average 1.52 fold, which over time affects individual survival; entanglement results in the consumption of endogenous energy reserves on the same order of magnitude as is consumed during reproduction or migration; entanglement can lead to energetic demands similar in magnitude and duration to other life history events; the onset and duration of these entanglements have significant impacts on the energy budget of individuals, especially reproductive females; and that even short-term or low-drag entanglements can result in extended calving intervals.

HIGHLIGHTS

This project has:

- Increased our understanding of the magnitude and variability of drag imposed from different entangling gear scenarios (Figure 1).
- Shown that at a minimum, entanglement doubles the drag experienced by a whale, and doubles the power required to swim.
- Provided formulae from which we can confidently estimate the drag on an entangled whale at the time of detection based on the dimensions of the gear involved (Figure 1).
- Reinforced the existing disentanglement practice of reducing trailing lines and the tether to the telemetry buoy to ~20 m.
- Illustrated the extent to which entanglement onset and duration, as well as added energetic burden, come into play when trying to predict the outcome of a given entanglement event (Figure 2).

- Made a side-by-side comparison of the energetic costs of entanglement and the costs of other life history events such as foraging, migration, and reproduction (Figure 2).
- Estimated the potential for entanglement in fishing gear to affect the reproductive output of North Atlantic right whales.

SOCIETAL BENEFITS

Understanding how drag from entanglement in fishing gear contributes to changes in swimming behavior, energy budgets, and reproduction in North Atlantic right whales is an essential piece to the overall management of protected species such as right whales in the broader context of ecosystem based management of commercially important fisheries, especially those that interact with protected species.

EDUCATION AND OUTREACH ACTIVITIES

Presentations

North Atlantic Right Whale Consortium Meeting, New Bedford MA. November 2014.
"Drag on Marine Mammals" Lecture, Nauset Regional High School Physics Class, March 2015
International Whaling Commission Meeting on Large Whale Entanglement Issues, Provincetown MA. April 2015.
"Entanglement in North Atlantic right whales: sublethal impacts on drag, movement, and energetic cost**."** Woods Hole Oceanographic Institution Biology Seminar, Woods Hole, MA, U.S.A. 30 July 2015.
North Atlantic Right Whale Consortium Meeting, New Bedford MA. November 2015.
International Whaling Commission Workshop to Support the Consideration of Non-Hunting Threats to Cetacean Welfare, Kruger Park, South Africa. May 2016.

Peer-Reviewed Publications in Preparation

Energetic cost of entanglement in North Atlantic right whales (*Eubalaena glacialis*) (Journal of Animal Ecology)
Predicting lethal entanglements as a consequence of drag from fishing gear (Marine Pollution Bulletin)
Swimming kinematics and efficiency of entangled North Atlantic right whales (Submitted, Endangered Species Research)

PUBLICATIONS

van der Hoop, J.M., Corkeron, P., Kenney, J., Landry, S., Morin, D., Smith, J., Moore, M.J., 2016. Drag from fishing gear entangling North Atlantic right whales. Marine Mammal Science 32, 619-642.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

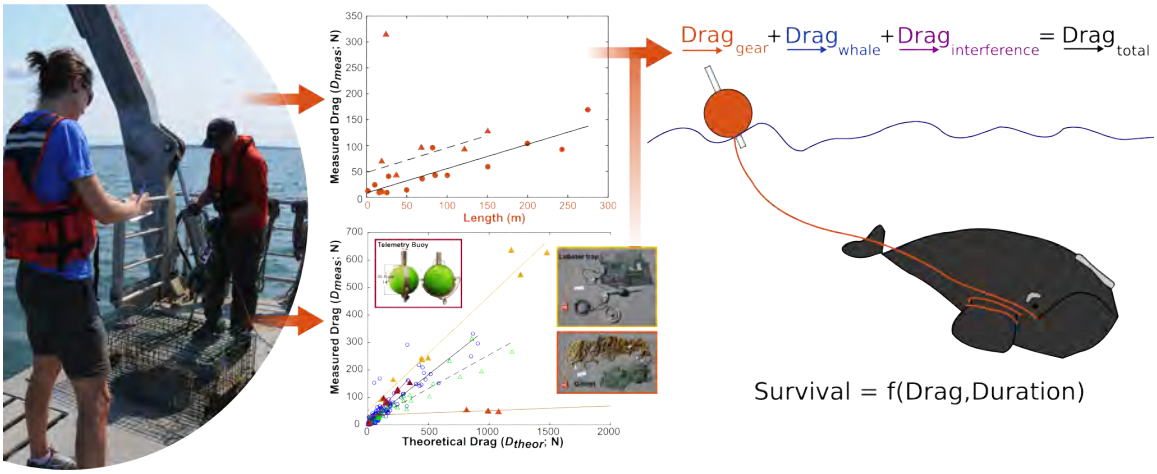

Figure 1. Schematic of the research approach, including measurement of fishing gear on a tensiometer to determine drag forces (left), linear regression and determination of formulae to estimate drag from gear length (center top), comparison of measured and theoretical drag estimated from gear dimensions (center bottom) and the overall drag calculations for an entangled whale which, over time, contributes to the overall survival probability (right).

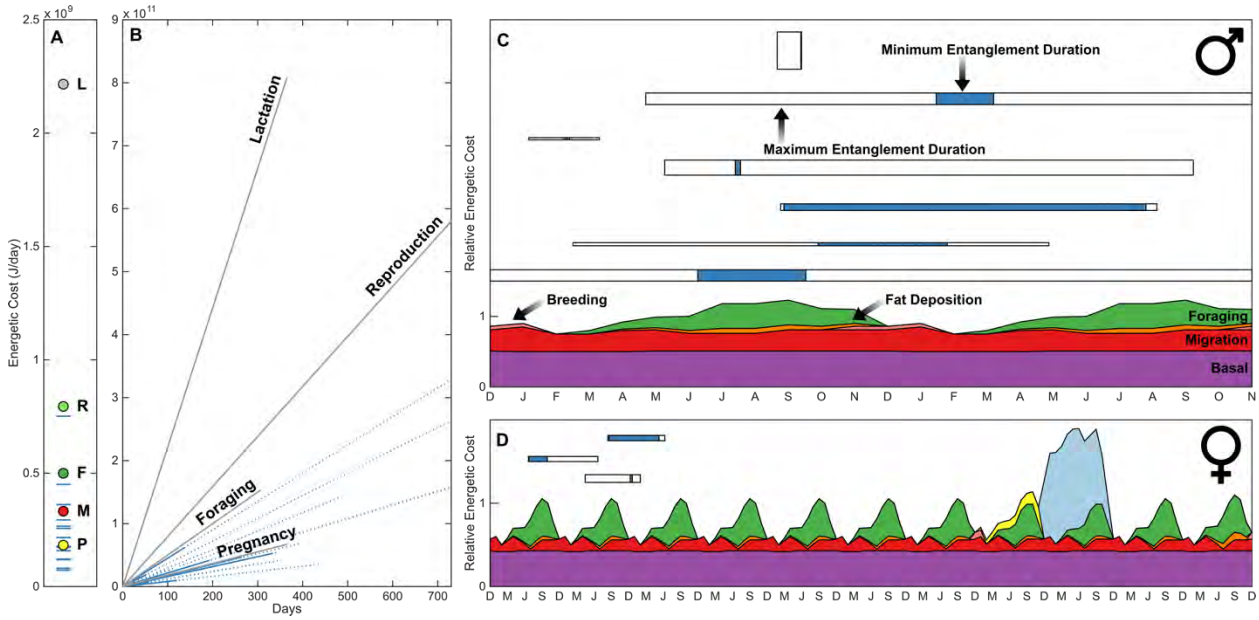

Figure 2. Daily energetic costs (J/day) from drag associated with entanglement in fishing gear (blue lines), compared to costs of other life history events: pregnancy (yellow, P; (Fortune *et al.* 2013)), migration (red, M; (van der Hoop *et al.* 2013b)), foraging (green, F; (McGregor 2010)), reproduction (green, R; pregnancy + lactation; (Klansjcek *et al.* 2007)) and lactation (light blue, L; (Fortune *et al.* 2013)) (A) and those daily energetic costs projected over the duration of each event (B). For entanglements, solid lines show the minimum entanglement duration and dotted lines the maximum entanglement duration. Relative energetic timelines of males (C) and females (D) showing the cyclic nature of energy demands in migratory whales. Horizontal bars show the temporal onset and extent of the minimum (blue) and maximum (white) entanglement durations; the height of each bar indicates the cost of each entanglement case relative to other life history events (n = 7 males, n = 3 females). The three female entanglements are shown relative to their known calving histories; five females included in the study but not in this figure have unknown calving histories.

Assessing the Pathogenesis and Host Susceptibility to Dolphin Morbillivirus in Cetaceans

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Michael Moore, WHOI

NOAA Sponsor: Teresa Rowles, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

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

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

Objectives: The project funds requested will continue to be used to provide materials needed to determine tissue tropism by quantification and distribution of DMV in cetacean host tissues. Potential reservoir species for CeMV will then be determined by detection of virus in host tissues. Sequencing of identified target amplicons of DMV will allow for determination of variability in cetacean populations.

The two specific questions being addressed are: (1) Does tissue tropism of DMV in bottlenose

dolphins reflect pathology, routes of exposure and shedding of the virus?, and (2) Are there reservoir species harboring DMV?

H1- Aim: Determine tissue distribution and other potential sites of virus shedding of DMV in bottlenose dolphins by quantification of virus in tissues.

The first phase of this project relied heavily on determining where and what bottlenose dolphin samples would be best to answer the first objective. Animals were chosen based on tissue condition code, diagnostic results on DMV obtained during the UME, age, spatial distribution, temporal distribution, and the availability of -80 ºC sample suite of tissues including lung, pulmonary lymph, liver, spleen, kidney, skin and brain. Additional samples were further identified to understand transmission and shedding including feces/urine, testis/ovary and skin or skin/mucosal lesions.

Processing of samples and analysis of initial results for the first Aim are currently underway, with continued coordination of tissue shipments from over ten marine mammal stranding facilities. A complementary project to investigate routes of exposure, quantification and shedding of DMV via immunohistochemistry (IHC), was completed in six of these dolphins in February 2016. Over 30 tissues from each individual were analyzed and quantitatively scored for DMV. These results further guided sample selection of the 50 individual dolphins, including additional tissues to understand transmission and shedding.

PCR of tissues is currently underway to understand viral tropism and routes of shedding. Findings from the histopathology reports of these cases, along with PCR results, will be used to answer our questions on tropism and possible routes of shedding and exposure. PCR and sequencing results for this aim will be completed by October 2016.

H2- Aim: Undertake a retrospective study to determine potential reservoir species for CeMV.

Fresh dead cetaceans with samples taken between 2008-2012 are being identified for this portion of the study. With the collaboration and cooperation of a multitude of marine mammal stranding facilities from Maine to Florida, samples will be sent for PCR and sequencing to identify host reservoir species of CeMV as well as to determine variability of the virus in cetacean species.

ACCOMPLISHMENTS

The goal for Year 1 of this project was to determine tissue distribution and abundance of virus and complete data analysis. Working with the cooperation of ten marine mammal stranding facilities and NOAA's MMHSRP, the target sample sizes of 50 bottlenose dolphins and over 250 specific samples have been identified, located ,and are in the process of analysis for DMV by PCR. Although analysis is still underway, results in the six dolphin cases examined to date by IHC and some PCR results indicated vast differences in the acute and chronic infection patterns. The tissue distribution in acute cases reflected systemic infection and viral replication, where viral antigen was visible in all but skin, muscle and heart tissue. Histological findings in the acute cases included viral inclusions, syncytial cells, necrosis of epithelial cells and lymphoid depletion. In contrast, chronic DMV cases had no indication of viral replication in the tissues

examined. Lesions consistent with prior DMV infection in these cases included axonal loss and meningitis in the brain and mild lymphoid depletion. Comparing all PCR results that are underway with all diagnostic findings in these cases will allow for a greater understanding of the impact of the virus on bottlenose dolphins.

HIGHLIGHTS

- Over 250 samples from 50 bottlenose dolphins have been identified to understand DMV tissue tropism.
- PCR to determine presence DMV in these tissues is underway.
- A retrospective analysis of samples available from 2008-2012 is underway to test for CeMV reservoir species.
- Design of a nested PCR protocol is underway for more sensitive detection of CeMV strains in reservoir species.
- Initial results combining several available diagnostics suggest vast differences in acute and chronic infection patterns of DMV in bottlenose dolphins.
- The differences seen in immunohistochemical (IHC) vs PCR diagnostics between acute and chronic cases emphasizes the need to use multiple diagnostic methods to detect the presence of virus or viral proteins.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

Invited Presenter “Assessing the Pathogenesis and Host Susceptibility to Dolphin Morbillivirus in Cetaceans” at the 2013-2015 Mid-Atlantic Bottlenose Dolphin Unusual Mortality Event Meeting, Long Island, NY. Feb 22-23rd, 2016

Physiological Ecology and Habitat Suitability: Combining Experiments and Surveys to Inform Stock Assessments

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31, 2016

CINAR Investigator: Grace Saba, Rutgers

NOAA Sponsor: Jonathan Hare, NMFS

Related Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

There is increasing importance to include habitat information into stock assessment models, as stock dynamics and observations of stock abundance are impacted by habitat. Part of the difficulty is because the scale of most habitat studies is not matched to the scale of most assessments. While more than fifteen models are used for stock assessments at the Northeast Fisheries Science Center (NEFSC), only a few have the ability to directly include habitat information. One recent success was the development of a habitat suitability model, coupled with a circulation model hindcast, for the assessment of pelagic forage fish, Atlantic Butterfish (*Peprilus triacanthus*). The model is parameterized using catch densities and temperatures from multiple fishery-independent surveys. However, extracting niche dimensions from field survey collections can problematic. Another approach is to develop niche dimensions experimentally, by determining the metabolic functional response of target species to a range of temperatures. These laboratory-based studies can then be used to improve the species niche models.
This project tests this premise. We (myself and NOAA collaborators) propose to parameterize mechanistic thermal niche models by measuring temperature-dependent metabolic rates for butterfish, compare habitat suitability models based on field and experimental data, then evaluate the effect of parameterization on catchability estimates for butterfish along the U.S. east coast in the context of the stock assessment model. This will allow us to identify priority habitat areas for butterfish. Experimental work during the first year of our project (2014-2015) was conducted by a joint NOAA (Rich Bell, Chris Taylor) and Rutgers (Grace Saba) team aboard the NOAA vessel *Pisces* during EcoMon cruise PC1405 from November 3, 2014 through November 20, 2014. While the first year of this project was valuable in setting up the respirometry systems and understanding the feasibility of conducting these experiments at sea, there were several challenges that in 2015 we worked to address in order to conduct experiments with adequate repetition this year.

ACCOMPLISHMENTS

The biggest challenge for this project has been acquiring and maintaining healthy butterfish. During the November 2014 cruise, butterfish were only captured in three out of 20 trawls. We were not successful at butterfish capture as it was too late in the season and the

species likely had already moved offshore. The butterfish we did capture in trawl nets were not in good condition (visibly damaged, missing scales, abnormal swimming behavior) and unfortunately did not perform well in the initial trials.

This past year the PIs laid out the work plan to ensure successful completion of the project. Our next course of action is to work with the commercial fishing community to collect butterfish via either short trawls with a well designed cod end aquarium or pound nets in Narragansett Bay or from day trawlers on the shelf of the Middle Atlantic Bight (MAB). Additionally, we will target fish collections during warmer periods when butterfish are more abundant in Narragansett Bay or on the MAB shelf (late spring – early fall 2016). We believe this approach will increase the catch number of butterfish and will yield a higher proportion of healthy (undamaged) butterfish – both of which are key to collecting reliable metabolic data. We have moved our experimental equipment to the NOAA Sandy Hook Laboratory in anticipation of conducting the experiments upon successful collection of undamaged butterfish.

Several PIs on this project, including myself, were recently funded by NOAA OAR to conduct similar experiments with spiny dogfish, black sea bass, and longfin squid that will also take place at the NOAA Sandy Hook Laboratory starting in June 2016. We plan to leverage that project to complete these butterfish experiments. The stable laboratory environment and increased space/number of tanks will allow us better control of water quality and temperature in the holding tanks and experimental treatments as well as the ability for increased replication.

HIGHLIGHTS

- To overcome challenges that occurred in Year 1 of the project, we devised a new work plan and method to promote successful collection of healthy butterfish for upcoming experiments.
- Experiments are planned for spring-fall 2016 at the NOAA Sandy Hook Laboratory.
- The laboratory environment will allow for increased replication and better control of water quality and temperature in the holding tanks and experimental treatments.
- We plan to leverage a recently-funded NOAA OAR project to complete these butterfish experiments.

SOCIETAL BENEFITS

Physiological results from this proposed work will be incorporated into the butterfish stock assessment and will provide information for estimating catch efficiency based on a habitat suitability model and identification of priority habitat areas for butterfish. In addition, our results will provide a direct comparison between habitat suitability models developed with three very different kinds of data. If there is agreement, this will bolster the use of survey-based models; if there is disagreement, the magnitude of the effect will be demonstrated and hypotheses will be developed for future research.

Deep-Sea Coral and Sponge Habitats in the Northeast and Mid-Atlantic Canyons: Integrative Imaging and Mapping of Unknown Canyon Environments and Ecosystems

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Timothy Shank, WHOI

NOAA Sponsor: Martha Nizinski and Tom Hourigan, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Protection and Restoration of Resources

PROJECT OVERVIEW

Submarine canyons off of the U.S. east coast are some of the most productive non-chemosynthetic habitats described in the deep sea and are thought to enhance local and regional species diversity, including those ecosystems most vulnerable to anthropogenic activities, deep-water coral ecosystems. However, coral locations, composition and diversity, and the diversity of life they support in these canyons are virtually unknown in canyons off of the U.S. east coast. Regional Fisheries Councils are seeking such information with which to assist their management and conservation of living and commercial resources. To assist in this and other research efforts, our objectives were to use recently obtained seafloor bathymetric data and WHOI's *TowCam*, a deep towed imaging system, to locate, document, and characterize deep-sea coral ecosystems in virtually unexplored northeast and mid-Atlantic canyons. In August 2015, we conducted 20 imaging tows using T*owCam* in areas predicted to host and be deep-sea coral "hotspots" as predicted by the existing model/maps in Chebacco, File Bottom, Heel Tapper, Dogbody, Sharpshooter, Clipper and Welker Canyons. Following the collection and initial enumeration of these image data, we were redirected in our goals by the timely management and conservation needs of the Mid-Atlantic Fisheries Management Council who requested the complete workup of similar *TowCam* data collected from Washington, Accomac, Lyndenkohl, Leonard, Wilmington, Spencer, and Cateret canyons in 2014. As a result of these data, the Mid-Atlantic Fisheries Management Council voted to approve sweeping measures to protect deep-sea corals in 15 zones containing dozens of submarine canyons from Norfolk Canyon in Virginia to Hudson Canyon in New York. This was a historic action, protecting ocean resources across a seafloor area encompassing nearly 40,000 square miles — an area about the size of Virginia — and the largest such closure ever established for the U.S. Atlantic coast.

ACCOMPLISHMENTS

To survey potential locations of coral, sponge and fish communities, we utilized high-quality multibeam data from recent ACUMEN mapping expeditions (including those conducted by NOAA Ships *Okeanos Explorer* and *Ferdinand Hassler*). Specifically, we focused on locating

high-relief bottom features that were likely to support coral habitat. We consulted mapping and slope estimate results from our recently developed habitat suitability models. This model uses various physical and biological data to predict where corals are likely to occur based on conditions found in locations where corals were previously reported. As it was towed at ~0.25 knots, *TowCam* recorded 16-megapixel images (F5.6 1/60s) every 10 seconds at an altitude between ~1 and 6 meters above the seafloor. *TowCam* was equipped with a Seabird CTD sensor (seabird SBE25; co-registered to Seabird) and altimeter to provide accurate depth and altitude for each image. We conducted 20 imaging tows using T*owCam* in areas predicted to host and be deep-sea coral "hotspots" as predicted by the existing model/maps in Chebacco, File Bottom, Heel Tapper, Dogbody, Sharpshooter, Clipper and Welker Canyons. The images were recorded internally and subsequently downloaded and stored on multiple storage hard drives, providing archived and working duplicates of the data.

Following the collection and initial enumeration of these image data (specifically, coral, fish and sponge catagories only), we were redirected in our goals by the timely management and conservation needs of the Mid-Atlantic Fisheries Management Council, who requested the complete workup of similar *TowCam* data collected from canyons in 2014. At that time, towed surveys were conducted Washington, Accomac, Lyndenkohl, Leonard, Wilmington, Spencer, and Cateret canyons, in most cases in three depth zones considered to be "shallow", "mid-depth", and "deep" (480-900 meters; 1000-1300 meters; 1500-2500 meters, respectively). Image files were visually screened to generate presence/absence data using *iView MediaPro 3.0* software. Fauna present in images were classified initially into three categories: "Coral", "Sponge", and "Fish". Images containing corals were further screened and observations placed into additional categories: hard corals, soft corals, sea pens, and *Anthomastus*. Observed organisms considered in the genus *Anthomatus*, a true soft coral, were subsequently chosen to be recorded in a separate category because previous image analysis of more northern canyons has yielded depth-specific distributional patterns (Shank unpub. data).

Each of the faunal catalogues were converted to text data files, exported and merged with ship navigation data using the time-date stamp from the image file names. This permitted the construction of excel software spreadsheets containing all coral/fish/sponge presence/absence geo-referenced location information for Washington Canyon (with this report). Quality assurance and control for each categorical database was performed through comparisons of the independent scoring of the same *TowCam* images by expertly trained research scientists experienced in identifying deepwater canyon fauna and whom had participated in the *Bigelow* expedition. Any differences in identifications were resolved among the data generators. Multiple internationally-known taxonomic experts of deep-sea corals (e.g., 3 to 5 scientists) and sponges were consulted (shown multiple representative images) to confirm identifications used in the data catalogues. We generated these database catalogues with QA/QC and entered them into a canyons geographical information system. We provided our first-order geo-referenced identification of organisms, reference and highlight images from each tow and canyon and their distribution within each canyon to the Mid-Atlantic Fisheries Management Council.

HIGHLIGHTS

- In addition to conducting 20 deep-sea towed camera surveys in 7 US east coast canyons (collecting more than 37,000 images), we enumerated more than 40,000 images from which we assembled geo-referenced databases for the presence of deep-water coral, fish, and sponges (based on distinguishable morphologies of the organisms).

- We enumerated the different types of coral communities encountered into categories of soft coral, hard coral, black coral, *Anthamastus* (an abundant type of soft coral), and sea pen, from images collected during 25 tows in Washington, Accomac, Lyndenkohl, Leonard, Wilmington, Spencer, and Cateret Canyons. Highly diverse coral fauna were discovered with clear differences in composition at different depths and across canyons. Each canyon appeared to have it's own signature coral fauna with depth.

- We mapped and assembled these locations for each canyon into GIS and provided a geo-referenced database, as well as highlight and reference images to the Mid-Atlantic Fisheries Management Council for their deliberations in which these data were utilized for making a historic recommendation for the largest Marine Protected Area (more than 40,000 square miles) in North America.

SOCIETAL BENEFITS

Data and ongoing research efforts from this project were utilized by the Mid-Atlantic Fishery Management Council (MAFMC) to approve of an amendment to protect deep sea corals from the impacts of fishing gear in the Mid-Atlantic. If approved by the Secretary of Commerce in the fall of 2016, the amendment will create "deep sea coral protection zones" in areas where corals have been observed or where they are likely to occur. In total, the areas proposed for designation encompass more than 38,000 square miles - an area nearly the size of Virginia (announcement released by many news outlets, including the New Yort Times (http://www.nytimes.com/2015/06/11/us/vote-aids-deep-sea-corals-in-much-of-mid-atlantic.html).

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

Table 1. The United States east coast canyon surveyed in 2014 and 2015, indicating their depth range and the number of seafloor images obtained on each tow.

Canyon Location	Cruise #	TowCam Dive #	GMT Date	Total No. of Images	Depth Range (m)
Washington Canyon	HB1404	01	8/6/14	2946	491-874
Washington Canyon	HB1404	02	8/7/14	x	DIVE ABORTED
Washington Canyon	HB1404	03	8/7/14	x	DIVE ABORTED
Washington Canyon	HB1404	04	8/7/14	2234	1126-1294
Washington Canyon	HB1404	05	8/8/14	1531	1515-1637
Accomac Canyon	HB1404	06	8/8/14	709	497-825
Leonard Canyon	HB1404	07	8/8/14	1262	1167-1235
Leonard Canyon	HB1404	08	8/9/14	1826	1348-1522
Wilmington Canyon	HB1404	09	8/9/14	2484	370-540
Wilmington Canyon	HB1404	10	8/10/14	2663	1130-1492
Wilmington Canyon	HB1404	11	8/10/14	1266	640-818
Wilmington Canyon	HB1404	12	8/10/14	2023	574-1031
Wilmington Canyon	HB1404	13	8/11/14	2088	1466-1610
Wilmington Canyon	HB1404	14	8/11/14	1518	661-847
Spencer Canyon	HB1404	15	8/12/14	1452	526-700
Spencer Canyon	HB1404	16	8/12/14	1585	757-1020
Spencer Canyon	HB1404	17	8/12/14	2090	1035-1313
Spencer Canyon	HB1404	18	8/13/14	x	DIVE ABORTED
Spencer Canyon	HB1404	19	8/13/14	1291	1302-1522
Spencer Canyon, very deep	HB1404	20	8/13/14	1325	2002-2121
Lindenkohl Canyon, Shallow	HB1404	21	8/14/14	1011	546-664
Lindenkohl Canyon, Mid	HB1404	22	8/14/14	1184	945-1139
Lindenkohl Canyon, Deep	HB1404	23	8/14/14	1396	1527-1607
Lindenkohl Canyon, Very deep	HB1404	24	8/14/14	1292	1762-1946
Carteret Canyon, Deep	HB1404	25	8/14/14	1003	1373-1478
Carteret Canyon, Very Deep	HB1404	26	8/15/14	863	1651-1724
Carteret Canyon, Mid	HB1404	27	8/15/14	1051	1200-1286
Carteret Canyon, Shallow	HB1404	28	8/15/14	1350	627-823
Dogbody Canyon -Shallow	HB1504	01	7/28/15	1810	558-675
Dogbody Canyon - Mid	HB1504	02	7/29/15	1627	894-1014
Dogbody Canyon - Deep	HB1504	03	7/29/15	1634	1461-1620
Chebacco Canyon - Shallow	HB1504	04	7/29/15	704	800-861
Chebacco Canyon - Shallow	HB1504	04	7/29/15	826	801-875

Chebacco Canyon - Mid/Deep	HB1504	05	7/30/15	1439	1284-1356
Chebacco Canyon - Mid/Deep	HB1504	05	7/30/15	1792	1133-1260
Chebacco Canyon - Very Deep	HB1504	06	7/30/15	2393	1909-2061
File Bottom Canyon - Shallow	HB1504	07	8/2/15	2399	664-887
File Bottom Canyon - Mid	HB1504	08	7/31/15	1094	1133-1198
File Bottom Canyon - Mid	HB1504	08	8/1/15	368	519-1029
File Bottom Canyon - Mid	HB1504	08	8/2/15	2157	1029-1077
File Bottom Canyon - Deep	HB1504	09	7/31/15	1801	1380-1640
Heel Taper Canyon - Shallow	HB1504	10	8/3/15	1392	666-772
Heel Taper Canyon - Mid	HB1504	11	8/2/15	1648	882-928
Heel Tapper - Deep	HB1504	12	8/4/15	1483	1304-1444
Welker Canyon - Shallow	HB1504	13	8/3/15	1543	559-778
Welker Canyon - Mid	HB1504	14	8/3/15	1547	851-1156
Welker - Deep	HB1504	15	8/4/15	720	1386-1386
Welker - Deep	HB1504	15	8/6/15	1844	1480-1650
Sharpshooter - Shallow	HB1504	16	8/5/15	1392	800-901
Sharpshooter - Mid	HB1504	17	8/5/15	7	NA
Sharpshooter - Mid	HB1504	17	8/6/15	1687	1144-1168
Clipper - Shallow	HB1504	19	8/5/15	1234	495-571
Clipper - Mid/Deep	HB1504	20	8/6/15	2962	1216-1455

THEME V. SUSTAINED OCEAN OBSERVATIONS AND CLIMATE

CINAR

Cooperative Institute for the North Atlantic Region

Global Ocean Observing coordination activities

NOAA Cooperative Agreement No. NA14OAR4320158
April 1, 2015-March 31, 2015

CINAR Investigator: Donald Anderson, WHOI

NOAA Sponsor: Stephen Piotrowicz, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

This project supports contributions to the World Meteorological Association's (WMO) global ocean observing coordination activities for 2012-2016 via the U.S. NOAA's Climate Program Office. These activities focus on developing international consensus on the requirements for ocean observations and technical support to ocean observing networks participating in the WMO-led Global Climate Observing System (GCOS) coordination activities which encompass, *inter alia*, the Global Ocean Observing System (GOOS). In investing in multilateral cooperation, the United States ensures that its substantial investment in global ocean observations is matched by other national investment in a system that is compatible and shares standardized data in real time.

Specifically supported is technical coordination within JCOMMOPS, the Observing Programme Support Centre of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). JCOMMOPS serves:

- the Data Buoy Cooperation Panel that maintains a network of surface drifting floats measuring temperature, pressure, and surface current,
- the Ship Observations Team that maintains volunteer commercial ship observations of meteorological parameters, as well as underway measurements of surface and subsurface ocean variables, and
- the Argo Information Center, a technical support and coordination activity for the global network of more than 3000 Argo profiling floats.

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

ACCOMPLISHMENTS

Data Buoy Cooperation Panel

Each month and ongoing, the Data Buoy Cooperation Panel **(**DBCP) technical coordinator (TC) provides the status of the drifting and moored buoys (and select rigs and platforms) to the Member States in the form of maps and graphs. These are available on the DBCP Website: http://dbcp.jcommops.org/network/status.html. The DBCP TC also maintains a website for the Panel at http://dbcp.jcommops.org, which has information on project overview, platforms, status and maps, data and metadata, community contacts, upcoming meetings, news items, etc. The website is constantly updated to reflect current information and recent status of the network. Latest maps of operational platforms were made available in May 2016, together with the required documentation for the DBCP yearly meeting by the former TC.

In addition to the website, the DBCP TC and JCOMMOPS maintain numerous mailing lists (email) to inform the community of changes. The DBCP sends out at least 1 message per month on the status of the array as well as any other pertinent information to the community.

Technical reports and other information are published at DBCP Annual Meetings and are available on the WMO Website http://www.wmo.int/pages/prog/amp/mmop/dbcp_reports.html.

OceanSITES

Support is given to the OceanSITES science team, who is working to develop requirements for each of the several networks embedded with the OceanSITES programme (www.oceansites.org). The overall JCOMMOPS infrastructure is providing integrated monitoring tools, including for OceanSITES. The TC has been establishing links with the community, and checking the quality of the OceanSITES metadata and requirements to include these in new information systems.

Argo

Support to the Argo programme is provided via a dedicated TC and Argo Information Centre (AIC) activities and website. Mathieu Belbeoch has been providing such support to Argo since Feb. 2001. Status maps and charts are regularly provided to the Argo Steering and Data teams (e.g., see http://www.jcommops.org/maps.html). New analysis tools are regularly designed and added. EEZ notification and warning system is gradually improved and maintained operational, to facilitate program managers tasks. Guidance is regularly provided to the community on the international regulations and best practices.

The AIC maintains appropriate tools to facilitate the implementation planning and optimize the network distribution. A scoring system of deployment plans has been designed. In depth analysis and reports on delays have permitted to dramatically improved them, and uncovered weaknesses in the data flow for some national centers. The AIC is also fostering the review of the Argo design to define design requirements (number of floats required per year, distribution, etc.). A new design is proposed each year to the AST meeting in March as discussion base. A set of performance indicators are then built on these targets.

Proper density maps are designed to track the spatial distribution of the network and guide implementation. Instruments performance is extensively tracked through various reliability

charts and statistics. The TC works closely with the Argo Teams to harmonize the vocabulary across JCOMMOPS matadata, Argo netCDF format and WIGOS/GTS code tables.
See: https://docs.google.com/spreadsheets/d/1Aw8B7FFUjG4e9MveD5qqvI7ZbB-z_x32IQnpHZbXVZA/edit#gid=1

Argo metadata are already available in the new Information System and the two systems are run in parallel to check potential problems. Following an internal review (with representatives of AST/ADMT) the new JCOMMOPS Argo website was publicly released over the past year: http://www.jcommops.org/board?t=Argo.

Ships

For the Ship Observations Team (SOT), the production of maps was maintained and various new maps developed, which include statistics on participating countries, data quality, automatization and timeliness or masking schemes (See http://www.jcommops.org/sot/)

For SOOP, the collection of metadata was resumed. Contrary to VOS, the collection of these data remains to be difficult. Only very few operators provide data as planned and requested, which made the production of SOOP statistics based on other sources than the GTS not possible, but good progress was made in this matter at the end of the period.

VOS metadata, gathered in WMO publication No. 47, are continuously monitored and incoherencies reported to the responsible national focal points, with the request to review and update their data. A large number of wrongly registered platforms was successfully identified, reported and modified.

For GO-SHIP, information on planned or recently accomplished cruises were gathered and compiled in a global cruise plan. Where no national focal points existed, appropriate scientists were identified and recruited for almost all active countries by the TC.

Across the programs coordinated by JCOMMOPS, the development of a cruise information center was initiated. It will centralize international level information on cruises from particularly research, commercial and sailing ships, with the aim to identify synergies, in particular deployment opportunities. Contacts with key sources such as UNOLS and POGO for research vessels have been established, agreements achieved and technical synchronization issues discussed.

Reports were provided to panels and steering teams on deployment opportunities and partnerships developed and finalized, or initiated with many new actors (industry, NGOs, sailing community, maritime operator, etc.).

JCOMMOPS

JCOMMOPS as a whole is also a growing structure which requires efforts with regards to its development, budget management, infrastructure, IT developments, staff issues, relationship with host, performance monitoring, etc. This is covered by the senior TC of the centre (Argo). A work plan was set up to clarify each staff priorities, duties, and deliverables. Such tool will allow

the networks and panels to change TC priorities according to their requirements. Furthermore, regular teleconferences are held with the governance (JCOMM Observations Coordination Group) to track the progress of the Centre and gather direct guidance from the panels.

An important work on designing integrated key performance indicators common to all programmes was initiated in April 2014, and the new generation of the JCOMMOPS Information System, websites and web services was released to the community.

It has to be noted that the Argo Technical Coordinator and de facto office manager for the office has succeeded after many years in:

- completing the physical transition of the office from a satellite based company (CLS) to an ocean pole (Brest/Ifremer) in excellent conditions
- creating, (identifying funding, documenting the requirements, and recruiting) two full time positions at the service of the JCOMM/GOOS networks
- identifying some new funding sources and support with local authorities which will allow the recruitment of a fifth permanent staff (assistant management/communication)
- Shaping the architecture of a new information system and webservices that will be used by the community in the next decade, and drive the ambitious developments using internal and external resources to boost productivity.

See: http://www.unesco.org/new/en/media-services/single-view/news/inauguration_of_the_operational_centre_for_ocean_observation_in_brest/

The TC was commended for those efforts and tenacity at the inauguration of the new office in 2015. Many challenges are still on JCOMMOPS plate, in a rather complex governance model, and very diverse community. A decade of integrated services is in sight, including a new set of website and web based services, a new integrated ship time service, via a strengthened team. JCOMMOPS has finally the means to achieve its full potential.

OOPC

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. 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.

In the past, OOPC has mainly focused on physical ocean variables in the open ocean. For the climate-relevant biogeochemical and biological ocean variables, OOPC has been in close collaboration with the International Ocean Carbon Coordination Programme (IOCCP). Due to the restructuring within GOOS following the development of the Framework for Ocean Observing (FOO), and the new GOOS expert panels for biology and ecosystem variables, OOPC's role has now evolved to oversee the ocean component of GCOS and the physical variables for GOOS, while defining sustained ocean observing requirements for WCRP, especially in regard to the WCRP Climate Variability and Predictability Project (CLIVAR).

Chaired by co-chairs Dr. Mark Bourassa (University of Florida, United States) and Dr. Bernadette Sloyan (CSIRO, Tasmania, Australi), OOPC met for its Nineteenth Session from 6-8 April 2016 in Espories, Spain, and was hosted by the Mediterranean Institute for Advanced Studies (IMEDEA) and the Balearic Islands Coastal Observing and Forecasting System (SOCIB). The 7th Session of the JCOMM Observations Coordination Group was held overlapping with the 19th Session of the Ocean Observations Panel for Climate.

EDUCATION AND OUTREACH

Outreach and education is an issue in the long run for all JCOMMOPS programs, in the context of sustained networks. This is a growing activity given the demand and potential. A number of technical developments have been made to democratize this access to information (e.g., Google Earth layers) and JCOMMOPS is participating in a number of training workshops, or specific actions (e.g. school visits, collaboration with aquariums, teacher, etc.). Some others tools based on social Medias are gradually being set up, including picasa albums, and a twitter feed: https://twitter.com/jcommops.

Webinar: The GOOS Webinar Series is a monthly opportunity to hear about activities and topics of interest to the GOOS community and to interact with the speaker. The Webinars are presented using a visual conferencing tool ,which allows viewers to interact with the speaker through a chat window: www.ioc-**goos**.org/**webinar**. Webinar archives are also accessible via this website.

Website: The OOPC website (http://ioc-goos-oopc.org) is also a valuable resource where all OOPC-related meeting documents are freely available. Furthermore, the website explains the wider concept of ocean observing, including which technical applications are currently being used, and how specific ocean indices (e.g., sea ice, ocean acidification) can be measured.

PUBLICATIONS AND REPORTS

Beyond daily support and monthly status reports, JCOMMOPS TCs provide technical reports to the panels and steering team, and to JCOMM OPA, on a yearly basis. It is an important and routine task. Most of them are available from the jcomm.info website.

JCOMMOPS delivers yearly reporting to its communities to cover different aspects of the programs:

- Implementation (e.g. national contributions, planning, network density, network design, requirements dimensioning, network growth).
- Instrumentation (e.g. instrument reliability, market evaluation).
- Data flow (quantitative, qualitative, delays, analyses, etc.)
- Operations (deployment opportunities)

JCOMMOPS monitoring products such as maps and charts are often used in scientific publications, and national reports or proposals.

An Eye in the Ocean: Exploration of High-Resolution Vertical Distributions of Plankton and Particles and Coincident Hydrography in the Western Chukchi Sea Data Synthesis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Carin Ashjian, WHOI

NOAA Sponsor: Kathleen Crane / Jeremy Mathis, OAR

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The overall goal of the proposed work was to describe the high-resolution vertical distributions of zooplankton and particles over a range of spatial and temporal scales. Video Plankton Recorder Surveys were conducted in 2009 and 2012 as part of the Russian-American Long-Term Census of the Arctic (RUSALCA) interdisciplinary cruises. Both a broad-scale survey of the different water masses and regions of the Chukchi Sea and a high-resolution survey of Herald Valley were conducted to obtain the high-resolution distribution of plankton/particles and coincident hydrography, and to describe physical-biological interactions in Herald Valley. The VPR data from the three RUSALCA interdisciplinary cruises (2004, 2009, 2012) will be compared to determine interannual variability and to understand if climate change is modifying the ecosystem.

ACCOMPLISHMENTS

All data were archived at the RUSALCA data archive. A paper that included VPR data was included in the special issue of Oceanography highlighting the RUSALCA program.

HIGHLIGHTS

- The vertical distributions of copepods and diatoms and marine snow particles were closely associated with the vertical structure of the water column and with different water mass types (Figure 1).
- Herald Canyon was very dynamic, with multiple water masses and complex velocity patterns. Plankton and particles were spatially heterogeneous. Along- or cross-canyon flux of plankton and particles in this region revealed that most types were primarily advected to the north while on the western side of the canyon substantial flux of algal mats was observed (Figures 2 & 3).
- The VPR was an effective means of obtain high-resolution vertical distributions of

plankton and particles that can be coupled to hydrography and to velocity in achieving a better

understanding of the complex interaction between biology and physics that structures this ecosystem.

SOCIETAL BENEFITS

Predicting the impact of climate on ecosystems requires an understanding of the important components and interactions in the ecosystem, both to identify change and to develop a predictive modeling capability for the ecosystem. Such information can ultimately be used to help us better conserve Arctic ecosystems, and in the future, potentially manage Arctic fisheries. Information on the high-resolution distributions of plankton in association with hydrography and currents can enhance our understanding of the ecosystem and contribute ultimately to better modeling of the system.

PUBLICATIONS

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

Bowhead Whale Feeding in the Western Beaufort Sea Oceanographic Conditions Whale Prey Distributions and Whale Feeding and Foraging Behavior

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Carin Ashjian, WHOI

NOAA Sponsor: Kim Sheldon, NMFS/AKFSC/NMML

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The Beaufort Sea Shelf to the north and east of Barrow, Alaska is a critical feeding area for bowhead whales, particularly during the fall migration from their summer grounds in the Canadian Arctic to their over-wintering grounds in the northern Bering Sea (e.g., Lowry et al., 2004). The project is a component of the larger "*Bowhead Whale Feeding in the Western Beaufort Sea"* project coordinated by the National Marine Mammal Laboratory (2007-2012). The project is complemented by an ongoing NSF funded Arctic Observing Network project that describes interannual variability in biological and physical ocean conditions in the Chukchi and Beaufort Seas near Barrow, AK. The work addresses relationships between the formation and distribution of bowhead whale prey (zooplankton) aggregations, oceanographic conditions, and bowhead whale distributions in the Western Beaufort Sea by conducting oceanographic sampling from a 43' boat, including sampling of whale prey, on both coarse and fine scales. The specific objectives for the past year included completion of data analysis, preparation of data for archiving, assistance in preparation of a report to be submitted by the NMML to BOEM, and participating in project meetings with collaborators to identify syntheses.

ACCOMPLISHMENTS

Progress continues on a synthesis paper describing results across the entire project. The animated film "*A Year in the Life of the Bowhead Whale*" to which the PI contributed was completed and released in January 2015. The PI also collaborated on a paper describing the core areas of use by bowhead whales (Citta et al., 2014).

HIGHLIGHTS

- Considerable interannual variability in physical and biological oceanography has been observed among the six years of our observations. To date, 2005, 2007, 2010, and 2011 were years with warm ocean water temperatures and little sea ice while 2006 and 2008 were years with much colder ocean water and considerable sea ice, and 2009 was intermediate in temperature between the two extremes.

- The oceanography and whale prey distribution on the shelf near Barrow are intimately tied to wind forcing.
- A favorable feeding environment for bowhead whales near Barrow is created when krill are upwelled onto the shelf from along the Beaufort Shelf break and subsequently trapped and aggregated there by ocean currents.
- This favorable feeding environment is created predictably each year, despite the considerable interannual variability in ocean conditions.
- Much lower abundances of adult and juvenile krill, key prey for the bowhead whale, were observed on the shelf in 2011 relative to previous years. Krill were predominantly of the furcilia life stage (small).

SOCIETAL BENEFITS

Defining and understanding the interannual variability in ocean conditions and whale prey and how it is associated with larger scale atmospheric and oceanographic conditions is critical to achieving a better understanding of the importance and persistence of the western Beaufort Shelf as a feeding environment for the bowhead whales during their fall migration. This in turn has implications to the success and resilience of Iñupiat subsistence whaling, and contributes to a better understanding of how to protect and manage the Western Arctic bowhead whale population.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

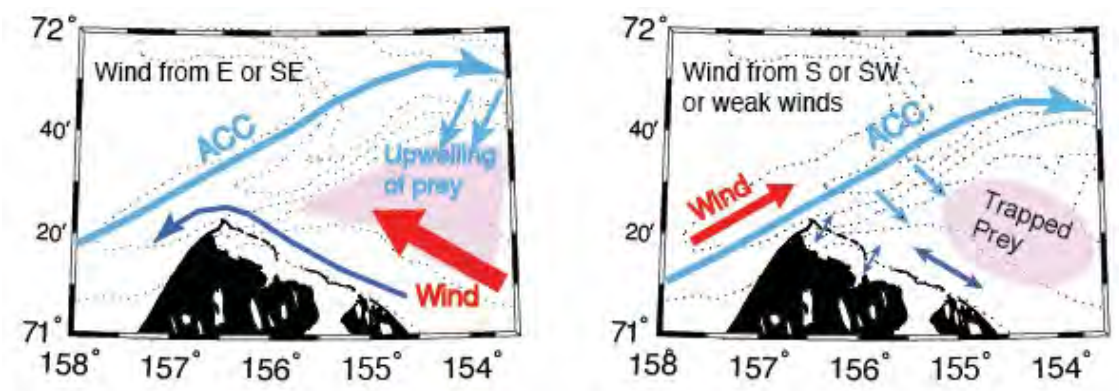

Figure 1. Schematic demonstrating mechanisms aggregating krill on the shelf near Barrow, AK. Left: Winds from the east upwell krill onto the shelf and move the strong Alaska Coastal Current (ACC) offshore, permitting water to exit the shelf to the west around Point Barrow. Right: If easterly, upwelling winds are followed by weak winds or winds from the S-SW, then the ACC moves inshore against the eastern wall of Barrow Canyon, trapping water and krill on the shelf and aggregating the krill in the convergence between shelf circulation and the ACC. Redrawn from Ashjian et al., 2010.

Pacific Group (PAG) Secretariat Office III, 2015-2016

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Jacqueline Grebmeier, UMCES

NOAA Sponsor: Dr. Jeremy Mathis, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The Pacific Arctic Group (PAG) is a networked group of international institutes and individuals that has as its mission to serve as a Pacific Arctic regional partnership to plan, coordinate, and collaborate on science activities of mutual interest. The current PAG science themes are focused on the structure and function of Arctic ecosystems, including atmosphere, sea ice, oceanography, and modeling. NOAA is continuing its efforts to maintain the US PAG Secretariat Office at the Chesapeake Biological Laboratory/UMCES, and PI Grebmeier is a member of the PAG Executive Committee. The US PAG Secretariat facilitates the PAG effort by assisting the international PAG Secretariat office in South Korea with science planning, maintaining the PAG listserver of participants, assists with updates of the international PAG website (http://pag.arcticportal.org), and supports PI Grebmeier to plan and prepare updates on ongoing activities pertinent to U.S. science efforts in the Pacific Arctic. The PAG activities are centered around networking oceanographic field activities in the Pacific Arctic region, with the U.S. PAG Secretariat helping with the development of the new Pacific Arctic Climate Ecosystem Observatory (PACEO), ongoing activities of the Distributed Biological Observatory (DBO), and the RUSALCA (Russian-American Long-Term Census of the Arctic) projects, and supports various synthesis activities by co-editing special projects in order to better understand and track ecosystem status and trends in the Pacific Arctic marine region.

ACCOMPLISHMENTS

The 2015-2016 support for the U.S. PAG Secretariat covered PI Grebmeier's effort to report on U.S. field activities in the Pacific Arctic during the October 2015 PAG meeting in Incheon, South Korea and the 2016 PAG spring meeting held during the 2016 Arctic Science Summit Week in Fairbanks, Alaska. She also edited the 2015 fall and 2016 spring PAG meeting reports as requested by the PAG Chair, who is located in South Korea. The GIS specialist in the PAG Secretariat office prepared data graphics for both meetings where Grebmeier gave five presentations, including: 1) U.S. country report, 2) a Distributed Biological Observatory (DBO) update report, 3) a DBO data report, 4) update on U.S. PACEO (Pacific Arctic Climate Ecosystem Observatory) activities, and 5) an update on PAG synthesis activities.

HIGHLIGHTS

- PI Grebmeier presented updates on U.S. field activities in the Pacific Arctic at PAG meetings in fall 2015 and spring 2016, including the DBO and PACEO.
- The PAG project office facilitated the third DBO data meeting held March 9-10, 2016, at NOAA/PMEL in Seattle, Washington in coordination with Dr. Sue Moore of NOAA, with over 50 national and international participants. The final report and presentations will be posted on the PAG and NOAA DBO websites.
- Preparation of annual PAG/DBO cruise table that is used by U.S. agencies and coastal Alaskan communities to know when and where ships are studying the Pacific Arctic region. This table is posted on the NOAA DBO website.
- PI Grebmeier is a co-editor for the Japanese Arctic research special issue in *Biogeosciences* on Japanese Arctic research results.

SOCIETAL BENEFITS

The PAG activities highlight ongoing field and science activities in the Pacific Arctic relevant to national and international collaborations. The development by PI Grebmeier of the PAG/DBO cruise table is used by U.S. agencies and coastal Alaskan communities to know when and where ships are undertaking research cruises in the Pacific Arctic region. PI Grebmeier is co-chair of the U.S. IARPC (Interagency Arctic Research Policy Committee) DBO CT (Collaborative Team) with Dr. Sue Moore (NOAA) for connecting interagency science activities associated with the DBO, and to develop a 10-yr DBO Implementation Plan.

EDUCATION AND OUTREACH ACTIVITIES

PI Grebmeier led a DBO Town Hall, with multiple science presentations related to the DBO field findings, at the ASLO meeting in New Orleans, Louisiana in February 2016. She presented DBO and PAG science results at the Town Hall as well as an Arctic-subarctic session during the conference. She also presented PAG activities to the Forum of Arctic Research Operators (FARO) international group during the Arctic Science Summit Week in Fairbanks, Alaska in March 2016.

PUBLICATIONS

The fall 2015 and spring 2015 PAG meeting reports are posted on the PAG website (http://pag.arcticportal.org). The 3rd DBO data workshop report will be posted on the NOAA DBO website (http://www.arctic.noaa.gov/dbo/) by the end of June 2016.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

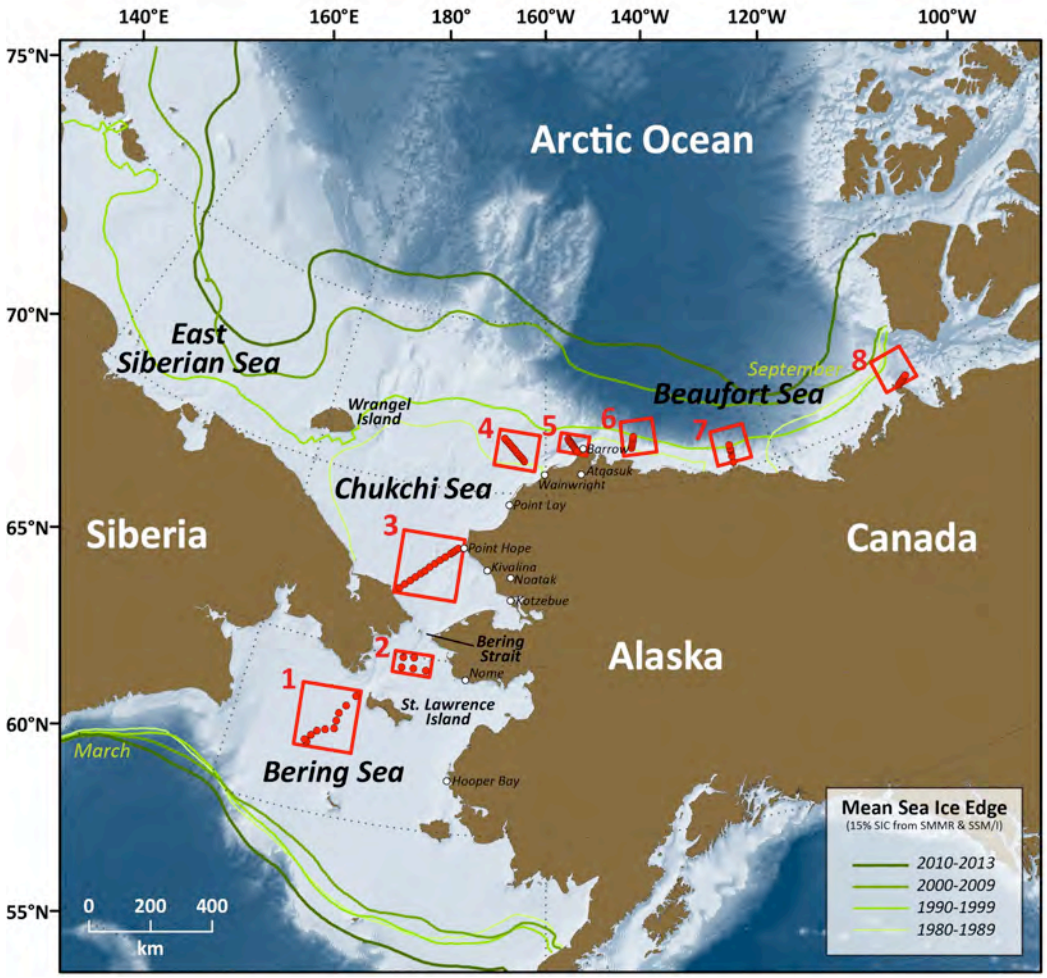

Figure 1. The Distributed Biological Observatory (DBO; http://www.arctic.noaa.gov/dbo/) is a time series, biologically focused observatory in the Pacific Arctic region where international ships agree to sample standard measurements seasonally. The DBO is coordinated through the Pacific Arctic Group (PAG; http://pag.arcticportal.org). Figure courtesy of Karen Frey, Clark University.

Synthesis Activities within the RUSALCA Program, 2015-2016

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Jacqueline Grebmeier, UMCES

NOAA Sponsor: Kathy Crane, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The Russian-American Long-term Census of the Arctic (RUSALCA) is a NOAA-sponsored program to document the long-term ecosystem health of the Pacific Arctic ecosystem, particularly as changes in various components are observed associated with climate forcing. Three full-scale ecosystem cruises were undertaken in August 2004**,** and August-September 2009 and 2012 in the Chukchi Sea (plus East Siberian Sea in 2009 only). Within the RUSALCA program, our project objectives were to evaluate the benthic community structure and carbon cycling in the Pacific-influenced waters in the Amerasian Arctic. Our work was focused on benthic biological communities and associated sediment chemistry. Our findings indicate higher export of carbon in the SE Chukchi Sea in areas of high primary production, and in areas around Wrangell Island and on the western side of Herald Canyon. We have also observed decadal changes in organic carbon processing and regional decline in benthic biomass at some time series sites in the SE Chukchi Sea. As part of the RUSALCA effort, we co-authored five publications in the September 2015 special issue of Oceanography with Russian colleagues, with our two lead PI authored articles developed during our trip to Moscow and St. Petersburg, Russia in February 2015.

ACCOMPLISHMENTS

We completed the processing and computer analyses of all RUSALCA 2012 cruise samples, including macrobenthic infaunal identification, abundance and biomass determinations, sediment parameters and oxygen uptake rate calculations, and sediment isotope work. We undertook statistical comparisons with prior RUSALCA cruises as well as other data sets from the Chukchi Sea, specifically population community analyses of benthic macroinfaunal organisms focused on time-series collections in the southern and western Chukchi Sea to develop a publication for the RUSALCA Oceanography special issue (Grebmeier et al. 2015).

We also analyzed the community oxygen consumption rates as an indicator of carbon export to the benthos in the context of the other oceanographic data (Cooper et al. 2015). These RUSALCA data included a subset of samples as a contribution to the Distributed Biological Observatory (DBO) effort that continues a 30-year time series in the southern Chukchi Sea, as

well as at other RUSALCA time series locations started in 2004. We have completed radioisotopic (Cs-137 and Pb-210) analyses for downcore determination of sedimentation rates for cores collected in 2009 and 2012. We completed production of GIS kriging of the data sets for comparison, statistical analyses using PRIMER software, as well as submission for the RUSALCA data archive, with appropriate metadata. Publications as part of this project included submission to the RUSALCA Oceanography (see publication list), the Synthesis of Arctic Research (SOAR), and Deep-Sea Research II.

The following is a brief summary of select findings from field and synthesis activities that were included in our multiple publications listed above. First, the highest carbon export to benthos is coincident with highest areas of infaunal biomass (gC m^{-2}), indicating strong pelagic-benthic coupling. The dominant macrofauna are bivalves and polychaetes that are important prey to walrus gray whales, and bearded seals. Highest macroinfaunal benthic abundance and biomass for all cruises was observed at the head of Herald Valley in the southeast Chukchi Sea in the known DBO3 "hotspot" of *Macoma* bivalves that extends across the US-Russian boundary, with biomasses ranging from 30 to ~100 gC m^{-2} (Fig. 1, left and right panel; see Grebmeier et al. 2015, RUSALCA Oceanography 28(3):116–133).

Sediment metabolism studies that measured sediment community oxygen respiration indicate that the highest rates of oxygen utilization (and related organic carbon export to the benthos) consistently occurred in the southeast Chukchi Sea "hotspot" site where we also have observed high biomasses of bivalves and polychaetes, as discussed above (Fig. 2**;** see Cooper et al. 2015, RUSALCA Oceanography 28(3):84–99). Seawater O-18 measurements indicate an increased level of sea ice melt in surface waters in 2012 with the coincident observed major sea ice retreat compared to more riverine influenced surface waters in 2004 (Fig. 3; see Cooper et al. 2015, RUSALCA Oceanography 28(3):84–99). Sediment stable carbon isotopes indicate marine (offsore) vs. terrestrial (inshore) influenced carbon content (see Cooper et al. 2015, RUSALCA Oceanography 28(3):84–99). In addition, sedimentation rates vary from low values in high current regimes (Herald Canyon) to moderate deposition rate in Long Strait; bioturbation has impact on profiles (Fig. 4).

The SE Chukchi Sea hotspot is an important foraging area for both walrus and gray whales that are known to forage in this hotspot seasonally due to high biomass levels of benthic prey (Grebmeier et al. 2015, Prog. Oceangr. 136:92-114). This hotspot is maintained by export of high chlorophyll a that is produced locally as well as advected by Pacific water masses transiting northward through the system. Notably the center of the highest benthic biomass regions has shifted northward in the DBO3) line occupied during the RUSALCA program (Grebmeier, pers. obs.). This northward shift has coincided with changing sediment grain size, an indicator of current speed, and is also likely a response to changes in primary production in the region.

HIGHLIGHTS

- Highest observed infaunal benthic biomass was observed at the head of Herald Valley in the southeast Chukchi Sea in the known "hotspot" of *Macoma* bivalves that extends from across

the U.S.-Russian boundary, with values ranging from 30 to ~100 gC m^{-2}.

- Lowest observed macroinfaunal biomass (0-10 gC m^{-2}) occurred towards the NW and offshore to the northern most stations, with the lowest biomass in coastal areas.
- Dominant infauna: bivalves and polychaetes are important prey to walruses, gray whales, and bearded seals.
- Persistent productivity of the Anadyr Water both north of Bering Strait are tied to tight pelagic-benthic coupling between the upper water column production zone and underlying benthos during annual primary production and deposition events.
- Sediment stable carbon isotopes indicate marine vs. terrestrial influenced carbon on the Chukchi continental shelves.
- Sedimentation rates vary from low values in high current regimes (Herald Canyon) to moderate deposition rate in Long Strait; bioturbation has an impact on profile shape.
- Sediment grain size data can act as an indicator of current speed. Results from the three RUSALCA cruises indicate a reduction of current speed and coincident deposition of fine silt and clay sediment (high %≥5 phi) in a northwest direction from Bering Strait down Herald Valley and Herald Canyon northward to the slope in all cruises.
- Higher silt and clay (%) in upper/central Herald Valley and western side of Herald Canyon; also around Wrangell Island.
- Sandy sediments (low % silt/clay) are found along the Alaskan and Chukotka coastline.
- Sedimentation rates for the RUSALCA study region were measured using Cs-137 where the maximum value at depth corresponds to the maximum 1963 bomb fallout. The lowest sedimentation rates were in the East Siberian Sea (apparent bomb fallout peak at 3 cm) that indicates low bioturbation and well-preserved profile suggesting lower current flow in the overlying waters. By comparison, the slower current region in the center of Long Strait allowed for moderately high sedimentation rates.
- Shift is O-18 values in seawater from 2004 to 2012 related to increasing sea ice melt in the surface waters.

SOCIETAL BENEFITS

The RUSALCA (Russian American Long-term Census of the Arctic) NOAA-led international project is aligned with the CINAR mission to "is to conduct and coordinate cutting-edge research engaging both NOAA and academic scientists to enable informed decisions by NOAA for sustainable and beneficial management [including the Arctic]", particularly through its foci to *"understand climate variability and change to enhance society's ability to plan and respond."*

EDUCATION AND OUTREACH ACTIVITIES

Reports from the cruises of research activities and photos are available for both the 2009 and 2012 cruises through NOAA's Ocean Exploration program:
http://oceanexplorer.noaa.gov/explorations/12arctic/logs/sept13/sept13.html
Results of all aspects of the RUSALCA program were presented at the 2014 RUSALCA PI meeting in Honolulu, Hawaii, USA and new summaries of activities and findings across all RUSALCA cruises are available on the NOAA RUSALCA website

http://www.arctic.noaa.gov/aro/russian-american/. We are also cross-linking RUSALCA data at the SE Chukchi Sea DBO3 line for the DBO observing project http://www.arctic.noaa.gov/dbo/. We made presentations at the 2016 ASLO Ocean Sciences meeting in New Orleans, LA, that included RUSALCA data.

PUBLICATIONS

Grebmeier, J.M., B.A. Bluhm, L.W. Cooper, S. Danielson, K.R. Arrigo, A.L. Blanchard, J.T. Clark, R.H. Day, K.E. Frey, R.R. Gradinger, M. Kedra, B. Konar, K.J. Kuletz, S.H. Lee, J.R. Lovvorn, B.L. Norcross, and S.R. Okkonen (2015) Ecosystem characteristics and processes facilitating persistent macrobenthic hotspots and associated benthivory in the Pacific Arctic. Progress in Oceanography 136:92-114

Cooper, L.W., A. Savvichev, and J.M. Grebmeier (2015) Abundance and production rates of heterotrophic bacterioplankton in the context of sediment and water column processes in the Chukchi Sea. Oceanography 28(3):84–99

Denisenko, N.V., J.M. Grebmeier (2015) Spatial patterns of bryozoan fauna biodiversity and issues of biogeographic regionalization of the Chukchi Sea. Oceanography 28(3):134–145

Denisenko, S.G., J.M. Grebmeier, and L.W. Cooper (2015) Assessing bioresources and standing stock of zoobenthos (key species, high taxa, trophic groups) in the Chukchi Sea. Oceanography 28(3):146–157

Grebmeier, J.M., B.A. Bluhm, L.W. Cooper, S.G. Denisenko, K. Iken, M. Kedra, and C. Serratos (2015) Time-series benthic community composition and biomass and associated environmental characteristics in the Chukchi Sea during the RUSALCA 2004–2012 program. Oceanography 28(3):116–133

Pisareva, M.N.R.S. Pickart, K. Iken, E.A.Ershova, J.M. Grebmeier, L.W. Cooper, B.A. Bluhm, C. Nobre, R.R. Hopcroft, H. Hu, J. Wang, C.J. Ashjian, K.N. Kosobokova, and T.E. Whitledge. (2015) The Relationship Between Patterns of Benthic Fauna and Zooplankton in the Chukchi Sea and Physical Forcing. Oceanography 28(3):68–83

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

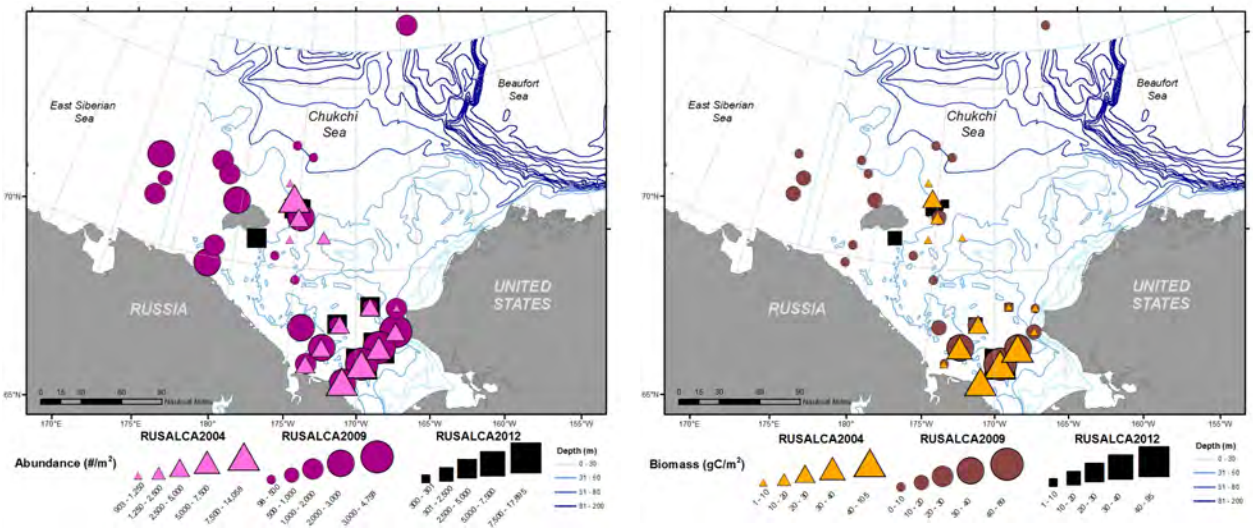

Figure 1. Distribution of benthic macroinfaunal abundance (left panel) and biomass (right panel) during the RUSALCA 2004, 2009, and 2012 cruises.

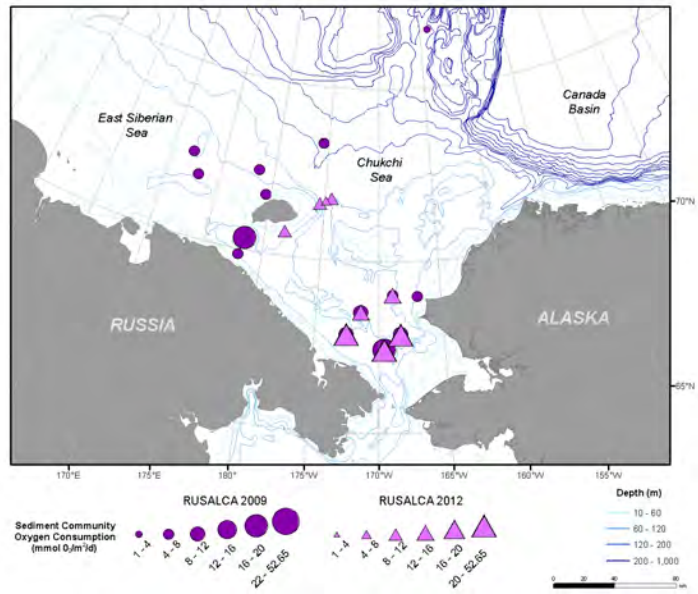

Figure 2. Sediment community oxygen consumption (mmol O_2 m^{-2} d^{-1}) from RUSALCA09 and 12.

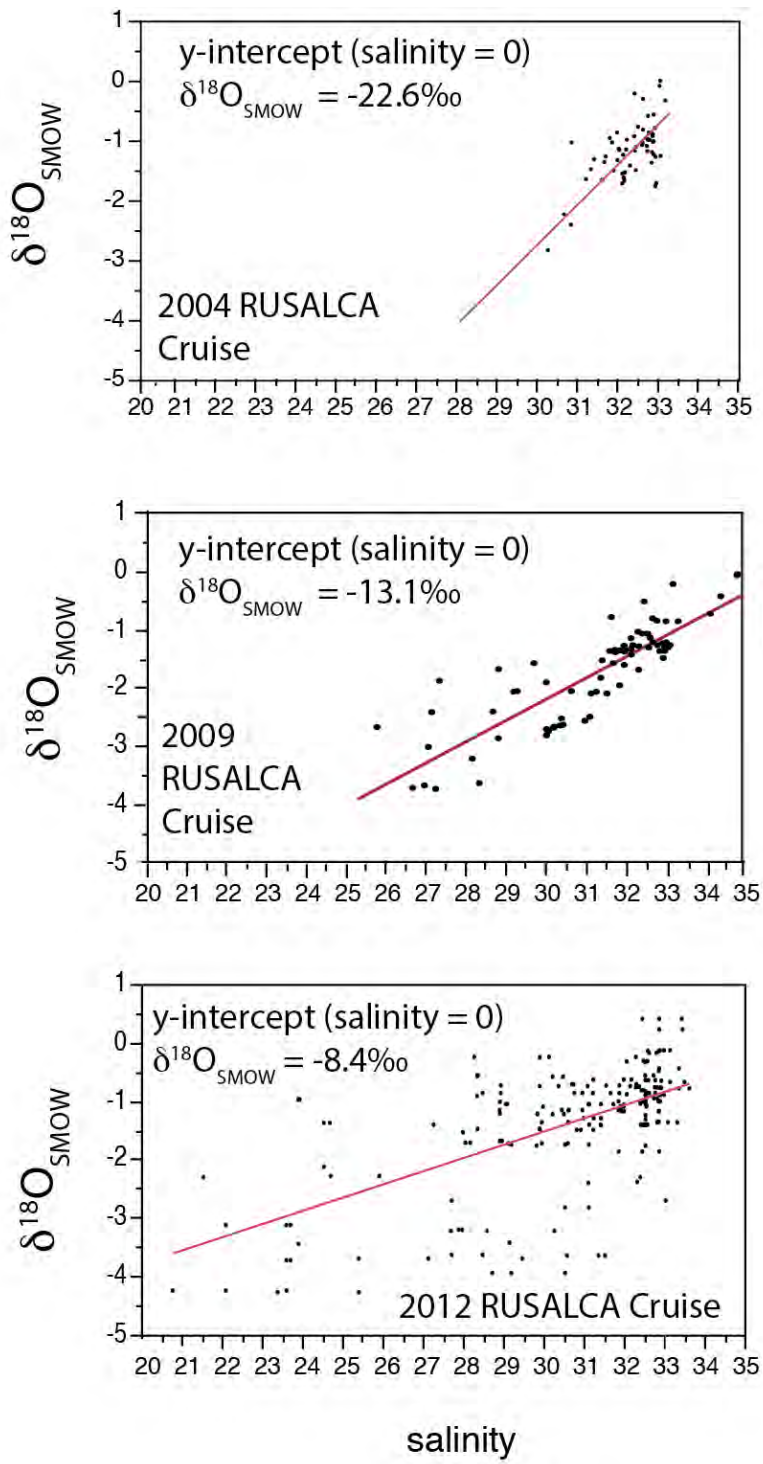

Figure 3. Oxygen-18 versus salinity relationships for the 2004, 2009, and 2012 RUSALCA cruises showing a shift in the freshwater end-member from a runoff-dominated system in 2004 (freshwater $\delta^{18}O$ = ~-22.6‰) to one dominated by melted sea ice in 2012 (freshwater $\delta^{18}O$ = ~ -8.4‰).

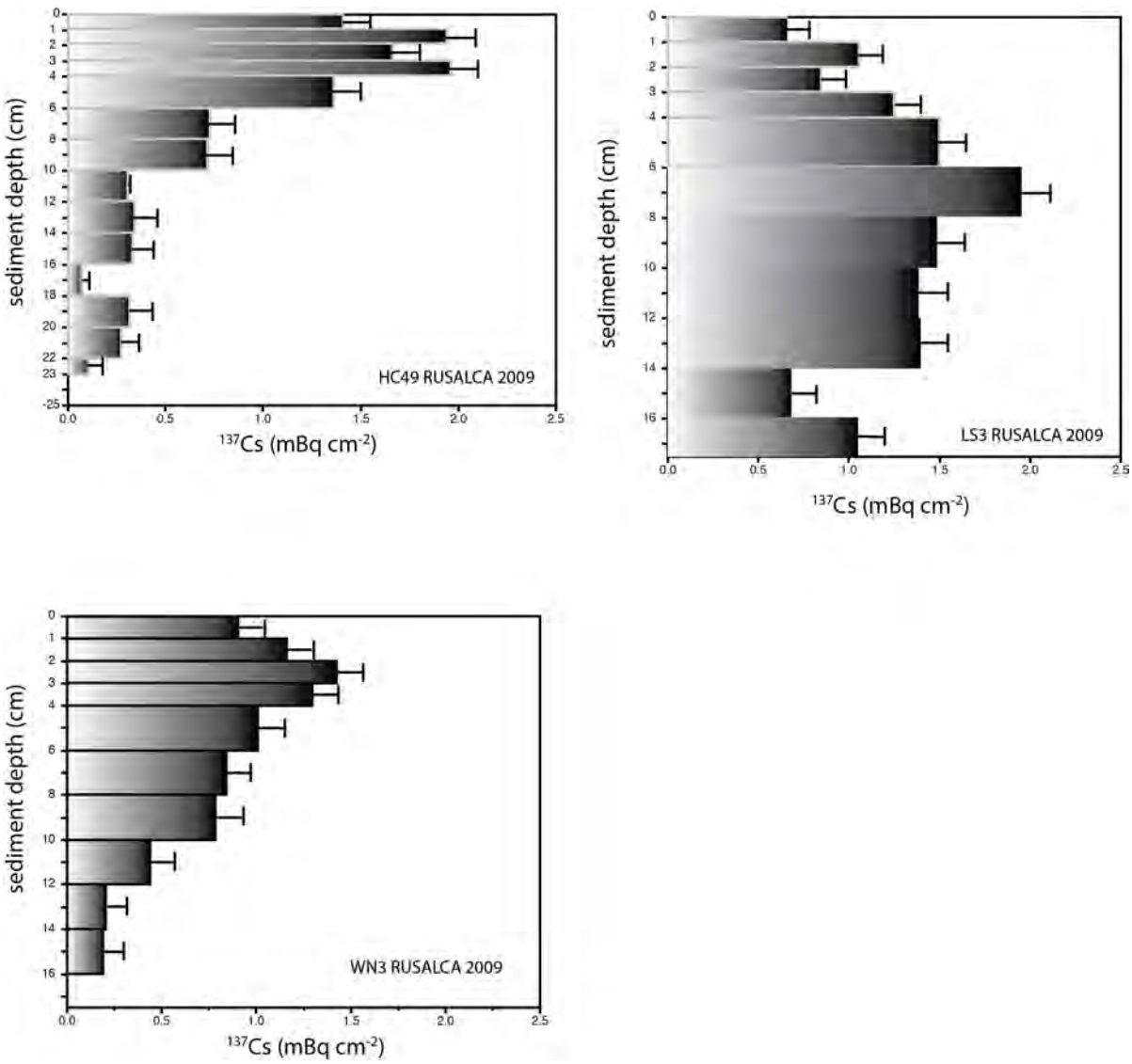

Figure 4. Sedimentation rates during the RUSALCA program varied from low values in high current regimes in Herald Canyon (HC-top left panel) to moderate deposition rate in Long Strait (LS; top right panel). The lower left panel shows a moderate sediment rate profile from station WN3 that is influenced by high bioturbation.

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

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31, 2016

CINAR Investigator: Steven Jayne, WHOI

NOAA Sponsor: Stephen Piotrowicz, OAR

Related Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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. Over 3500 Argo floats presently provide over 120,000 ocean profiles each year.

ACCOMPLISHMENTS

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

HIGHLIGHTS

WHOI deployed 71 Argo floats between April 1, 2015 and March 30, 2016. See attached figure.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

WHOI hosted a guest student, Emily Cody, from University of Vermont who is pursuing her Ph.D. in Applied Math

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

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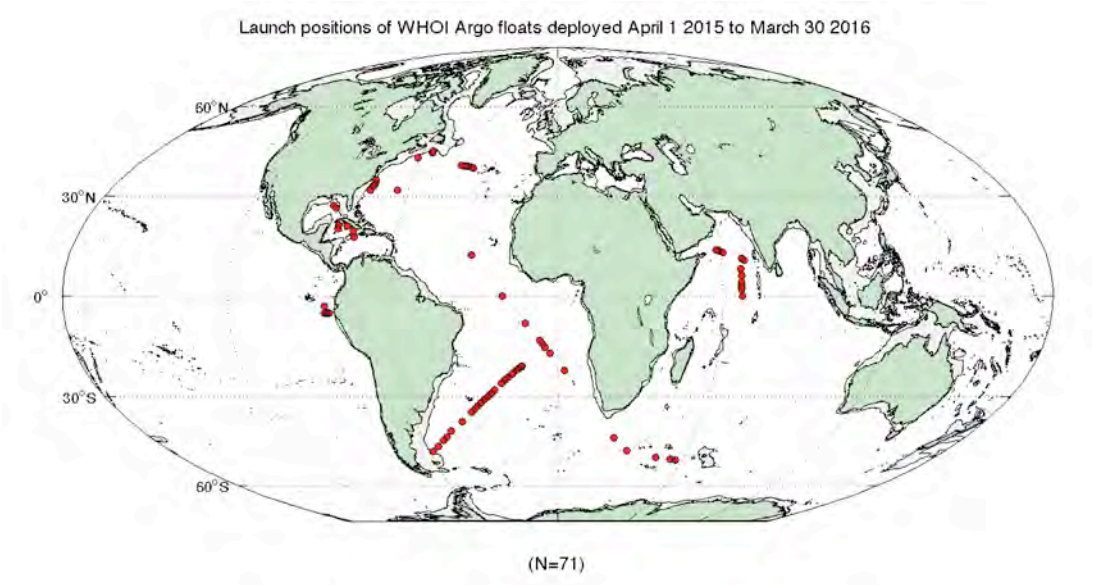

Figure 1. Deployment locations for WHOI Argo floats deployed between April 1, 2015 and March 30, 2016.

An Experimental Study of the Impact of Ocean Acidification on the Early Life Stages of Sea Scallops, including the Interactive Effects of Feeding

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Daniel McCorkle, WHOI

NOAA Sponsor: Libby Jewett, OAR

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Sustained Ocean Observations

PROJECT OVERVIEW

This study is evaluating the hypothesis that Atlantic salmon marine growth provides a mechanism that links changing ecosystem conditions to Atlantic salmon survival and productivity. Statistical analyses and modeling are being used to investigate: (1) how changes in marine survival and productivity are related to changes in marine growth of Atlantic salmon; and (2) how changes in marine growth are related to ecosystem conditions that affect salmon marine energetic requirements and energetic resources available via salmon prey.

Specifically, it will accomplish three main objectives:

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

In years 1 and 2, our plans focused on analyzing changes in growth of Atlantic salmon from the Penobscot River, relationships between growth and survival ,and relationships between growth and ecosystem conditions. In addition, we planned to hire a postdoc and run a workshop to identify commonalities in ecosystem change and fish population changes across the North Atlantic. Our progress towards these goals has been re-organized for several reasons. First, we are still filling data gaps in scales from the Penobscot fish. Second, a funding shortfall in year 2 caused us to shift the timeline for hiring a postdoc. However, progress towards all of these project activities is underway.

ACCOMPLISHMENTS

To date, we have obtained archived scales of Atlantic salmon that returned to the Penobscot River from ME Department of Marine Resources, and NMFS has read scales to measure circuli and seasonal growth increments from 1SW and 2SW in three clusters of smolt years (1978-1980, 1986-1988, and 1998-2000) that align with periods of high, medium, and low marine

survival. Our initial plan had been to have samples sizes of 50 scales from each sea age/smolt year combination. However, due to unreadable scales in the initial target and back-up sets, some years have fallen as much as 20% below the target sample size. We are currently making a final attempt to identify readable scales from those that remain in the archive and reading those to collect growth data.
An intern was hired during the summer of 2015 to set up R code that will be used for standard data processing needs in this project. The intern developed quality assurance processes to determine rates of difference between human-read and computer-calculated marks on the scales. In addition, he set up code for calling to different temperature and oceanographic data sets as well as wrapper functions so that standard inputs (e.g., latitude-longitude boundaries of areas of interest) can be used to define data that are retrieved from those data sets; this effort will simplify ecosystem data collection and processing throughout this project.

Tim Sheehan and Kathy Mills proposed a session for the 2016 ICES Annual Science Conference, which has been accepted. This session will address a project goal to broadly evaluate how changing ecosystem conditions are affecting Atlantic salmon growth and survival across the North Atlantic, not just in North America. We have expanded the focus of the session to facilitate comparisons of how climate and ecosystem changes are affecting diadromous as well as marine fish population productivity, with a goal of being able to broadly synthesize commonalities in climate-ecosystem-fish population linkages across the North Atlantic basin.

Finally, we have completed the interview process for postdoctoral research associates and plan to issue an offer in a few days. The postdoc will play a major role in all modeling associated with this project (primarily Objective 3).

HIGHLIGHTS

- Growth data have been obtained from Atlantic salmon from the Penobscot River, and current data gaps are in the process of being filled.
- R codes have been written for quality assuring the biological data and for facilitating retrieval of climate and ecosystem data from global data sources (e.g., SST data).
- ICES session proposal has been accepted and organizing is underway to bring together diverse experts and contributions to shape a basinwide understanding and framework for how climate and ecosystem changes are affecting fish population productivity.
- Postdoctoral hire for the project is imminent.

SOCIETAL BENEFITS

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

The Western Chukchi Sea: Physical Drivers and Biological and Geochemical Responses

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Robert Pickart, WHOI

NOAA Sponsor: Kathleen Crane, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The overall goal of the Russian-American Long-term Census of the Arctic (RUSALCA) program is to document and understand the ecosystem response of the Pacific sector of the Arctic Ocean to the pronounced recent changes in climatic forcing. The broad-scale component of RUSALCA has included a series of multi-disciplinary cruises sampling the water column and benthos of the Chukchi Sea (and eastern portion of the East Siberian Sea). To date there have been three broad-scale surveys: in August 2004, September 2009, and September 2012. We recently finished the synthesis stage of the program, bringing together the various data sets to understand how this important ecosystem functions – and how it might react to the changing environmental conditions. This culminated in a special issue of Oceanography Magazine in September 2015. Our study related the physical drivers on the shelf, including the circulation, atmospheric forcing, and sea-ice concentration, to different components of the biological system, including the benthic community and water column distributions of zooplankton.

ACCOMPLISHMENTS

Using data from a number of summer surveys of the Chukchi Sea over the past decade – including the three broad-scale RUSALCA surveys – we investigated aspects in which the benthic fauna, sediment structure, and zooplankton on the shelf are related to circulation patterns and hydrographic conditions. These results were published in an article in the RUSALCA special issue of Oceanography Magazine. The author list included physical oceanographers, benthic ecologists, zooplankton researchers, geochemists, and modelers. The study highlighted the close relationship between physical drivers (wind forcing, water masses, circulation, and sediment type) in the Chukchi Sea and the biological signals in the benthos and the plankton on a variety of time scales.

In addition, a previous study investigating the circulation on the Chukchi shelf, and how this is influenced by wind, was presented at the 2016 Ocean Sciences meeting.

HIGHLIGHTS

A flow speed map, constructed using historical acoustic Doppler current profiler (ADCP) data, revealed the major pathways on the shelf. This compared favorably to output from a high-resolution numerical model. It demonstrated that regions of enhanced flow speed are dictated by lateral constrictions—in particular, Bering Strait and Barrow and Herald Canyons—and by sloping topography near coastlines.
For the most part, benthic epifaunal and macrofaunal suspension feeders are found in high flow regimes, while deposit feeders are located in regions of weaker flow.
Variations in atmospheric forcing, particularly wind, during the three RUSALCA sampling periods caused significant changes in the lateral and vertical distributions of the summer and winter water masses. These water mass changes, in turn, were reflected in the amounts and species of zooplankton observed throughout the Chukchi shelf.

SOCIETAL BENEFITS

By documenting the changes in the circulation and ecosystem of the western Chukchi Sea, including the atmospheric forcing and links to the Bering Strait inflow, we will improve our understanding of how the western Arctic Ocean responds to climate warming. This impacts issues such as marine mammal habitat and fisheries management.

EDUCATION AND OUTREACH ACTIVITIES

The study of the circulation on the Chukchi shelf was presented at the 2016 Ocean Sciences meeting.
A guest student, Maria Pisareva from Shirshov Institute of Oceanology in Moscow, was supported by the project.

PUBLICATIONS

Pisareva, M, R.S. Pickart, M. Spall, C. Nobre, D. Torres, G.W.K. Moore, 2015. Flow of Pacific water in the western Chukchi Sea: Results from the 2009 RUSALCA Expedition. Deep-Sea Research I, 105, 53-73.

Pisareva, M.N., R.S. Pickart, K. Iken, E.A. Ershova, J.M. Grebmeier, L.W. Cooper, B.A. Bluhm, C. Nobre, R.R. Hopcroft, H. Hu, J. Wang, C.J. Ashjian, K.N. Kosobokova, and T.E. Whitledge. 2015. The relationship between patterns of benthic fauna and zooplankton in the Chukchi Sea and physical forcing. Oceanography 28(3):68–83.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

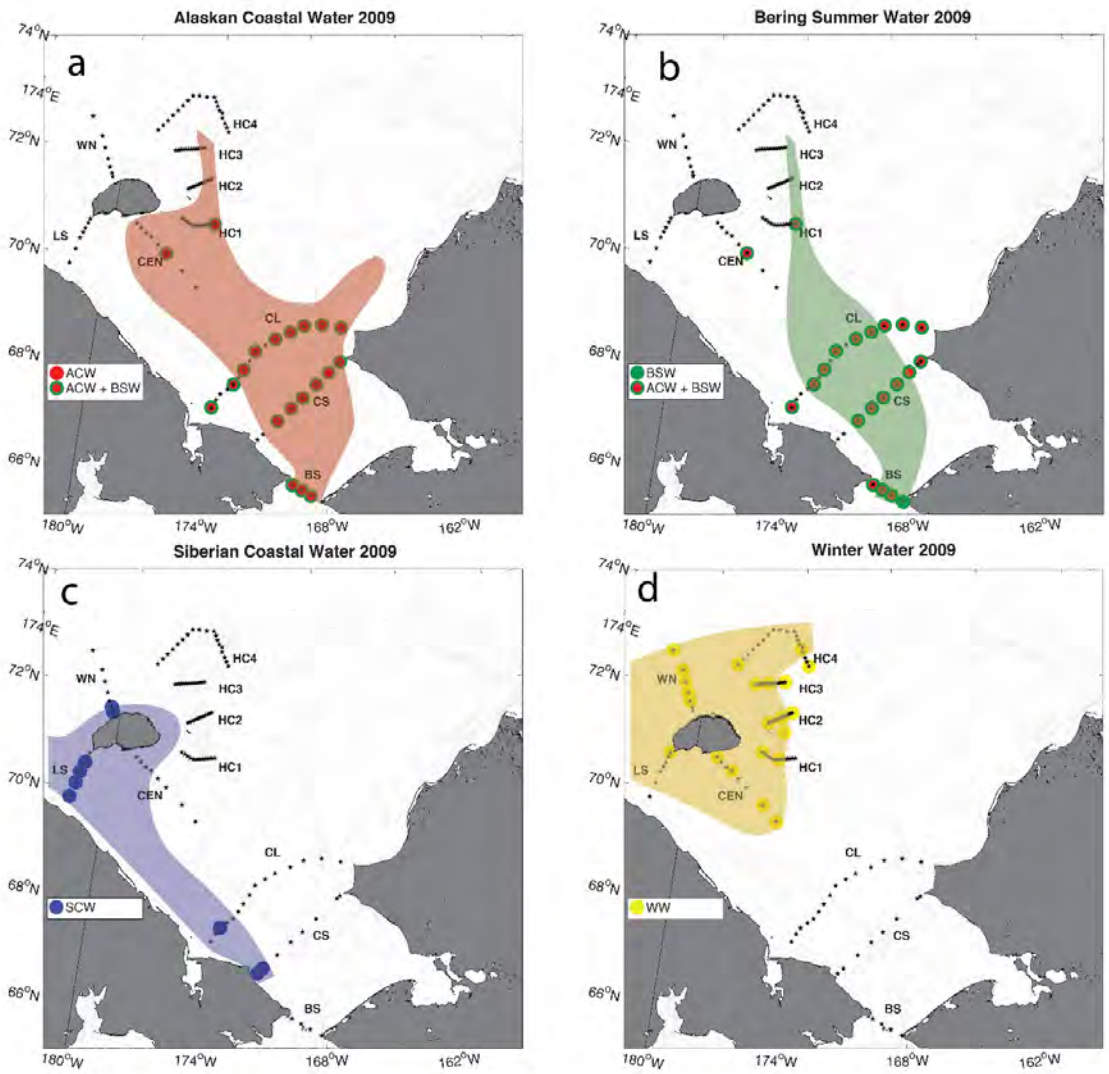

Figure 1. Lateral distributions of water masses for the 2009 RUSALCA survey (shading) in comparison to the measured zooplankton clusters (colored circles) indicating the close relationship between the zooplankton and the water type. ACW = Alaskan coastal water; BSW = Bering summer water; SCW = Siberian Coastal water; WW = Pacific winter water.

Synthesis of Physical Measurements from the Pacific Arctic Group: Flux of Pacific Water through Barrow Canyon, Chukchi Sea

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015-March 31, 2016

CINAR Investigator: Robert Pickart, WHOI

NOAA Sponsor: Kathleen Crane, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

In 2012 a program called the Distributed Biological Observatory (DBO) was started in the Pacific sector of the Arctic Ocean. The goal of the DBO is to document and understand the changing ecosystem in the Bering and Chukchi Seas and determine the physical drivers responsible for those changes. Five priority regions were identified across the latitudinal extent of the domain, and international ships of opportunity occupy transects within the regions and collect measurements in the water column, sediments, and sea-ice as time and logistics permit. The implementation of the DBO has required significant coordination and communication, and the Pacific Arctic Group (PAG) continues to help lead this effort. To date, six years of DBO data have been collected (2010-15). We received NOAA funding to begin the scientific analysis of a portion of the data. The goal of the project was to analyze the collection of DBO transects across Barrow Canyon (DBO line 5) to characterize the water masses in the canyon, document the seasonal evolution, and determine the role of wind forcing in dictating the conditions in the canyon.

ACCOMPLISHMENTS

Our study focuses on the DBO-5 transects collected between 2010- 14. The seasonal coverage of data is roughly evenly distributed over the months of July to October, and the interannual distribution of occupations is also fairly uniform. The conductivity- temperature-depth (CTD) data were used to identify the different water masses in the canyon and how they vary through the summer and fall. This was done in T/S space and in the vertical plane. Using the wind record from the Pt. Barrow meteorological station, together with the North American Regional Reanalysis fields, we investigated the relationship between the atmospheric forcing and the manner in which Atlantic water is upwelled into the canyon.

HIGHLIGHTS

- There is pronounced seasonal variability in the water masses passing through Barrow Canyon, with Pacific Winter Water being the most prevalent water mass throughout the summer.
- All upwelling events were characterized by the presence of Atlantic water in the deep part of the canyon and decreased amounts of Alaskan Coastal water in the upper part of the water column.
- Upwelling is associated with a deepened Aleutian Low that extends farther to the northeast, likely associated with a preferred storm track that progresses into the Bering Sea.

SOCIETAL BENEFITS

Detecting changes in the Pacific Arctic via long timeseries, such as that provided by the DBO, will enable us to better understand the impacts of a warming climate on this high-latitude ecosystem. This has bearing on issues such as marine mammal habitat and fisheries management in the Bering and Chukchi Seas.

EDUCATION AND OUTREACH ACTIVITIES

The results of this study were presented at the 2016 Ocean Sciences meeting.

Nobre, C., R. S. Pickart, K. Arrigo, C. Ashjian, C. Berchok, L. Cooper, J. Grebmeier, I. Hartwell, J. He, M. Itoh, T. Kikuchi, K. Moore, P. Stabeno, and S. Vagle, 2016. Seasonal to Mesoscale Variability of Water Masses in barrow Canyon, Chukchi Sea. Eos Trans. AGU, abstract HE54A-155

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

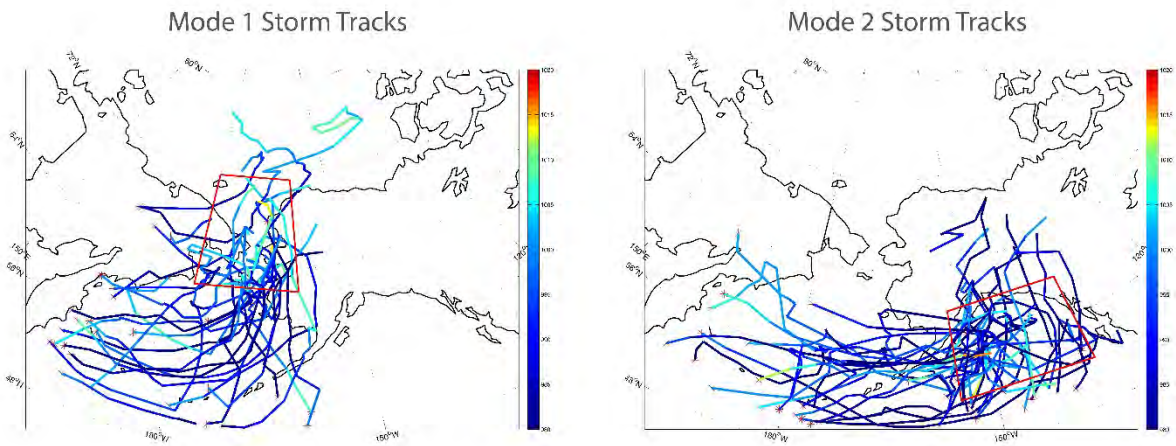

Figure 1. Using a Graphical User Interface (GUI), all of the storms in the study region were tracked for the months of July-October during 2010-14. Two dominant "modes" of tracks were revealed, which together account for 70% of all storms. The mode 1 storms progressed into the northern Bering Sea (through the red box in the left-hand panel), while the mode 2 storms followed a more zonal track into the Gulf of Alaska (through the red box in the right-hand panel). We hypothesize that mode 1 storms lead to upwelling in Barrow Canyon.

Tracking Changes in North American Marine Species Distributions

NOAA Cooperative Agreement NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Malin Pinsky, Rutgers

NOAA Sponsor: Jonathan Hare, NMFS

Related Strategic Plan Goal: Healthy Oceans

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

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

ACCOMPLISHMENTS

We acquired the latest scientific survey data from the Eastern Bering Sea, Aleutian Islands, Gulf of Alaska, West Coast US, Northeast US, and the Southeast US, and integrated these data into the visualization website, http://oceanadapt.rutgers.edu. We also wrote additional processing scripts in the R language to make the updating process easier in the future. The scripts and metadata are now publicly available at https://github.com/mpinsky/OceanAdapt.

We also added animated maps of species disributions to the website and wrote blog-style posts about the species, the surveys, climate impacts, and related topics.

Presentations about OceanAdapt were made to the Ecosystem Based Management Tools Network and to the Species on the Move conference.

HIGHLIGHTS

- The OceanAdapt website provides maps, graphs, and stories about the changing distributions of marine animals in the U.S.
- The OceanAdapt website is built on the principles of open data, and transparently hosts, analyzes, and displays the results from NOAA bottom trawl surveys on the continental shelves of North America.

SOCIETAL BENEFITS

This research helps to inform society about the impacts of climate, fishing, and other factors on marine life.

EDUCATION AND OUTREACH ACTIVITIES

Presentations about OceanAdapt were made to the Ecosystem Based Management Tools Network and to the Species on the Move conference.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

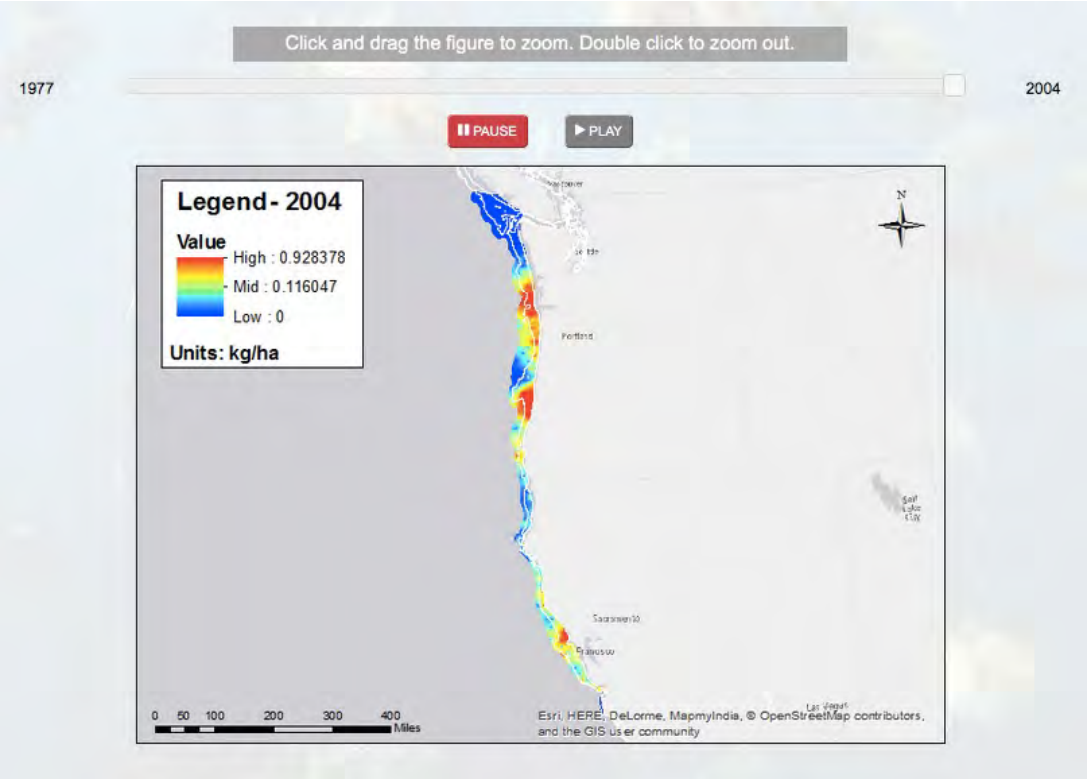

Figure 1. Example map showing Dungeness crab distribution in 2004.

Ocean Climate Observations and Analyses - NTAS

NOAA Cooperative Agreement No. NA14OAR 4320129
July 1, 2010 - June 30, 2016

CINAR Investigator: Albert Plueddemann, WHOI

NOAA Sponsor: Diane Stanitski, OAR

Related Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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.

A no-cost extension was granted in May of 2015 for the NTAS Operations project. Following a mooring failure in 2014, funds budgeted for NTAS operations remained in the account due to savings on shipping costs and a reduced salary load for post cruise activities. The reprogramming allowed remaining funds to be allocated to the replacement of instruments lost when the mooring failed.

ACCOMPLISHMENTS

The basic deliverables from the ORS are the high quality data, supported by the documentation of the methods. The directly observed data fall into three main categories: (1) surface meteorology and air-sea fluxes; (2) surface oceanographic data; and (3) ocean observations of temperature, salinity, and velocity along the mooring line. Surface meteorology is available in real-time and the remaining data follow in delayed mode. 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; and the fifth product is (5) deep T and S - all of the ORS moorings include additional sensors to obtain deep ocean temperature and salinity. Ancillary observations by cooperating investigators add product (6) Surface wave data using a NOAA National Data Buoy Center wave package.

The purchase of replacement instruments was successfully completed during the no-cost extension period, and the 2016 NTAS mooring was deployed with a full suite of subsurface sensors. Modest instrumentation upgrades were possible within budget restrictions. For example, we are now providing real-time telemetry of temperature and salinity from five depths rather

than three.

The NTAS ORS addresses the following observing system program deliverables:

- **Sea surface temperature (SST) and surface currents.** The NTAS surface buoy has been instrumented to provide improved sea surface temperature observations. Because they sample surface and near-surface ocean temperature and because they have collocated, high-quality air-sea fluxes, NTAS ORS data are sought by investigators working on climate dynamics, air-sea interaction, diurnal warm layer dynamics, and remote sensing of SST.
- **Ocean heat content and transport.** The NTAS ORS is equipped with temperature, salinity, and velocity sensors from about 150 m to the surface and also the deep sensors at about 4900 m. As a result, the temporal evolution of the mixed layer and its heat storage can be tracked as well as the heat content of the upper ocean.
- **Air-Sea Exchanges of Heat, Momentum and Freshwater.** The NTAS ORS is equipped to make state of the art, sustained air-sea flux observations, providing the air-sea exchanges of heat, freshwater, and momentum. The NTAS surface meteorological and air-sea flux data, uniquely, are both high quality and withheld from real-time assimilation into weather and climate models.

HIGHLIGHTS

- A unique, high quality long time series data set is being provided the NTAS ORS, deployed since March 2001 in the Northwest Tropical Atlantic.
- This is a region of very high scientific interest and challenge, as evidenced by biases found there in ocean and climate models and by it being a region of little change in sea surface temperature or even cooling in a world where SST is generally warming.
- The uniqueness of the NTAS ORS time series stems from their being withheld and independent of the models, their high quality, their provision of coincident surface forcing and ocean variability, and their high vertical and temporal resolution in the upper ocean.
- The NTAS ORS is now providing five depths of temperature and salinity in real-time via inductive communications on the mooring and data telemetry from the surface buoy via Iridium satellite (Figure 1).

SOCIETAL BENEFITS

The ORS results are particularly significant in two areas: (1) Providing benchmarks to validate and improve climate and weather models, and (2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean. The ability of society to prepare for and mitigate weather and climate variability depends heavily on the realism of models, and the withheld, high quality time series from the ORS are a key asset in the effort to improve models and build an improved understanding of the ocean’s role in the earth system.

EDUCATION AND OUTREACH ACTIVITIES

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

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

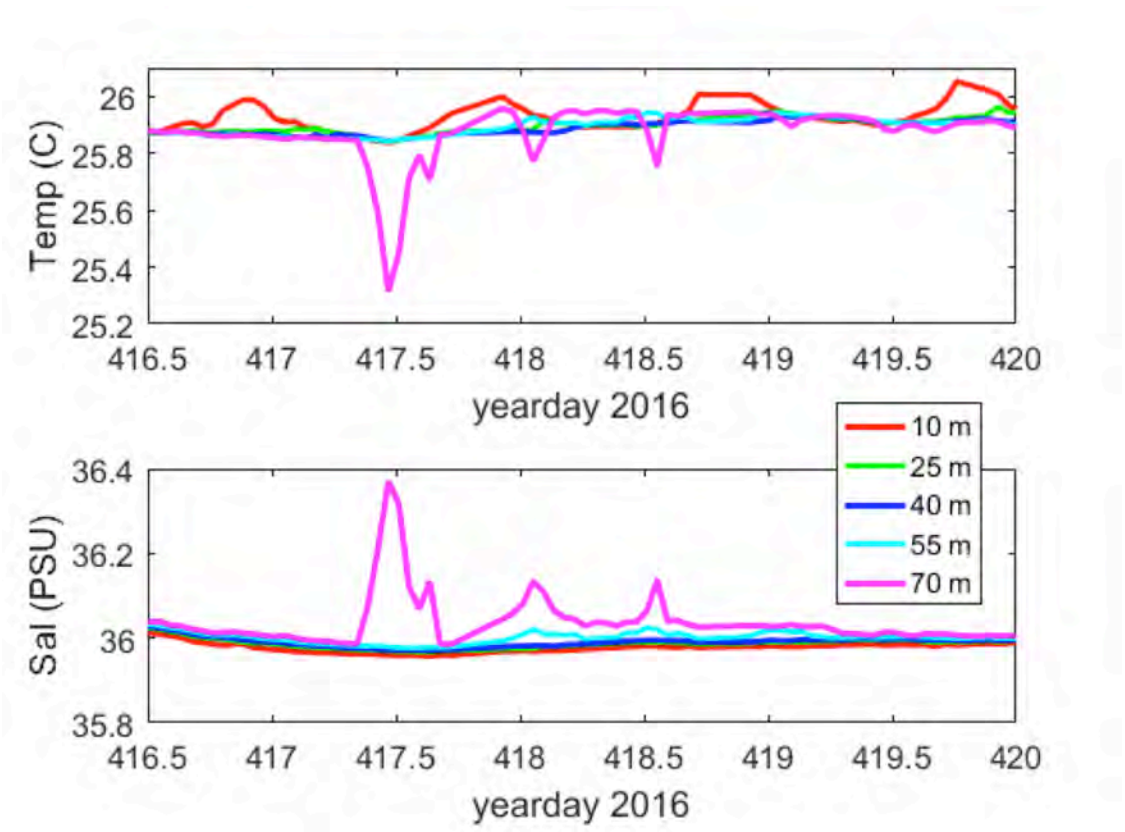

Figure 1. A 3.5 day section of temperature (upper) and salinity (lower) obtained via telemetry from the NTAS ORS. The upper 4 sensors are typically within the mixed layer during this period and show nearly uniform temperature and salinity, although the 10 and 25 m temperature records show evidence of diurnal warming. The sequence of cold, salty "spikes" in the 70 m record beginning on year day 417.5 is a result of this instrument alternating between the mixed layer and the pycnocline below.

Supplement to: Ocean Climate Observations and Analyses

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- march 31, 2016

CINAR Investigator: Albert Plueddemann, WHOI

NOAA Sponsor: Diane Stanitski, OAR

Related Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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. Supplemental funds were used to ensure timely servicing of the NTAS ORS in 2014 and 2016.

ACCOMPLISHMENTS

The basic deliverables from the ORS are the high quality data, supported by the documentation of the methods. The directly observed data fall into three main categories: (1) Surface meteorology and air-sea fluxes; (2) Surface oceanographic data; and (3) Ocean observations of temperature, salinity, and velocity along the mooring line. Surface meteorology is available in real-time and the remaining data follow in delayed mode. 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; and the fifth product is (5) Deep T and S - all of the ORS moorings include additional sensors to obtain deep ocean temperature and salinity. Ancillary observations by cooperating investigators add (6) Surface wave data using a NOAA National Data Buoy Center wave package.

The supplemental funds allowed two mooring service cruises for the NTAS ORS to be conducted so that the ORS deliverables were obtained. In December 2014 the University of Rhode Island R/V *Endeavor* was used to recover the mooring deployed the previous year (NTAS-13) deploy a refurbished mooring (NTAS-14). In January-February 2016 the R/V

Endeavor was again used, this time to recovery the NTAS-14 ORS and deploy NTAS-15

HIGHLIGHTS

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

SOCIETAL BENEFITS

The ORS results are particularly significant in two areas: (1) Providing benchmarks to validate and improve climate and weather models, and (2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean. The ability of society to prepare for and mitigate weather and climate variability depends heavily on the realism of models, and the withheld, high quality time series from the ORS are a key asset in the effort to improve models and build an improved understanding of the ocean's role in the earth system.

EDUCATION AND OUTREACH ACTIVITIES

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

Developing Carbon Dioxide Climatology and Ocean Acidification Indicators in the Northeastern U.S. Coastal Waters

NOAA Cooperative Agreement NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Zhaohui Aleck Wang, WHOI

NOAA Sponsor: Erica Ombres

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

The Northeastern U.S. coastal region, including the Gulf of Maine (GoME) and the Mid-Atlantic Bight (MAB), may be more susceptible to ocean acidification than has previously been thought, 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 potential effects, all 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. However, 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 CO_2 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.

This year, the objective is to help Nathan Rebuck and Jon Hare at NEFSC to conduct data analysis of legacy pH and alkalinity data from 1980's and newer dissolved inorganic carbon (DIC) and total alkalinity data in the NE coastal/shelf region. This will consist of a peer-reviewed paper focusing on seasonal and potentially inter-annual variabilities of carbonate chemistry in this region. It will serve as a climatology baseline for any future changes in carbonate chemistry to compare with under ocean acidification.

ACCOMPLISHMENTS

We have evaluated the data quality of legacy pH and TA data collected from 1980s from the NE shelf region. The conclusion is that there may be unknown errors in these data because of lack of Certified Reference Materials (CRMs) to standardize TA measurements and use of the non-preferable potentiometric method for pH measurements. These issues pose questions on the accuracy of these measurements. However, the precision of these data may be suitable for discussion of relative changes, such as seasonal variations, as they are self-consistent and have higher spatial and temporal coverages.

Alternatively, the later data collected in 2000s – now are in high quality but in lower spatial and temporal resolution. As such, the decision for the paper is to use the later data from 2000s to generate climatology maps of aragonite saturation states both for surface and near bottom water covering at least two seasons. The early legacy data will be used to examine more details on seasonal variabilities and any potential changes in terms of spatial and temporal patterns between 1980s and 2000s. We are currently in the process of making these data synthesis, producing maps and plots for the paper.

HIGHLIGHTS

- Evaluate the quality of the pH, TA, DIC data collected in 1980s and 2000s by various NOAA monitoring programs in the NE coastal/shelf region.
- Start to write a peer-reviewed paper focusing on producing the climatology baseline of aragonite saturation states and carbonate chemistry both for surface and near bottom water covering at least two seasons.

SOCIETAL BENEFITS

Products of this project 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 NE coastal/shelf region.

Supplement Ocean Climate Observations

NOAA Cooperative Agreement No. NA09OAR4320129
July 01, 2009-March 31, 2016

CINAR Investigator: Robert Weller, WHOI

NOAA Sponsor: Diane Stanitski, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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.

In April 2015, the Chilean Navy vessel *Cabo de Hornos* was used to recover and redeploy the Stratus ORS. This project provided the necessary additional funds required to carry out work on the Stratus ORS subsequent to the recovery cruise and in preparation for the planned recovery and redeployment cruise in 2016. The work included refurbishment of recovered instrumentation and mooring hardware, processing and quality control of the data recovered from the instruments recovered in April 2015, and preparations for the redeployment cruise planned for the *RV Nathaniel B. Palmer* in mid-2016.

ACCOMPLISHMENTS

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

and (8) Dissolved oxygen using sensors deployed both under this project and by Dr. Lothar Stramma from Geomar in Kiel, Germany.

The Stratus ORS thus addresses the following ocean observing system program deliverables:

- **Sea surface temperature (SST) and surface currents.** The Stratus surface buoy has been instrumented to provide improved sea surface temperature observations. Because they sample surface and near-surface ocean temperature and because they have collocated, high-quality air-sea fluxes, Stratus ORS data are sought by investigators working on climate dynamics, air-sea interaction, diurnal warm layer dynamics, and remote sensing of SST.
- **Ocean heat content and transport.** The Stratus ORS is equipped with temperature, salinity, and velocity sensors from about 2000 m to the surface and also the deep sensors at 4500 m. 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 Stratus ORS is equipped to make state of the art, sustained air-sea flux observations, providing the air-sea exchanges of heat, freshwater, and momentum. The Stratus surface meteorological and air-sea flux data, uniquely, are both high quality and withheld from real-time assimilation into weather and climate models.
- **Ocean Carbon Uptake and Content.** Collaboration with NOAA PMEL provides pCO_2 observations from Stratus.

HIGHLIGHTS

- A unique, high quality long time series data set is being provided the Stratus Ocean Reference Station Stratus site, deployed since October 2000 under the marine stratus clouds, in the eastern boundary of the South Pacific. This is a region of very high scientific interest and challenge, as evidenced by biases found there in ocean and climate models and by it being a region of little change in sea surface temperature or even cooling in a world where SST is generally warming. The uniqueness of the Stratus ORS time series stems from their being withheld and independent of the models, their high quality, their provision of coincident surface forcing and ocean variability, and their high vertical and temporal resolution in the upper ocean.
- Weller (2015) has found long-term trends in surface meteorology and air-sea fluxes at the Stratus ORS. Using the firs ten years of Stratus data, statistically significant trends were found in wind speed, wind stress, latent heat flux, and net heat flux. Increases in wind speed, wind stress, and latent heat flux were 0.8 m s^{-1}, 0.022 N m^{-2}, and 20 W m^{-2} or 13, 29, ad 20% of the respective means. The decrease in annual mean net air-sea heat flux was 39 W m^{-2} or 104% of the mean.

SOCIETAL BENEFITS

The Stratus ORS long-term observing effort is particularly significant in two areas: (1) It provides benchmarks to validate and improve climate models in a region important to global climate but presently not well-modeled, and (2) Identifying and quantifying the processes at work across the air-sea interface and in the ocean that maintain the state of the upper ocean,

including the SST and heat content. The ability of society to prepare for and mitigate weather and climate variability and impacts depends heavily on the realism of models, and the withheld, high quality time series from the Stratus ORS are a key asset in the effort to improve models and build an improved understanding of the earth system.

EDUCATION AND OUTREACH ACTIVITIES

- Whenever possible, cruises to the Stratus ORS have involved NOAA Teachers at Sea and also undergraduate and graduate students, including some from Chilean universities.
- "Variability and Trends in Surface Meteorology and Air-Sea Fluxes at a Site off Northern Chile", International Conference on Southern Hemisphere Meteorology and Oceanography, Santiago, Chile, October 2015.
- Visit to the Department of Meteorology, Universidad de Chile, Santiago, Chile, October 2015.
- Visit to the First Naval District Headquarters, Chilean Navy, Valparaiso, Chile, April 2015.
- "Research at the Stratus ORS", talk on board the Chilean Navy vessel *Cabo de Hornos*, April 2015.
- "Oceanic Response to Surface Forcing off Northern Chile", seminar at the Department of Meteorology, Universidad de Chile, Santiago, Chile, October 2015.
- "Circulation, eddies, oxygen and nutrient changes in the eastern tropical Pacific Ocean", European Geophysical Union annual meeting, April 2016, given by Czeschel.

PUBLICATIONS

Czeschel, R., L. Stramma, R.A. Weller, and T. Fischer, 2015. Circulation, eddies, oxygen and nutrient changes in the eastern tropical South Pacific Ocean. *Ocean Sci.*, 11, 455-470, doi:10.5194/os-11-455-2015

Weller, R.A., 2015: Variability and Trends in Surface Meteorology and Air–Sea Fluxes at a Site off Northern Chile. *J. Climate*, **28**, 3004–3023. doi: http://dx.doi.org/10.1175/JCLI-D-14-00591.1

Sutton, A.J., C. L. Sabine, R. A. Feely, W-J Cai, M. F. Cronin, M. J. McPhaden, J. M. Morel, J. A. Newton, J-H Noh, S. R. Olafsdottir, J. E. Salisbury, U. Send, D. C. Vandermark, and R.A. Weller, 2016: Using present-day observations to detect when anthropogenic change forces surface ocean carbonate chemistry outside pre-industrial bounds. *Biogeosciences Discuss.*, doi:10.5194/bg-2106-104.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

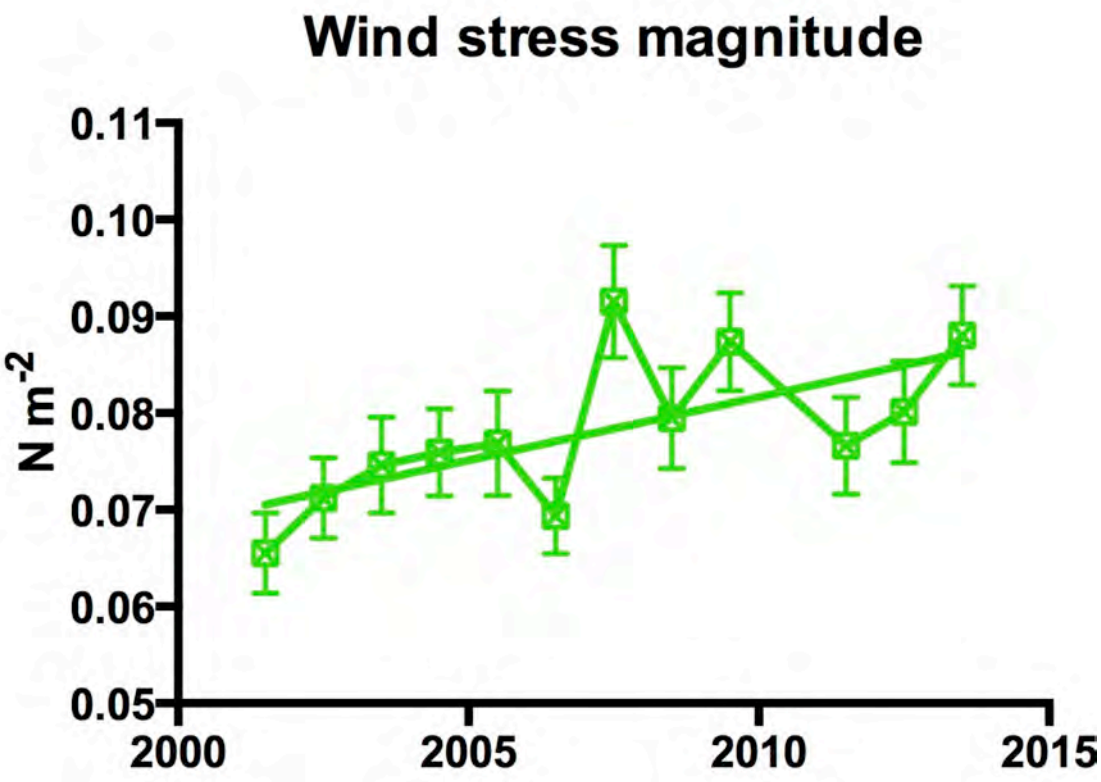

Figure 1. Annual mean wind stress magnitudes, with 95% confidence limits, plotted using Stratus ORS data. The linear fit line is 0.0013±0.0008 N m^{-2} yr^{-1}.

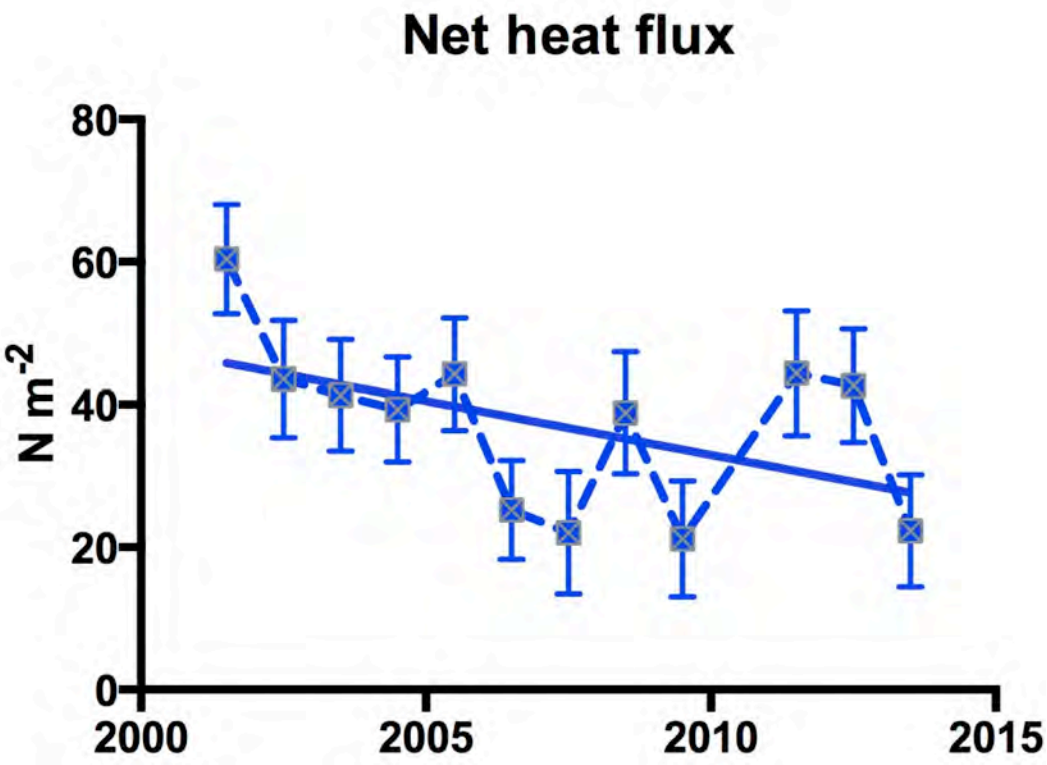

Figure 2. Annual mean net air-sea heat flux, positive meaning the ocean gains heat, plotted with 95% confidence limits using data from the Stratus ORS. The linear fit line is given by -1.5±0.8 W m^{-2} yr^{-1} and shows a statistically significant decrease in the amount of heat the ocean gains from the atmosphere each year.

Ocean Climate Observations and Analyses

NOAA Cooperative Agreement No. NA09OAR4320129
July 01, 2009 – March 31, 2016

CINAR Investigator: Robert Weller, WHOI

NOAA Sponsor: Diane Stanitski, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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.

In FY 2015, the WHOI Ocean Reference Station project carried out cruises to the three sites to recover moorings that had been in service for a year or more, and deploy new moorings. In April 2015, the Chilean Navy vessel *Cabo de Hornos* was used to recover and redeploy the Stratus ORS. In July 2015, the WHOTS mooring was recovered and a fresh mooring deployed from the NOAA Ship *Hi'ialakai*. In January-February 2016, the NTAS ORS was recovered and redeployed using *RV Endeavor*. 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).

ACCOMPLISHMENTS

The basic deliverables from the ORS are the high quality data, supported by the documentation of the methods. The directly observed data collected by the Stratus ORS fall into three main categories: (1) Surface meteorology and air-sea fluxes. The surface wind speed and direction, air temperature, relative humidity, barometric pressure, incoming shortwave radiation, incoming long wave radiation, and rain rate are measured at a once per minute rate. Logged at the same

time are buoy bridle temperature and salinity; (2) Surface oceanographic data; (3) Ocean observations of temperature, salinity, velocity, and dissolved oxygen along the mooring line. The surface meteorology, surface temperature, and surface current are used with the bulk forumulae to compute the following fourth product: (4) Air-sea fluxes of heat, freshwater, and momentum. In addition, the Stratus ORS obtains: (5) Deep temperature and salinity – all three moorings carry additional sensors near the sea floor to record deep temperature and salinity; (6) Surface wave data using a NOAA National Data Buoy Center wave package; (7) pCO_2 observations using NOAA Pacific Marine Environmental Laboratory (PMEL) instrumentation; (8) Dissolved oxygen using sensors deployed both under this project and by Dr. Lothar Stramma from Geomar in Kiel, Germany; and (9) In water radiance observations at WHOTS by Sam Laney of WHOI.

The surface moorings are a very effective methodology. The WHOTS mooring has been on station 100% of the desired time. The Stratus and NTAS moorings have each provided 94% of the planned station time. Close to a complete (99.6%) record of surface meteorology has been delivered by the three ORS. In spite of biofouling, fishing gear entanglement, and other challenges 87% of the ocean sensor data sought while on station has been recovered; and, with redundancy in ocean instrumentation on the moorings, the result has been very effective observation of the variability and structure of the upper ocean.

The ORS addresses the following ocean observing system program deliverables:

- **Sea surface temperature (SST) and surface currents.** The ORS surface buoys have been instrumented to provide improved sea surface temperature observations. Because they sample surface and near-surface ocean temperature and because they have collocated, high-quality air-sea fluxes, ORS data are sought by investigators working on climate dynamics, air-sea interaction, diurnal warm layer dynamics, and remote sensing of SST.
- **Ocean heat content and transport.** The ORS are equipped with temperature, salinity, and velocity sensors concentrated from about 1000 m to the surface and also the deep sensors close to the bottom. As a result, the temporal evolution of the mixed layer and its heat storage can be tracked as well as the heat content of the upper ocean.
- **Air-Sea Exchanges of Heat, Momentum and Freshwater.** The ORS are equipped to make state of the art, sustained air-sea flux observations, providing the air-sea exchanges of heat, freshwater, and momentum. The Stratus surface meteorological and air-sea flux data, uniquely, are both high quality and withheld from real-time assimilation into weather and climate models.
- **Ocean Carbon Uptake and Content.** Collaboration with NOAA PMEL provides pCO_2 observations from Stratus and WHOTS.

HIGHLIGHTS

- Weller (2015) reported finding long-term trends in surface meteorology and air-sea fluxes at the Stratus ORS. Increases in wind speed, wind stress, and latent heat flux over nine years were 0.8 m s^{-1}, 0.022 N m^{-2}, and 20 W m^{-2} or 13, 29, and 20% of the respective nine-year means. The decrease in the annual mean net heat flux was 39 W m^{-2} or 104% of the mean.

- Comparisons of annual mean wind stress magnitudes from the Stratus ORS and the NCEP2

and ERA-Interim Reanalyses should differences. ERA winds reproduce the temporal variability in stress observed at the buoy quite well, but the ERA winds have a strong high bias. NCEP2 winds, while closer to the means from the buoy, have different year-to-year variability and a weaker slope. Indeed, from 2000 to 2007, NCEP2 wind stress would suggest a negative slope or decreasing wind stress (Figure 1).

- The vertical structure of the ocean at the Stratus ORS and the presence of a low oxygen layer has been the focus of continued attention through our partnership with German investigators (Lothar Stramma, Kiel). To address this, we have added oxygen sensors and added instruments from Stramma.
- WHOTS, like the other ORS, records local air-sea forcing (exchanges of heat, freshwater and momentum) as well as local ocean variability. We partner with the University of Hawaii (R. Lukas and M. Church, with NSF funding) on the oceanographic instrumentation, and recent work by R. Lukas points to several processes acting to control the local ocean state, including changes in the balance between surface rainfall and evaporation and transports by eddies of masses of water from distant locations. It is found that salinity in the mixed layer is increasing in association with a negative freshwater flux (loss of freshwater from the ocean) while temperature is decreasing, resulting in a density increase that is statistically significant over the first 10 years of the WHOTS record. Our own results from the buoy data point to trends in WHOTS surface forcing (net heat flux, net shortwave, and rain) and surface salinity (Figure 2).
- The NTAS ORS is in a region where the mechanisms controlling SST and upper ocean heat content are of interest. NTAS is a region where interaction between wind, evaporation and SST are important, and there is interest in the role of advective cooling during periods of wind relaxation when evaporative cooling is reduced and thus there is a tendency for local SST increase (without advection). We have looked to see if the Atlantic trade wind regime has shown significant trends as seen at WHOTS and Stratus and have not yet found significant trends at NTAS (Figure 3).

Significance of these scientific advancements: The ORS results are particularly significant in two areas:

1. Benchmarking three trade wind sites – the three ORS now provide accurate local climatologies of surface forcing and upper ocean variability. As such they form the basis for us to go forward and examine model errors and biases and identify those that are characteristic of how these models represent the trade wind region. They also form the basis for tracking anomalies in surface forcing and upper ocean heat content and identifying the spatial representativeness of such anomalies by looking at decorrelation scales in the atmosphere (in model and OA Flux fields) and in the ocean (in Argo float data).
2. Quantifying the processes at work to maintain the state of the upper ocean – the combination of accurate local forcing and good time/space resolution in the upper ocean allows us to identify the major contributors to local heat, freshwater, and momentum balances. Stratus, for example, at first obtained accurate fluxes that showed, in contrast to models, that the upper ocean there was heated by the atmosphere and needed ocean processes for cooling and freshening. Subsequently, Stratus data has motivated modelers and other researchers to examine the roles of ocean eddies and vertical mixing and, more recently, to examine the ability of models to reproduce and explain the trends observed in the surface forcing at Stratus. In addition, with the partnership with Stramma, the Stratus ORS now serves as a

focal point for collaborative study of the low oxygen layer found below the upper thermocline.

We have now started two related efforts, working with R. Lukas and J. Potemera of U. Hawaii. These are an examination of tropical biases in models and an effort to define climate indicators. Both will use the ORS data. The accurate and quality-controlled ORS surface forcing and coincident, high vertical and temporal resolution ocean time series are ideally suited to these efforts.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

- Whenever possible, cruises to the Stratus ORS have involved NOAA Teachers at Sea and also undergraduate and graduate students, including some from Chilean universities.
- "Variability and Trends in Surface Meteorology and Air-Sea Fluxes at a Site off Northern Chile", International Conference on Southern Hemisphere Meteorology and Oceanography, Santiago, Chile, October 2015
- Visit to the Department of Meteorology, Universidad de Chile, Santiago, Chile, October 2015
- Visit to the First Naval District Headquarters, Chilean Navy, Valparaiso, Chile, April 2015
- "Research at the Stratus ORS", talk on board the Chilean Navy vessel *Cabo de Hornos*, April 2015
- "Oceanic Response to Surface Forcing off Northern Chile", seminar at the Department of Meteorology, Universidad de Chile, Santiago, Chile, October 2015
- "Spatial analysis of abyssal temperature variations observed from the Aloha cabled observatory and WHOTS moorings", Ocean Sciences Meeting, February 2016, given by Santiago-Mandujano, U. Hawaii
- "Accelerating salinity trends at Station ALOHA in the North Pacific Subtropical Gyre", ", Ocean Sciences Meeting, February 2016, given by Santiago-Mandujano, U. Hawaii
- "Circulation, eddies, oxygen and nutrient changes in the eastern tropical Pacific Ocean", European Geophysical Union annual meeting, April 2016, given by Czeschel

PUBLICATIONS

Czeschel, R., L. Stramma, R.A. Weller, and T. Fischer, 2015. Circulation, eddies, oxygen and nutrient changes in the eastern tropical South Pacific Ocean. *Ocean Sci.*, 11, 455-470,

doi:10.5194/os-11-455-2015

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Sutton, A.J., C. L. Sabine, R. A. Feely, W-J Cai, M. F. Cronin, M. J. McPhaden, J. M. Morel, J. A. Newton, J-H Noh, S. R. Olafsdottir, J. E. Salisbury, U. Send, D. C. Vandermark, and R.A. Weller, 2016: Using present-day observations to detect when anthropogenic change forces surface ocean carbonate chemistry outside pre-industrial bounds. *Biogeoscinces Discuss.*, doi:10.5194/bg-2106-104.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

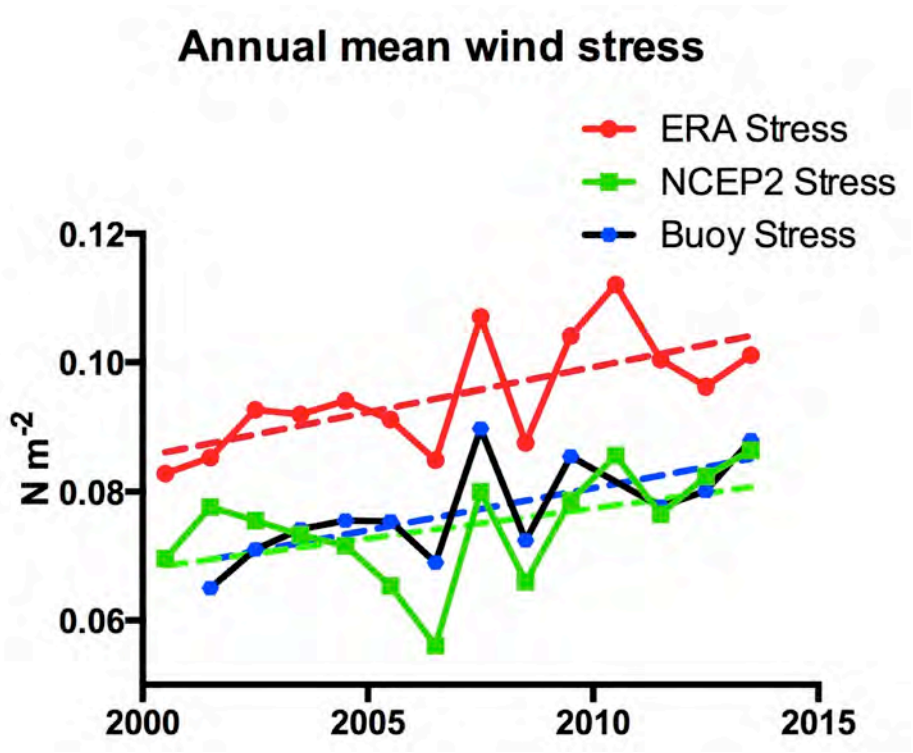

Figure 1. Annual mean magnitudes of wind stress at the Stratus ORS location from the buoy observations (blue), from NCEP2 Reanalysis (green), and ERA Interim Reanalysis (red).

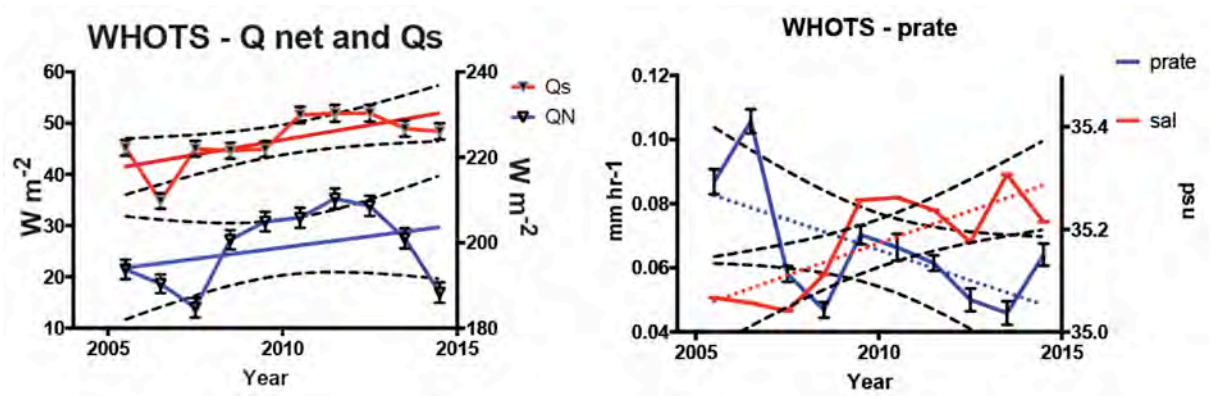

Figure 2. (Left) Annual means of net heat flux (blue) with a linear fit with a slope of 2.0 W m^{-2} yr^{-1}, and annual means of net shortwave radiation (red) with linear fit with a slope of 1.7 W m^{-2} yr^{-1}. 95% confidence intervals are shown on the mean value, and the dashed lines show the envelope of possible slopes. (Right) Annual means of precipitation rate (blue) with a linear fit with a slope of -0.005 mm hr^{-1} yr^{-1}, and annual means of surface salinity with linear fit with a slope of 0.03 psu yr^{-1}.

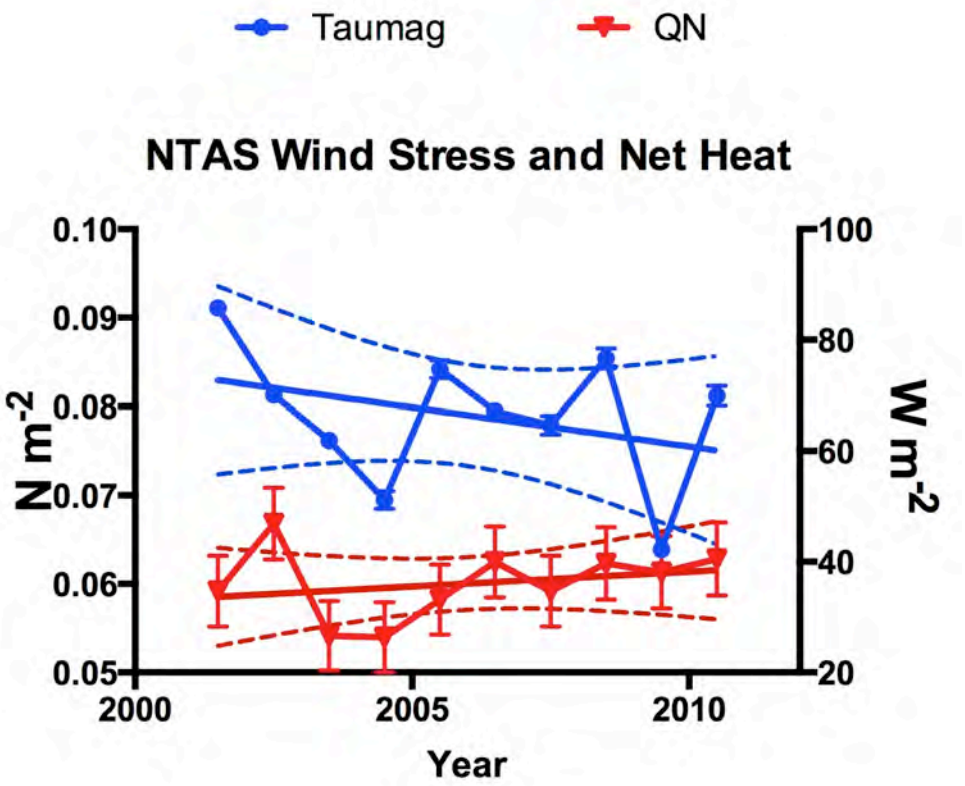

Figure 3. Annual means and linear fits for NTAS wind stress magnitude and net heat flux. These trends are not statistically significant, and the dashed lines show the envelope of possible slopes. 95% confidence intervals are shown as well.

Building Tools for Applying Climate Science to Fisheries Management

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Riley Young Morse, GMRI

NOAA Sponsor: Ellen Mecray, NESDIS

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

Working in partnership with the NOAA NCDC Northeast Regional Climate Center, The Gulf of Maine Research Institute (GMRI) is continuing with the development of an online dashboard to make a variety of information available to fisheries management community.

The high level goals and objectives for year two of the project were:
- Develop dashboard prototype
- Vet with stakeholder group for input
- Integrate data sources
- Launch dashboard

ACCOMPLISHMENTS

The "content advisory team" continued to meet regularly through 2015 to shape the development of our dashboard prototype.

In parallel with our "Accessing and visualizing satellite data for use by fisheries managers in the Northeast" CINAR project sponsored by NESDIS, the initial data views were developed for sea surface temperature (SST) as a metric to establish a clear path to include more products in the future.

1. User Interface

Our project aims to advance these efforts through the development of a climate and fisheries data dashboard which will produce new and dynamically updated views into the data, specifically historical, current and future projections of conditions in the NES LME for variables directly relevant to the fisheries stakeholder community, a community comprised of fishermen, fishing industry members (e.g. dealers and processors), and managers (council members, council staff, members of the Science and Statistical Committee). For the various data streams, we will enable users to look at the past in order to identify what is “normal” range of conditions. From there, they can view current data against the normal to see where we are today compared to history, and look to future projections to see where are we headed. We will apply a similar approach to historic landings data by species of interest to the stakeholder groups in the region (e.g.

groundfish, emerging fisheries, lobsters, etc.) to build a similar interactive view of these data. By integrating the historic landings data with the environmental data, patterns in the appearance of certain species in historic fishing areas earlier or later than usual may be detected. The dashboard will be a new, highly accessible resource that supports and compliments the ongoing efforts in the region, and we intend to highlight and include reference to these resources for deeper interpretation.

2. Prototype

Using an iterative approach, we engaged with stakeholders to vet the data we will integrate and determine the best way to present the information which allowed us to fine-tune the interface to their specifications. Through a series of focused interactions (in-person meetings and webinars) we worked through mockups of the user interface concepts and requirements for the interface, leveraging the NCDC climate data record product as a data sample to be included on the dashboard. The outcome of pilot work with fisheries dashboard project has infomed path forward on this project, specifically in confirming specific additional data sources, presentation of information, and what interpretation or descriptive text is needed for each derived data product in the dashboard. The Fisheries Climate Dashboard will provide a home for existing and future relevant climate and forecasting products. Data-driven products include seasonal temperature forecasts from NOAA's NMME, centennial scale climate projections from ESRL, and NASA-funded seasonal lobster forecasts being developed by GMRI. Additional products developed by regional partners, such as the NCDC Northeast Climate Outlook and NEFSC Ecosystem Status Report http://www.nefsc.noaa.gov/ecosys/climate_change/) will be accessible from the dashboard as well.

HIGHLIGHTS

- Developed working prototype of dashboard with interactive widgets for anomaly, climatology and map-based views of the OISST data
- Redesigned to display data for "sub regions" vs. point locations
- Developed additional content on the dashboard to describe and link to outlook and advisory products and efforts in the region.

SOCIETAL BENEFITS

This project contributes to the CINAR themes of sustained ocean observations and climate, and to conduct research and develop decision-support tools for sustainable fisheries management. Additionally, this project contributes to the NOAA research goal of understanding climate variability and change to enhance society's ability to plan and respond.

EDUCATION AND OUTREACH ACTIVITIES

- PI Young Morse presented a poster of the project at the 2015 American Geophysical Union meeting in San Francisco. The poster was entitled "Accessing and Visualizing Satellite Data for Fisheries Managers in the Northeast Large Marine Ecosystem".
- PI Riley Young Morse shared the dashboard project with targeted industry stakeholders at the

2016 Fishermen's Forum in Rockport, Maine.

- PI Young Morse presented on the fisheries dashboard project and gave a demonstration of the dashboard at the 2016 Climate Prediction Applications Science Workshop in Burlington, VT. Co-I Ellen Mecray also discussed the project in her presentation on climate tools in the region.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

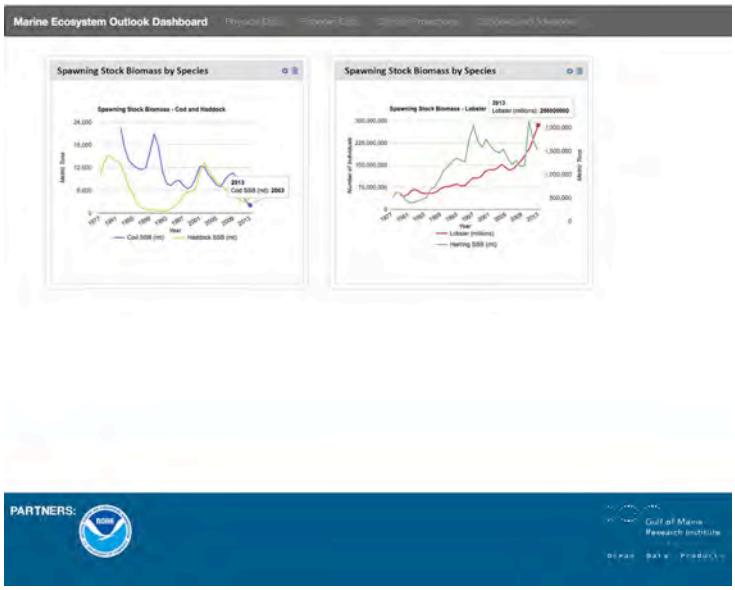

Figure 1. Screenshot of the prototype dashboard launched in spring 2016 – landing page shown.

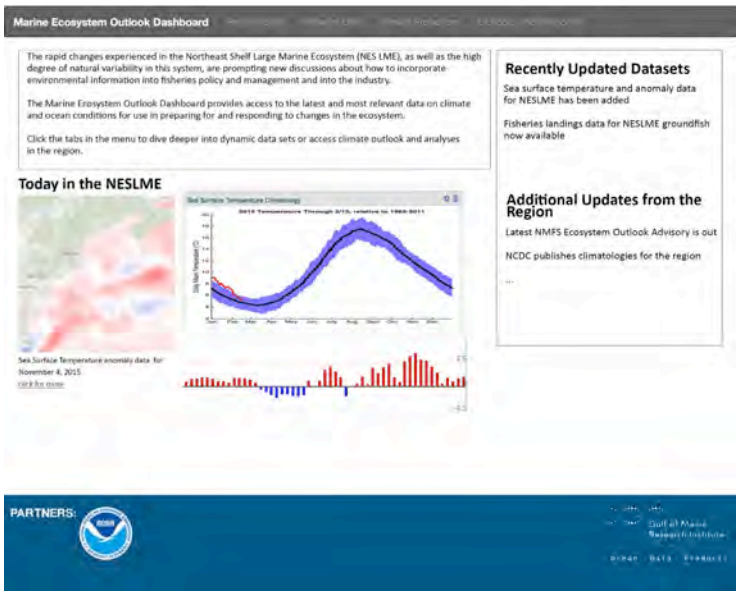

Figure 2. Screenshot of physical data

Figure 3. Screenshot of fisheries data.

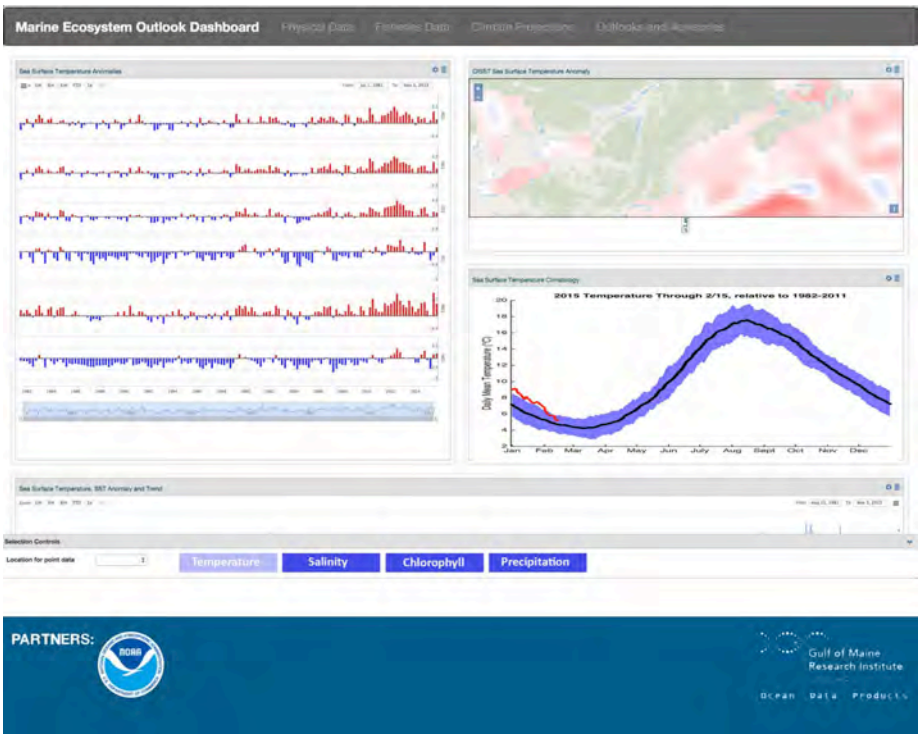

Figure 4. Outlook and advisories data.

Accessing and visualizing satellite data for use by fisheries managers in the Northeast

NOAA Cooperative Agreement No. NA14Oar4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Riley Young Morse, GMRI

NOAA Sponsor: Walter Glance, NESDIS

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

PROJECT OVERVIEW

In year two, we refined our goals based on work with our stakeholder engagement group and review of preliminary data products produced in the first year.

For both products, we have long-term data sets as well as forecasts. Through this and our "Building tools for applying climate science to fisheries management" effort, we are working closely with fishery stakeholders to ensure that the data views that we develop are intuitive and that the data products we identify are likely to be useful.

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.

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 dashboard.

ACCOMPLISHMENTS

1) Data acquisition

Year one was focused on accessing and acquiring data from services at the Climate Data Records Program. The initial scripts were used to query the data services at CDR and return time series for data at a point coordinate that mapped to a known sensor (in this case, NERACOOS buoys). We determined the appropriate filters to subset data (temporal, geospatial, parameter - SST/Anomaly). We developed scripts (python) to query the OISST Thematic Realtime Environmental Distributed Data Services (THREDDS) through NetCDF Subset Services (NCSS) that returned point data time series (subset by temporal and spatial boundaries) for each location, which were then output as JSON (JavaScript Object Notation). We initially used the location of NERACOOS data buoys for reference. This approach led to some confusion about whether the data was from the buoys not satellite data. It also identified a shortcoming of the OISST anomaly calculations for our purposes. The OISST anomalies are calculated on the climatologies for the global data set, not for the sub-region. In the end, we moved forward with a plan to aggregate data for sub-regions, and develop higher resolution climatologies for the sub-regions to identify more subtle trends in the system. The process is described below.

2) Spatial averaging

The resolution of gridded data is determined by the size of the individual grids within the data set. In order to make more relevant comparisons between the data, we have selected specific regions within the boundaries of the NES LME that more closely match the stock oceanographic regions of Ecological Production Units (EPUs) (Figure 1) and management areas for stock boundaries in the Gulf of Maine, Georges Bank, and Southern New England used by fisheries managers. Four EPUs have been defined for the NES LME. With the boundaries selected, we then average the values within that region.

3) Build reference level/climatology of data

Sea surface temperature is a variable with a strong impact on fish abundance and distribution. To answer the simple question: ‘are we hot or cold?’ poses some complex challenges. First, implicit in the question is the need for a reference point or climatology that defines what is normal. Using the OISST 30 year period (1/1/1982-12/31/11) we 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 values then provide a background climatology that current conditions (monthly/daily) can be overlaid. The climatology is fixed, but the current data will be dynamically updated on a daily basis.

HIGHLIGHTS

- Developed automated processes to aggregate and calculate spatial averages from data subsets that map to bounding boxes fisheries management areas.
- Calculated climatology statistics and higher resolution anomalies for subsetted data.
- Modified scripts to automate the process of accessing latest data from SST and SST anomaly

time series from OISST services to append to visualizations.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

- Co-I Ellen Mecray provided a briefing of this effort at a CDR meeting in Asheville, NC August 2015.
- PI Young Morse and CO-I Mecray worked with NOAA/NCEI Climate Data Records Program on the development of a use case from the OISST CDR dashboard.
- PI Young Morse provided an updated briefing of the project via webinar to the NCEI CDR office.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

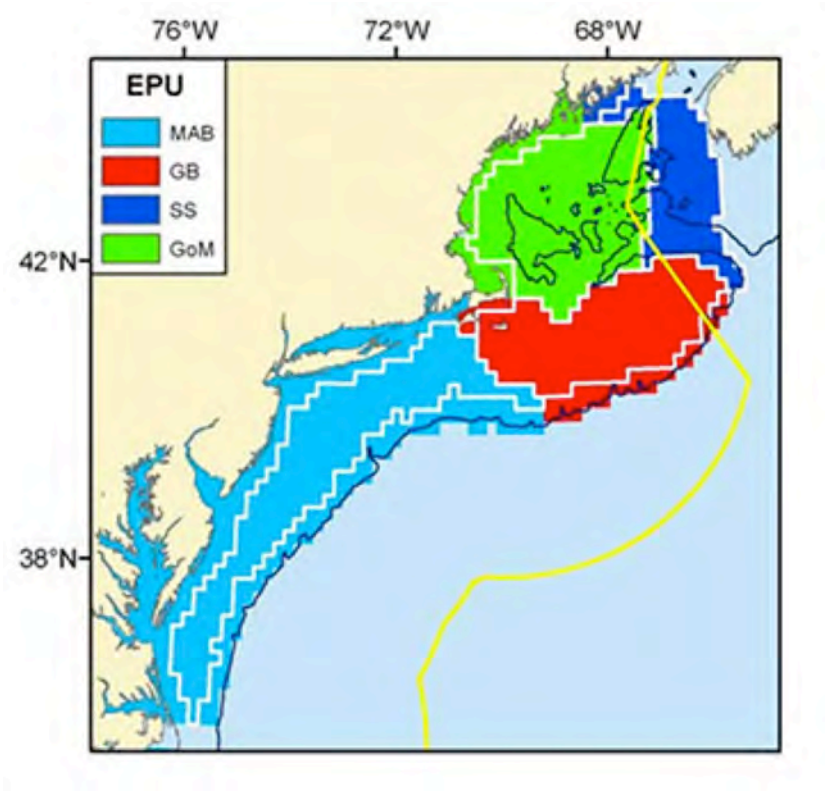

Figure 1. Map of the four Ecological Production Units (EPUs) as defined for the NES LME for MAB = Mid Atlantic Bight, GOM = Gulf of Maine, GB = Georges Bank, SS = Scotian Shelf. (http://www.nefsc.noaa.gov/publications/crd/crd1207/crd1207.pdf).

50 Year

Global Ocean Surface Heat Flux Analysis

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015- March 31, 2016

CINAR Investigator: Lisan Yu, WHOI

NOAA Sponsor: David Legler, OAR

Related NOAA Strategic Plan Goal: Climate Adaptation and Mitigation

CINAR Theme: Sustained Ocean Observations and Climate

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 producing 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 May 1, 2013, the project home page has been accessed 13,645 times and the data download page 12,465 times. The OAFlux products have been cited in 747 papers since their online dissemination in 2008. A new recent trend shows that OAFlux has emerged as a leading source of verification and validation for climate models and data assimilation models
.
The OAFlux global products of 50-years continue to provide new insights into the fundamental changes in the global climate under warm conditions. Evidence yielded by the OAFlux products leads to wide recognition of the intensification of ocean evaporation since the late 1970s, providing observational support for the Intergovernmental Panel on Climate Change (ICPP) 5th assessment report (AR5) on the acceleration of the global hydrological cycle in the past warm decades. The OAFlux products lead to the finding of the important role of the strengthening ocean surface wind speed in increasing ocean evaporation, providing a thought-provoking addition to the theory based on the Clausius-Clapeyron equation. The OAFlux datasets lead to the identification of the non-negligible contribution of high-latitude sensible heat flux (i.e., the thermal exchange at the air-sea interface due to air-sea temperature differences) to the global energy balance. The OAFlux global products have demonstrated in many ways their value in stimulating advances in our understanding of the role of the ocean in the global energy budget, the global hydrological cycle, and the change and variability of the Earth's climate.

ACCOMPLISHMENTS

Technical accomplishments

In FY2015, we made two technical achievements. We extended and maintained the project's existing 57-year time series of global ocean evaporation, and turbulent latent and sensible heat fluxes (1958 onward) to meet the demands of the research and operational community, as the products have a broad user group and been used in a wide range of applications. Concurrently, we completed the algorithm development for retrieving Ta and qa directly from satellite measurements of atmospheric sounding profiles and column-integrated water vapor, and produced three new sets of high-resolution satellite-based flux products starting from July 1987 onward. These include (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). We are working toward public dissemination of the products in the coming fall.

Scientific achievements
Three research themes were addressed.

(1) OAFlux multi-decadal time series of surface forcing functions: how has the forcing been changing in recent decades?

The annual-mean time series of the OAFlux turbulent latent and sensible heat fluxes (LHF and SHF) (positive denotes the ocean releases heat to the atmosphere) from 1958 to 2014 show a pattern of multi-decadal oscillation (Yu et al. 2015). During the 57-year data record, the ocean turbulent latent (evaporative) heat loss reached a minimum around 1977-78 and a maximum around 1998-99. Therefore, LHF has contrasting behaviors during the two recent decades: an increase of LHF in the 1990s when there is a rapid rise in global temperatures and the reduction of LHF in the 2000s when there is a pause, or "hiatus", in the global warming.

In addition, the time series of the global ocean-surface wind speed between 1988-2014, which was merged from 14 satellite sensors including both scatterometers and passive microwave radiometers (Yu and Jin 2015), reveals that the ocean winds have changed from a rapid intensification in the 1990s to a "hiatus" after the peak in 1998-1999. The coherent pattern of change in surface turbulent heat and momentum fluxes is of great climate interest. Ongoing work is investigating the pattern differences between the two decades and the cause of the differences.

(2) Decadal changes in ocean surface temperature and humidity: new development in high-resolution analysis of global Ta and qa.

One major improvement made to the high-resolution flux products is the retrieval algorithm for qa and Ta that we developed using buoys. The methodology is similar to Jackson and Wick (see Jin et al. 2015), which is based on nonlinear regression of satellite humidity and temperature soundings using in situ observations as training datasets. However, the approach is different. We used 98 buoys time series and a total of 49,195 matched data points to compute the regression coefficients. We retrieved Qa and Ta at 2m and added SST retrievals to the regression equations. We did regressions separately for the cold/dry regions and warm/wet regions, and then merged them together to fit the global ocean. We included a total of 8 satellite sensors (AMSU-A N15, N16, N17, and N18; SSMI F13, F14, F15, and F17) in developing the time series.

(3) Frontal-scale air-sea interaction

Air-sea flux variability associated with mesoscale eddies (defined as typical horizontal scales of less than 100 km and timescales on the order of a month) and related fronts and filaments is a dominant feature over the global ocean. These eddies are the weather of the ocean and can dictate the way of their interaction with the atmosphere. We are aware that the currently distributed 1° analysis (~110km) does not have sufficient resolution to resolve the mesoscale variability. Thus, how much high-resolution (0.25°) OAFlux products can improve the representation of the mesoscale variability has been a central focus in our development of new retrieval schemes and synthesis approaches. The extensive analyses we have conducted indicate that the high-resolution products we have obtained may be the best products to choose. Two

studies were conducted. One is the coupling between the turbulent latent plus sensible heat fluxes and the SST in the Gulf Stream region during a cold air outbreak event in February 1-15, 2007. The comparison of OAFlux-0.25° with OAFlux-1° and four other reanalysis products indicates that resolution does matter in resolving the flux variability arising from the interaction between the ocean front and atmosphere.

The second study is on the coupling between turbulent heat and momentum fluxes in the southern ocean depicted by OAFlux-0.25° and OAFlux-1°. The monthly-mean field in July 2012 is shown. To the first order, both products have depicted well the frontal-scale flux variability associated with the southern ocean current system, such as the Agulhas return current between 0 and 90E and the Brazil-Malvinas (Falkland) current between 70W and 10W. The coupling details vary, however, particularly in regions away from the two strong fronts. The high-resolution field displays a closer connection between SST and heat fluxes and between SST and wind speed. It is worth noting that heat flux computation used SST, but the wind speed is derived directly from satellite sensors and is independent of SST. The high correlation between SST and turbulent heat/momentum fluxes is a clear indication of the important role of the mesoscale ocean eddies in the atmospheric-ocean system of the southern ocean.

HIGHLIGHTS

- We extended and maintained the project's existing 57-year time series of global ocean evaporation, and turbulent latent and sensible heat fluxes (1958 onward) to meet the demands of the research and operational community.
- We constructed three new sets of high-resolution satellite-based flux products starting from July 1987 onward. These include (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).
- We contributed to NOAA State of Ocean Climate assessment reports on global change of heat/freshwater fluxes and ocean surface winds in 2015.

SOCIETAL BENEFITS

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

EDUCATION AND OUTREACH ACTIVITIES

The PI routinely presents research results at national and international scientific meetings. She serves on the NOAA Ocean Observing System Team of Experts and has led the analysis of global ocean surface flux for the NOAA State of Climate annual assessment report since 2005. She serves on the CLIVAR Global Synthesis and Observations Panel, and is a member of the NASA Sea Surface Temperature Science Team, NASA Ocean Surface Salinity Science Team, and NASA Ocean Vector Wind Science Team. She is a member of NOAA Climate Reanalysis Task Force, and actively promotes the integration of the OAFlux products with NOAA climate observing and modeling activities.

The PI is a member of the Tropical Pacific Observing System (TPOS) 2020 Back Bone Task Team, and is in charge of assessing the role of the tropical array in satellite observations and surface fluxes.

PUBLICATIONS

Jin X., L. Yu, D. L. Jackson and G. A. Wick, 2015: An Improved Near-Surface Specific Humidity and Air Temperature Climatology for the SSM/I Satellite Period. *J. Atmos. Oceanic Technol.*, **32** (3), 412-433. doi:10.1175/JTECH-D-14-00080.1

Yu, L., 2015: Sea-surface salinity fronts and associated salinity-minimum zones in the tropical ocean, J. Geophys. Res. Oceans, 120, 4205–4225, doi:10.1002/2015JC010790.

Yu, L., X. Jin, P. W. Stackhouse, A. C. Wilber, S. A. Josey, Y. Xue, and A. Kumar, 2015: Ocean surface heat and momentum fluxes. In "State of the Climate in 2014". *Bull. Amer. Meteor. Soc.*, 96(7), S68-S71

Josey, S. A., J. Grist, D. Kieke, I. Yashayaev, and L. Yu, 2015: Extraordinary ocean cooling and new dense water formation in the North Atlantic. In "State of the Climate in 2014". *Bull. Amer. Meteor. Soc.*, 96(7), S67-S68.

Liang, X., and L. Yu, 2015: Variations of the global net air-sea heat flux during the "hiatus" period (2001-2010). J. Climate. 29(5), 3647–3660 DOI: http://dx.doi.org/10.1175/JCLI-D-15-0626.1

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

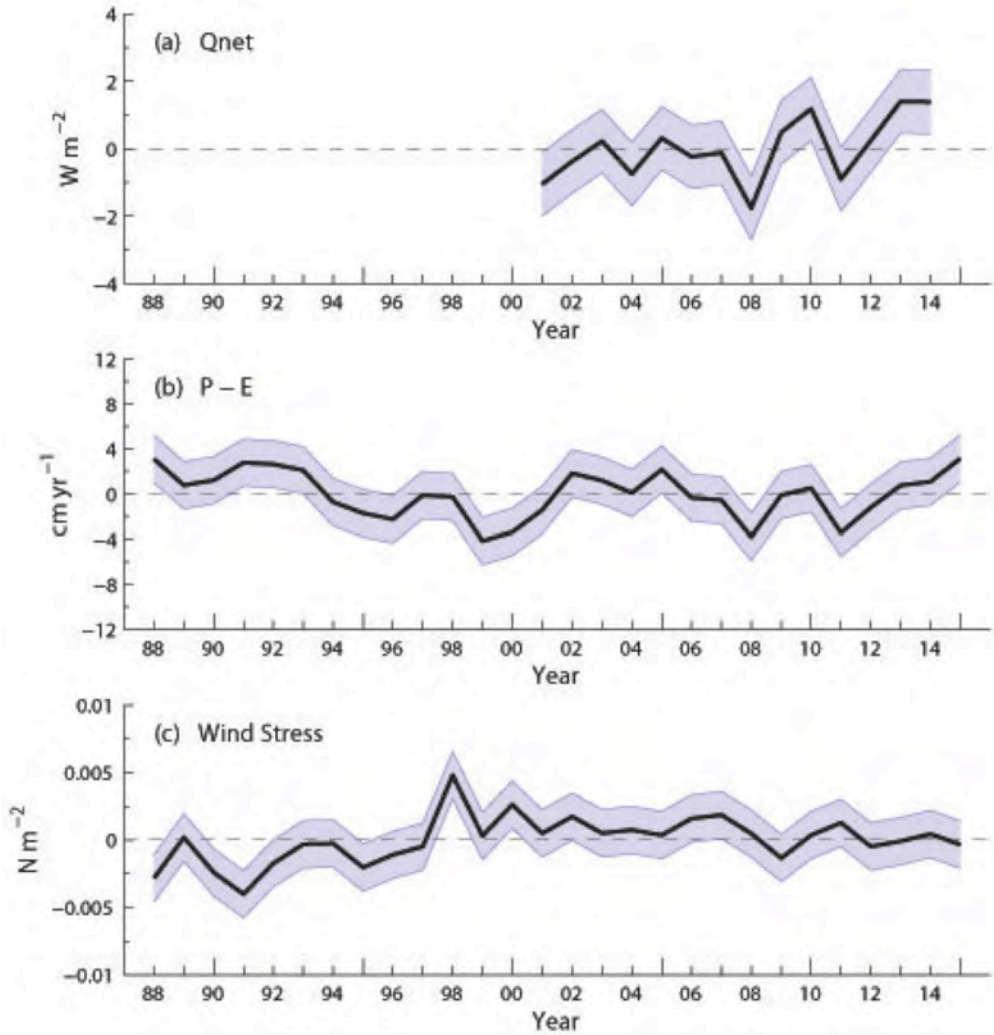

Figure 1. Annual-mean time series of global averages of (a) net surface heat flux (Qnet) from the combination of CERES EBAF SW+LW and OAFlux LH+SH, (b) net freshwater flux (P-E) from the combination of GPCP P and OAFlux E, and (c) wind stress magnitude from OAFlux High-resolution vector wind analysis. The shaded area denotes one standard deviation of annual-mean variability.

THEME VI. EDUCATION AND OUTREACH

CINAR

Cooperative Institute for the North Atlantic Region

Research and education in quantitative fisheries and ecosystem science

NOAA Cooperative Agreement No. NA14OAR4320158
July 1, 2009-March 31, 2016

CINAR Investigator: Donald Anderson, WHOI

NOAA Sponsor: Bill Karp, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

PROJECT OVERVIEW

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

ACCOMPLISHMENTS

This program began in 2012, and the first CINAR Fellows were appointed in early 2013. Progress reports on their activities during 2015-2016 are given in the attached Appendix, and are summarized below.

Rubao Ji, Associate Scientist, Biology Department. Dr. Ji's CINAR Fellowship is allowing him to work on transferring the modeling tools and data products developed in his previous and on-

going research projects for fisheries stock assessment and management, and to enhance/expand his existing education and training activities with NOAA and SMAST.

Porter Hoagland, Senior Research Specialist, Marine Policy Center. As a CINAR Fellow, Porter Hoagland is continuing work with colleagues on the development of a conceptual framework for the contribution of the social sciences to ecosystem-based fisheries management (EBFM). Further, he is studying the implications of competing models of the US northeast shelf ecosystem for the economic and welfare impacts of alternative fishery conservation and management strategies. Of particular interest is the identification of strategies that perform well under different ecological models and are, therefore, robust against model uncertainty.

Gareth Lawson, Assistant Scientist, Biology Department. In collaboration with colleagues at the NEFSC, Dr. Lawson is focusing on the development of acoustic techniques for sampling zooplankton and micronekton for the purpose of ecosystem assessment. He will also apply such techniques to the study of euphausiid ecology in the Gulf of Maine region and ecosystem dynamics at the New England continental shelf break.

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

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

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

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

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

SOCIETAL BENEFITS

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

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

APPENDIX A
CINAR Fellow Progress Reports

CINAR Fellow: Porter Hoagland, WHOI

PROJECT OVERVIEW

Linking economic and ecological models for ecosystem based fisheries management (EBFM) with a focus on their relationship to and use in coastal and marine spatial planning.
Teaching graduate and undergraduate students in the Department of Marine Affairs, University of Rhode Island. Mentoring graduate and undergraduate students at WHOI.

ACCOMPLISHMENTS

One new paper has been published:
Jin D, DePiper G, Hoagland P. 2016. An empirical analysis of portfolio management as a tool for implementing ecosystem-based fishery management. No. Am. J. Fish. Mgmt. 36:652-669.

One new abstract has been published:
Jin D, DePiper G, Hoagland P. 2015. An empirical analysis of portfolio management as a tool for implementing ecosystem-based fishery management. *American Fisheries Society* Portland (August 16-20, 2015).

HIGHLIGHTS

Portfolio management has been suggested as a tool to help implement ecosystem-based fisheries management.

The portfolio approach involves the application of financial portfolio theory to multispecies fishery management to account for species interdependencies, uncertainty, and sustainability constraints. By considering covariance among species, this approach allows economic risks and returns to be calculated across varying combinations of stock sizes. Trade-offs between expected aggregate returns and portfolio risk can thus be assessed.
We developed a procedure for constructing portfolio models to help implement ecosystem-based fisheries management in the northeastern United States, using harvest data from the National Marine Fisheries Service.

We proposed a measure of excessive risk taking, which may be used by managers to monitor signals of non-optimal harvests.
We conducted portfolio assessments of historical commercial fishing performance at different accounting stances: the large marine ecosystem, the New England region, and the community (fishing ports).
We show that portfolio analysis could inform management at each level. Results of the study suggest that excessive risk taking is associated with overfishing, and risk management is therefore important for ensuring sustainability.

SOCIETAL BENEFITS

This research has led to advances in understanding theories and practice relating to linked models of economics and marine ecology in the areas of ecosystem service valuation, coastal and marine spatial planning, and ecosystem-based fisheries management.
These advances, particularly the modeling approaches, are likely to see eventual adoption as sources of decision support.
The research has been communicated to social scientists and natural scientists in a variety of professional forums.
The research has been communicated to graduate and undergraduate students in the field of marine affairs and to Ph.D. candidates in marine affairs, environmental planning, and education.

EDUCATION AND OUTREACH ACTIVITIES

Department of Marine Affairs, University of Rhode Island: Taught one course: MAF 482: Quantitative Methods in Marine Affairs (Spring 2016).
Mentoring of students working on related research:
Joseph Dwyer, M.S., Department of Marine Affairs, University of Rhode Island
Aria Finkelstein, Ph.D. Candidate, Department of Urban Planning, Massachusetts Institute of Technology
Kelly Heber, Ph.D., Department of Urban Planning, Massachusetts Institute of Technology

PUBLICATIONS

Jin D, DePiper G, Hoagland P. 2016. An empirical analysis of portfolio management as a tool for implementing ecosystem-based fishery management. *No. Am. J. Fish. Mgmt.* 36:652-669.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

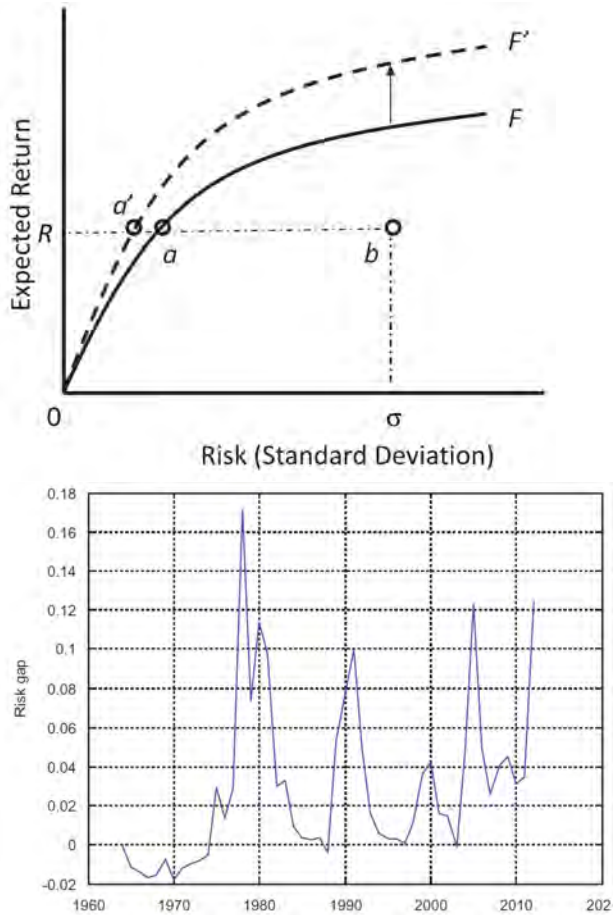

Figure. 1: Jin *et al*. (2016) developws a financial portfolio approach to ecosystem-based fisheries management for the Northeast and Mid-Atlantic fisheries, involving estimates of the tradeoffs between risks (modeled as the covariance among catches by species) and expected commercial returns. For any level of expected return, management is "efficient" when risks (which are costly) are minimized, such as outcomes occurring along the optimal risk-return curve *F*. A "risk gap" appears when *actual* risks depart from such efficient levels of risk. The emergence of risk gaps could signal the impending overexploitation of fisheries, implying that their measurement and interpretation could help to inform an "ecosystem-based" fisheries management. Panel (i) illustrates the principle of the risk gap, comprising the distance from an efficient portfolio "a" and a realized portfolio "b". Panel (ii) is a plot of the estimated historical risk gaps for all fisheries prosecuted in the Northeast Shelf Large Marine Ecosystem from 1964 to 2012.

CINAR Fellow: Rubao Ji, WHOI

PROJECT OVERVIEW

This project has three major components, including research, education/training and outreach.

1) Research: develop research proposals for the Northeast US Continental Shelf region; write research papers with scientists from NOAA and CINAR partner institutes.
2) Education/training: Advise students from the MIT-WHOI joint program and from School for Marine Sciences and Technology (SMAST) at University of Massachusetts.
3) Outreach: disseminate research results through international meetings; play a leadership role in research community activities.

ACCOMPLISHMENTS

- Developed 3 proposals that are related to the CINAR region, including 1) NSF BioOce proposal to examine Calanus finmarchicus population connectivity in the North Atlantic Ocean (Co-PIs include Ann Bucklin from UConn, Changsheng Chen from University of Massachusetts and Ann Tarrant from WHOI). 2) NSF LTER pre-proposal 1: Linking pelagic community structure with ecosystem dynamics and production regimes on the changing Northeast US. (Lead PI: Heidi Sosik from WHOI; involving two NMFS scientists in the proposal). This proposal was encouraged to submit a full proposal. 3) NSF LTER pre-proposal 2: Stellwagen Bank National Marine Sanctuary: A model for processes that generate ecosystem services on the US continental shelf. (Lead PI: Leslie Kaufman from Boston University; involving two NMFS scientists).
- Worked on 6 papers with scientists from NOAA and/or CINAR collaborators, with 3 papers published and 3 papers being prepared. The topics of the papers cover hydrodynamics, lower-trophic level food web and zooplankton population dynamics on the Northeast US Continental Shelf.
- Advised two PhD students and one Postdoc investigator. Served as an advisor for one MIT-WHOI Joint program student (Ben Jones) and as a committee member for one UMass student (Yu Zhang). Advised Postdoc (Dr. Yun Li) who has been with Drs. Paula Frantantoni and Jon Hare from NMFS and Dr. Changsheng Chen from UMass on stratification of NW Atlantic Shelf.
- Led research community activities: Serve as a steering committee member for RARGOM Annual Science Meeting 2015; Continue to participate ICES Working Group activities after rotating off as a co-chair in 2015; Co-hosted a workshop in the ICES/PICES 6th Zooplankton Symposium; Serve as a special volume editor for ICES Journal of Marine Science.

HIGHLIGHTS

- Developed 3 research proposals focusing on the CINAR region. All proposals involve CINAR partner institutes and NOAA collaborators.
- Leadership activities in the local (RARGOM) and regional (ICES/PICES) research communities by organizing science meetings and workshops.

SOCIETAL BENEFITS

1. Provided training for next generation fisheries oceanographer
2. Produced oceanography products that can help stock assessment and ecosystem-based management

EDUCATION AND OUTREACH ACTIVITIES

- Co-chair ICES Working Group on Integrated, Physical-biological and Ecosystem Modelling (*WGIPEM*) (rotated off in 2015).
- Steering committee member for RARGOM Annual Science Meeting 2015.
- Co-convene a workshop in the ICES/PICES 6th Zooplankton Production Symposium in Bergen, Norway, 2016 (W5 – The 'to' in the end-to-end models).
- Invited lecturer on ecosystem modeling in the Ocean Outlook Conference (Joint conference between WHOI and Bergen Ocean Cluster in Norway).
- Selected presentation 1: Ji, R., Z. Feng, B. Jones, C. Thompson, C. Chen, N. R. Record, J. A. Runge. Testing a new hypothesis on the persistence of *Calanus finmarchicus* in the Gulf of Maine: Coastal Amplification of Supply and Transport (CAST). 6th Zooplankton Production Symposium, 2016, Bergen, Norway.
- Selected presentation 2: Ji, R. 2016. Scale of ecosystem models. Ocean Outlook Conference, Invited lecture. April 2016, Woods Hole, MA, USA
- Selected presentation 3: Ji, R. Top down control on zooplankton. ICES Working Group meeting (WGIPEM). Brest, France.

PUBLICATIONS

Published:

- Jones, BT and Solow, A and Ji, R, 2016. Resource allocation for Lagrangian tracking. Journal of Atmospheric and Oceanic Technology. http://dx.doi.org/10.1175/JTECH-D-15-0115.1.

- Friedland, K. D., coauthors, Ji, R. (2016). Seasonal phytoplankton blooms in the North Atlantic linked to the overwintering strategies of copepods. Elementa: Science of the Anthropocene, 4, 000099. http://doi.org/10.12952/journal.elementa.000099
- Sathyendranath, S., R. Ji, and H. I. Browman, 2015. Introduction to the Themed Section: 'Revisiting Sverdrup's Critical Depth Hypothesis'. ICES Journal of Marine Science, 72(6), 1892–1896. doi:10.1093/icesjms/fsv110. (Editor for the special issue).

In preparation:

Ji, R., Z. Feng, B. Jones, C. Thompson, C. Chen, N. R. Record, J. A. Runge. Testing a new hypothesis on the persistence of Calanus finmarchicus in the Gulf of Maine: Coastal Amplification of Supply and Transport (CAST).

Li Y., R. Ji, P. S. Fratantoni, C. Chen, Y. Sun, J.A. Hare. Changing rhythm of stratification on the Northwest Atlantic shelf: interannual variability and its biological implications.

Fan. W, R. Ji. Model-based estimation of nitrogen budget in the Gulf of Maine.

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

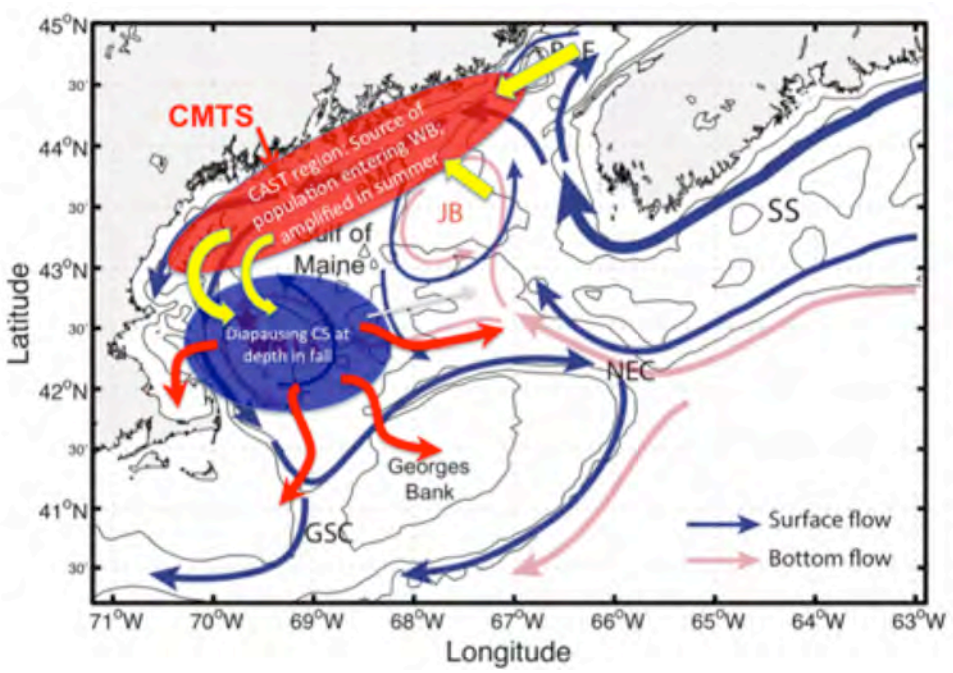

Figure 1. A new hypothesis on the persistence of a key zooplankton species, Calanus finmarchicus, in the Gulf of Maine, with a focus on the coastal amplification of supply and transport (CAST). Currently, Lagrangian tracking experiments using a copepod life history

CINAR Fellow: Gareth Lawson, WHOI

PROJECT OVERVIEW

My CINAR fellowship activities focus on research and education concerning two overarching topics: (1) Development of acoustic methods for sampling zooplankton and fish for the purpose of stock and ecosystem assessment, (2) Application of acoustic techniques for the study of euphausiid ecology and fisheries interactions in the Gulf of Maine region and ecosystem dynamics at the New England continental shelf break. This research program is highly collaborative, involving colleagues from the Northeast Fisheries Science Center (NEFSC) and the commercial fishing and acoustic manufacturing industries, as well as multiple students and postdocs.

For my CINAR fellowship I have been working on three inter-related research topics:

1. Collecting ancillary to routine NEFSC assessment surveys (e.g., ECOMON, marine mammal surveys, trawl surveys) as indices of zooplankton and micronekton abundance and for use in Integrated Ecosystem Assessment, spatial planning, and ecosystem-based management. This is a collaboration with Debra Palka, Michael Jech, Jonathan Hare (NEFSC), Dezhang Chu (NWFSC), and Peter Wiebe (WHOI).
2. Exploring the potential of new commercially available off-the-shelf broadband acoustic technologies for fish stock and ecosystem assessment through collection of field and laboratory data and community outreach. With Michael Jech (NEFSC), Andone Lavery (WHOI), Jeffrey Condiotty, Lars Andersen (Kongsberg Simrad), and Captain Christopher Roebuck (Commercial fisherman).
3. Examining spatial and inter-annual variability in the distribution of euphausiids along the northern flank of Georges Bank using multi-frequency acoustic data and quantifying the interaction of euphausiids with herring and other predators. With Michael Jech (NEFSC) and Michael Lowe (formerly WHOI now at LSU).

My educational activities mostly focus on training in acoustics, which I am achieving through course-based instruction and by working with students and postdocs with specific interest in the use of active acoustics for ecosystem assessment.

ACCOMPLISHMENTS

Multi-frequency acoustics for ecosystem assessment

I have a long-standing interest in the use of multi-frequency acoustic data for studying zooplankton and fish ecology. Under the CINAR fellowship, I have worked on the use of such data collected during routine assessment surveys (typically non-acoustic surveys) for ecosystem assessment. With NEFSC collaborators I am deriving indices of zooplankton and micronekton abundance from multi-frequency acoustic and ancillary data collected during marine mammal surveys conducted at the New England continental shelf break and slope during 2009-2015. Efforts to discriminate different kinds of organisms in these data are ongoing, after which they will be incorporated into marine mammal habitat models and used to examine the concentrating effects of submarine canyons. A doctoral student (Erin LaBrecque) involved in this work defended her dissertation earlier this year and has two manuscripts in development based on these data.

In a collaboration led by Dezhang Chu of the Northwest Fisheries Science Center, I contributed

to the development of a non-linear inversion method for estimating simultaneously multiple organismal parameters from multi-frequency acoustic data, including animal abundance, size, and behavior (i.e., orientation). This study was based on simulated data for fish (herring) and euphausiids. A paper based on this work recently appeared in the Journal of the Acoustical Society of America. This method will next be applied to real multi-frequency acoustic data from euphausiid aggregations observed in the wild.

Stemming from a successful session on ecosystem applications of acoustic methods that I convened with Kelly Benoit-Bird (OSU) at the ASLO-AGU Ocean Sciences 2014 meeting, we co-authored an invited review for the Annual Review of Marine Science.

Broadband acoustics

Prior to my fellowship, myself and others at WHOI have conducted pioneering field deployments of broadband echosounders, using a variety of custom-built systems. One focus of my fellowship is to contribute to the transitioning of this broadband approach to more routine use and to convince the acoustic community to adopt these new methods. To this end, together with WHOI, NEFSC, and industry collaborators I conducted tests and field deployments of a prototype Simrad broadband acoustic system for stock and ecosystem assessment. Analyses of data from a 2014 cruise suggest that the acoustic spectra of Atlantic butterfish, spiny dogfish, and Northern krill can be resolved and used to discriminate among species; this verified the central advantage of the broadband approach of providing improved acoustic target identification. Tank experiments have examined questions of calibration and also demonstrated that broadband measurements provide improved resolution of targets near boundaries (e.g., fish near the seafloor). These findings were presented at the 2015 ICES Symposium on Marine Ecosystem Acoustics and two manuscripts are in the final stages of preparation for the ICES Journal of Marine Science.

In 2015, the prototype Simrad system was officially released as the first commercial off-the-shelf broadband echosounder, and as a consequence there is an increasing amount of interest in broadband. During the 2015 ICES symposium I co-convened a well-attended and well-received workshop on broadband acoustic methods for fisheries and stock assessment, the goal of which was to chart a way forward for the international community as it moves towards adopting broadband approaches. These various broadband efforts have also led to a current collaboration with the Norwegian IMR examining groundfish. Furthermore, processing code, methods, and ideas have been exchanged with domestic collaborators at the AFSC, NWFSC, NOAA NOS Center for Coastal Fisheries and Habitat Research, and UNH Center for Coastal and Ocean Mapping, as well as international collaborators in Spain, New Zealand, and the UK.

Euphausiid ecology in the Gulf of Maine

One of my main ongoing research interests is in the ecology of euphausiids in the Northeast Shelf Large Marine Ecosystem, including understanding the bio-physical interactions underlying spatial and temporal variability in abundance and distribution, and how this variability in turn affects the distribution and population dynamics of predators (e.g., commercial fishes, marine mammals, seabirds). Michael Jech (NEFSC) and I have combined multi-frequency analysis of acoustic data collected during herring assessment surveys (1999-2012) with models of euphausiid scattering to estimate euphausiid biomass in the southern Gulf of Maine and verified these estimates relative to other information. These analyses were presented recently at the ICES Working Group on Fisheries Acoustics Science and Technology (WG-FAST). We will next

examine spatial variability in euphausiid distribution and seek to relate inter-annual variability in abundance to climate and environmental factors. Working with my former postdoc Michael Lowe we will also use NEFSC stomach content data to quantify the importance of euphausiids to herring population dynamics.

Education and Outreach

In 2014 I co-founded the WHOI-NEFSC seminar series on Fisheries and Ecosystem Acoustics, as one of my fellowship activities. The seminar series continued this past year, convening approximately every two months at NEFSC and also distributed as a webinar. By holding the seminar at NEFSC we have sought to encourage interactions between WHOI and NEFSC personnel, and attendance from both institutions has been high. The online audience has also regularly been large, including participants from other science centers (including the Pacific Islands, despite the time difference) as well as academic institutions, indicating a strong interest in this topic and a need for this kind of specialized seminar. The interactive nature of the webinar furthermore has allowed questions and discussion among the on-line and physical audiences and speaker.

In 2014, I co-developed a new inter-disciplinary oceanography course for the MIT-WHOI Joint Program. That course continued this past year and included a module on fisheries and climate in the Gulf of Maine, focused on Atlantic cod. I have involved multiple graduate students and postdocs in my research program, providing training in acoustics and ecosystem science. I have continued my participation in the ICES Working Group on Fisheries Acoustics Science and Technology and the Working Group on Target Classification, including contributions to the latter's forthcoming ICES Cooperative Research Report.

HIGHLIGHTS

- Analyses were conducted of multi-frequency acoustic data collected ancillary to routine NEFSC surveys in order to generate indices of zooplankton and micronekton abundance as indices for Integrated Ecosystem Assessment, spatial planning, and ecosystem-based management, including indices of zooplankton and micronekton abundance from shelf-break marine mammal surveys (2009-2014) and estimates of euphausiid biomass from herring assessment surveys (1999-2012).
- Successful tests and analyses of tank and field data were conducted with a new broadband echosounder, investigating the potential of this technology for stock and ecosystem assessment. Two publications are in the final stages of preparation.
- Co-authored a review paper on ecosystem applications of active acoustic methods.
- Co-authored a paper presenting a new non-linear method for simultaneous estimation of multiple organism parameters (e.g., abundance, size, and orientation) from multi-frequency acoustic data.
- Co-convened a WHOI-NEFSC seminar series on Fisheries and Ecosystem Acoustics; attendance has been high, including online participation via webinar.
- Co-convened a workshop on broadband acoustic methods at the ICES Symposium on Marine Ecosystem Acoustics, the major international venue for acoustic-related research.
- Multiple educational activities were conducted, including course-based activities and involvement of students in acoustic research.

SOCIETAL BENEFITS

My work using multi-frequency data collected during routine non-targeted assessment surveys leverages an under-utilized data stream to address the need for indices for Integrated Ecosystem Assessment, while the more experimental work on broadband acoustics addresses the problems of target identification and resolving fish near the seafloor, two chronic issues in acoustic assessment surveys. My ongoing studies of euphausiid ecology and of the New England shelf break are drawing attention to the management relevance of these under-studied organisms and this under-sampled region, filling gaps in currently available data and providing key information for ecosystem models and ecosystem-based fisheries management. The educational activities I am pursuing center on developing the necessary acoustic expertise in the next generation of assessment scientists, and three recent graduates from my lab and greater research group have found positions within NOAA.

EDUCATION AND OUTREACH ACTIVITIES

Education

- WHOI host and advisor for Robert Levine, a graduate student in the Cornell-WHOI Master's program working on krill at the New England shelf break. Mr. Levine defended his thesis in May 2014 and accepted a contract position in the acoustics group at the NMFS AFSC. I continue to work with Mr. Levine on developing his thesis for publication.
- WHOI host for Erin LaBrecque, a Ph.D. student at Duke University working on acoustic methods for assessing marine mammal prey fields via the WHOI-Duke Fellowship in Marine Mammal Conservation. In 2016, Ms. (now Dr.) LaBrecque successfully defended her Ph.D. and is presently developing her dissertation chapters for publication.
- Co-advisor with Michael Fogarty and Jason Link (NEFSC) of NOAA post-doctoral researcher Michael Lowe, with research interests focused on euphausiids and shelf break trophic interactions. Dr. Lowe has applied, so far unsuccessfully, for multiple positions within NOAA NMFS. Dr. Lowe recently accepted a new postdoc position at LSU.
- WHOI host for guest postdoc Timothy White (CUNY), a seabird ecologist relating bird distribution to concurrent acoustic observations of prey made during cruises conducted by my lab in 2010. In fall of 2014 Dr. White accepted a contract position with the NOAA Biogeography Branch and in 2016 has applied for a permanent biologist position.
- I worked closely with Christopher Bassett, a WHOI post-doctoral scholar advised by my collaborator Andone Lavery, including on methods for processing broadband acoustic data and discriminating targets near boundaries (e.g., fish near the bottom). Following his time at WHOI Dr. Bassett accepted a position with NOAA AFSC.

Outreach

- Lawson, G., A. Lavery, M. Jech, P. Wiebe, and N. Copley. 2015. Integrated acoustic, optical, and net studies of euphausiid ecology in the Gulf of Maine. ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.
- Bassett, C., A. Lavery, T. Weber, G. Lawson, M. Jech, R. Korneliussen, G. Macaulay, and E. Ona. 2015. Application of broadband echosounders for detection and characterization of targets near boundaries. ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.
- Chu, D., P. Wiebe, and G. Lawson. 2015. Quantifying the non-uniqueness in a nonlinear inversion method using a Bayesian approach. ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.

- Jech, M., A. Lavery, G. Lawson, and C. Bassett. 2015. Acoustic Observations of Fish and Zooplankton Over a Wide Frequency Band (15 - 400 kHz). ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.
- Reynisson, P., A. Gislason, and G. Lawson. 2015. Target strength estimation of the euphausiid Thysanoessa raschii in an Icelandic fjord by in situ method and a theoretical scattering model. ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.
- Lawson, G. 2015. Advanced sampling technologies for marine fisheries and ecosystem research. Transatlantic Science Week 2015: Blue Futures. Boston, MA. [Invited]
- Lowe, M., G.L. Lawson, M. Fogarty. 2015. Drivers of Spatial and Temporal Variability in the Distribution and Abundance of Krill in the Northeast U.S. Shelf Large Marine Ecosystem. AFS Annual Meeting, Portland OR.
- Convened a workshop on broadband acoustics at the ICES Symposium on Marine Ecosystem Acoustics, Nantes, France.

PUBLICATIONS

Benoit-Bird, K.J. and G.L. Lawson. 2016. Ecological insights from pelagic systems acquired using active acoustic techniques. Annual Review of Marine Science, 8: 21.1-21.28.

Chu, D., G.L. Lawson, and P.H. Wiebe. 2016. Estimation of biological parameters of marine organisms using linear and nonlinear acoustic scattering model-based inversion methods. Journal of the Acoustical Society of America, 139: 2885

FIGURES/PHOTOGRAPHS/ILLUSTRATIONS

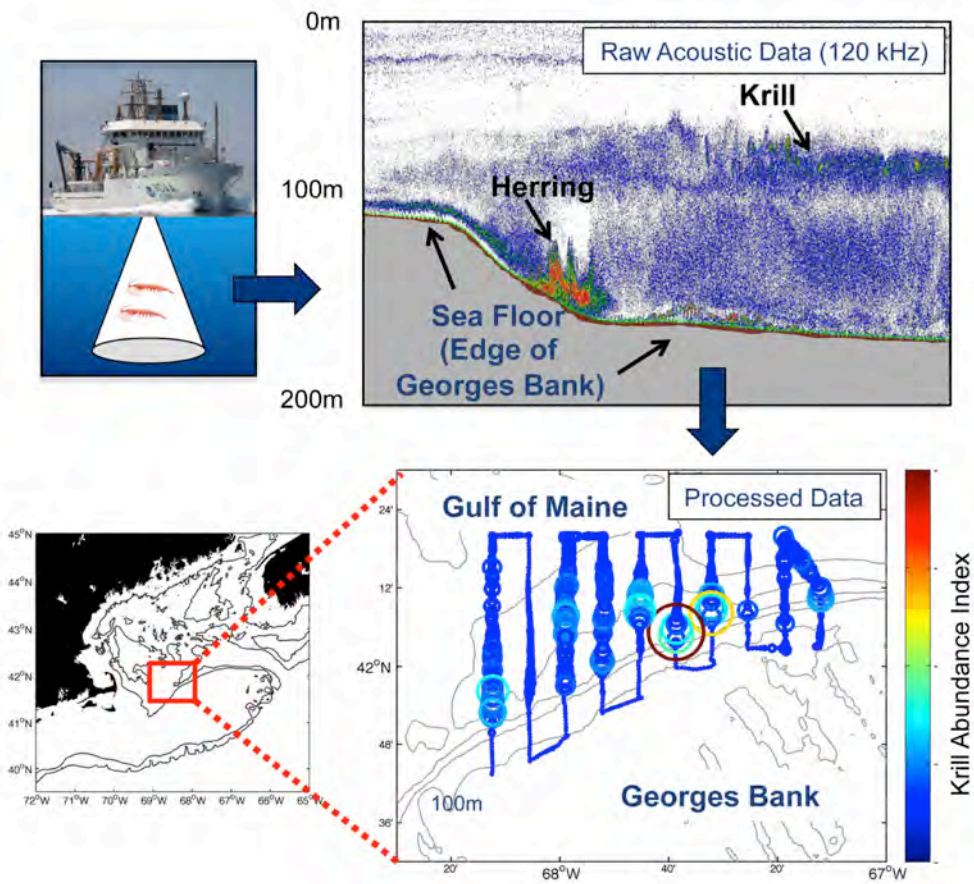

Figure 1. Top: Echogram of acoustic data (120 kHz) collected along the edge of Georges Bank showing layers of krill and herring. Bottom: Index of krill abundance integrated over the water column derived from multi-frequency analyses.

SMAST Faculty, Gavin Fay

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

ACCOMPLISHMENTS

Dr. Gavin Fay was hired as new tenure-track assistant professor at SMAST, and started in September, 2015.

This grant provided Dr. Fay was with 95% of his salary support during academic year 2015-2016, and also for conference travel to fund his attendance at the First World Summit on Atlantis Ecosystem Model, Honolulu, HI, December 2015 (http://atlantis.cmar.csiro.au/www/en/atlantis/Atlantis-Summit.html). This conference was the first of its kind for this ecosystem model and brought together researchers from across the world to work on best practices and future directions for the Atlantis modeling framework. I was a member of the steering committee, which was made up of researchers from the U.S., Australia, Norway, France, and Iceland.

Graduate students were supported in 2015-2016 by the previous CINAR award (NA09OAR4320129), which is described in the current progress report for this grant.

Classroom activities:

Dr. Fay taught the four classes during the 2015-2016 academic year,

- MAR580-01 Models for Marine Ecosystem Based Management (solo taught 3 unit course).
- MAR580-03 Advanced Population Modeling, co-taught with Prof. Cadrin (team-taught 1 unit courses).
- MAR536 Biological Statistics II, co-taught with Prof. Cadrin (team-taught 1 unit courses).
- MAR700-02 Graduate Seminar, Fisheries Oceanography (team-taught 1 unit courses).

MAR 580-03 and MAR 536 were revised and planned to develop a more integrated curriculum in quantitative fisheries science with Prof. Cadrin, while MAR 580-01 was a new course. Dr. Fay also develed a new graduate course that will be taught in Fall 2016, “Quantitative workshops in fishery and ecosystem science”. This course is designed as a series of in depth seminars with participation by federal and state agency scientists. It is intended this course will help foster student interactions and collaborations with agency partners.
A brief description of each is provided below:

MAR 580-03: Advanced Population Modeling

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

MAR 580-01: Models for Marine Ecosystem Based Management
This course provides instruction, demonstration, and exercises in quantitative modeling tools used for Ecosystem Based Management (EBM) of living marine resources. There is an increasing need for fisheries and wildlife professionals to provide scientific advice for management in an ecosystem context. Part 1 of the course will provide students with hands on experience applying fisheries stock assessment and population models that include ecosystem effects, and consider the policy implications of including this information. Part 2 of the course will focus on broader multiple-use and human dimensions and include economic and behavioral models and models for marine spatial planning. The final section of the course will introduce whole-of-ecosystem models and demonstrate how these can be used to provide strategic advice for marine management and consider a broad suite of objectives. Although the examples used will be in a marine context, the types of models and methods discussed in the course have application in other systems.
This was a new course, with lectures, computer labs, and online learning modules.

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

In addition to these activities, Dr. Fay organized a training course in the stock assessment software Stock Synthesis (Apr 2016) for SMAST students and staff, and NMFS and state agency (MA, RI, NC) assessment scientists. Graduate students from Rutgers University and the University of Maine also attended. The course was held at SMAST II, Fairhaven and was taught by NOAA Fisheries Chief Scientist for stock assessment, Dr. Rick Methot, and NOAA Fisheries Operations Research Analyst Dr. Teresa A'mar.

Dr. Fay also co-chaired an International Council for the Exploration of the Sea (ICES) student review group with Prof. Cadrin (May 2016). 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 was able to use time on CINAR funds in the initial semester to develop and submit 9 grant proposals. Six of these have been funded. One is currently pending, and two were unsuccessful. Newly funded grants include:

- Fay, G., S.X. Cadrin. Developing and testing stock assessments for black sea bass using Stock Synthesis. Mid-Atlantic Fisheries Management Council. $68,768.
- Georgianna, D., G. Fay, S. Inglis, K. St. Martin, M-Y. Lee, K.S. Stokesbury. Combining Fishermen's Knowledge with Oceanographic and Economic Models to Locate, Evaluate, and Predict Gray Meat Outbreaks in Atlantic Sea Scallops. Saltonstall Kennedy NOAA-NMFS-FHQ-2015-2004246. $299,551.
- Fay, G. Peer review of red drum stock assessment. Atlantic States Marine Fisheries Commission. $3,000.
- Fay, G., M.V. Winton. Estimating loggerhead sea turtle density in the US Mid-Atlantic. NOAA Northeast Fisheries Science Center. EE-133F-15-RQ-0798. $51,582.
- Miller, T.J., G. Fay, K. Curti. Development and evaluation of a state-space multispecies fisheries assessment model. NOAA Stock Assessment Analytical Methods. $193,303. ($18,603 to UMass Dartmouth)
- Morzaria-Luna, H.N., E. Andonegi, T. Ihde, C. Ainsworth, I. Kaplan, G. Fay, A. Keth, J. Link. Exploring ecosystem-level effects of fisheries, management, and climate change in marine systems. Microsoft Research. $20,000 (in computing time).

HIGHLIGHTS

- Four peer-reviewed publications published or in revision, and six technical reports.
- Three courses and one seminar taught in topics relevant to NOAA QUEST program priorities.
- Support for proposal development has resulted in six newly funded grants to help Dr. Fay continue to establish his research program at UMass Dartmouth.
- Partial or full support for 4 Ph.D. students at University of Massachusetts Dartmouth. 1 student defended thesis and is now employed as a stock assessment scientist at NOAA Fisheries Southeast Fisheries Science Center.

SOCIETAL BENEFITS

Research supported has direct application to improving the stock assessment and management of commercially important fish species. Dr. Fay worked as invited expert to provide advice to ICES implementation of integrated ecosystem assessments. Project supported the graduate education of four PhD students and also established a new faculty position at the University of Massachusetts Dartmouth who will train future NOAA stock and ecosystem assessment scientists.

EDUCATION AND OUTREACH ACTIVITIES

In addition to the aforementioned teaching activities, Fay was the speaker for the following talks:

- Fay, G., J.S. Link, R.J. Gamble, S. Lucey, S.K. Gaichas, R.P. Wildermuth, E. Olsen, EA Fulton, R. Gorton. 2015. Quantifying Tradeoffs for Ecosystem-Based Fisheries Management: Scenario Analysis in the Northeast US Using a Whole-of-System Model. American Fisheries Society Annual Meeting. Portland, OR, USA.
- Fay, G. 2015. Including regime shifts in fisheries assessments and harvest recommendations using hidden Markov models. ICES Annual Science Conference. Copenhagen, Denmark.
- Fay, G., S.K. Gaichas, G.S. DePiper, M.J. Fogarty, R.J. Gamble, S.I. Large, J.S. Link, S.M. Lucey, L.A. Smith, J.C. Tam. 2015. Testing an ecosystem-based fisheries management procedure for Georges Bank: a multi-model approach for quantifying societal and ecological tradeoffs. ICES Annual Science Conference. Copenhagen, Denmark.
- Fay, G. 2015. Testing management performance of ecosystem indicators using a multi-model approach. Gulf of Maine Research Institute, Portland, ME. October 2015 (invited seminar).

No CINAR funds from the current award (NA14OAR4320158) were used to support graduate students during this academic year; however, the following students were supported on the previous CINAR award (NA09OAR4320129):

- Robert Wildermuth, PhD. Thesis title: 'Qualitative and Bayesian network social-ecological models for use in Integrated Ecosystem Assessment' (at 100% from 1/18/15-6/3/15)
- Megan Winton, PhD. Thesis title: 'Methods for including electronic tagging data in integrated analysis of highly migratory species' (at 100% from 1/4/15-6/27/15)

PUBLICATIONS

- Olsen E, G. Fay, S. Gaichas, R. Gamble, S. Lucey, and J.S. Link. 2016. Ecosystem Model Skill Assessment. Yes We Can! PLoS ONE 11(1): e0146467.
- Weijerman M, J.S. Link, E.A. Fulton, E. Olsen, H. Townsend, S. Gaichas, C. Hansen, M. Skern-Mauritzen, I. C. Kaplan, R. Gamble, G. Fay, M. Savina, C. Ainsworth, I. van Putten, R. Gorton, R. Brainard, K. Larsen, T. Hutton. *In Press.* Atlantis Ecosystem Model Summit: Report from a Workshop. Ecological Modeling.
- Fay G., J.S. Link, J. Hare. Assessing the effects of ocean acidification in the Northeast US using an end-to-end marine ecosystem model. Marine Ecology Progress Series.
- Gaichas S.K., M. Fogarty, G. DePiper, G. Fay, R. Gamble, S. Lucey, L. Smith. Combining stock, multispecies, and ecosystem level fishery objectives within an operational management procedure: simulations to start the conversation. ICES Journal of Marine Science.

Technical Reports

- McNamee, J., G. Fay, and S. Cadrin. 2015. Data Limited Techniques for Tier 4 Stocks: An alternative approach to setting harvest control rules using closed loop simulations for management strategy evaluation. Report to the Mid-Atlantic Fishery Management Council Scientific and Statistical Committee. July 2015. 57p.
- SEDAR. 2015. SEDAR 44, Atlantic Red Drum, Section III: Review Workshop Report. In: SEDAR. 2015. SEDAR 44–Atlantic Red Drum Stock Assessment Report. SEDAR, North Charleston SC. 890 pp. available online at: http://sedarweb.org/sedar-44.
- Haas HL, Sasso CR, Winton MV, Smolowitz RJ, Fay G. (2016). Marine turtle tagging

volume. Five Year Report to the Atlantic Marine Assessment Program for Protected Species, 14 pp.

- SAW/SARC Black Sea Bass Working Group. 2016. Black Sea Bass Benchmark Stock Assessment Review. Term of Reference 1 – Spatial issues. Proposed partitioning of northern black sea bass stock for purposes of developing spatial stock assessment models. Report to the Mid-Atlantic Fishery Management Council Scientific and Statistical Committee. January 2016. 40p.
- ICES. 2016. Final Report of the Working Group on Working Group on the Northwest Atlantic Regional Sea (WGNARS), 21-24 March 2016, Falmouth, MA, USA. ICES CM 2016/SSGIEA:03. 30 p.
- Fay, G. & J. Brust. 2016. Peer review report for the Atlantic Red Drum stock assessment. Report to the Atlantic States Marine Fisheries Commission. April 2016. 14p.

U.S. National Office for Harmful Algal Blooms

NOAA Cooperative Agreement No. NA14OAR4320158
July 1, 2009-March 31, 2016

CINAR Investigator: Donald Anderson, WHOI

NOAA Sponsor: Quay Dortch, NOS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

PROJECT OVERVIEW

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:

National HAB Web Site: The *Harmful Algae* Web Site (www.whoi.edu/redtide) serves as a critical resource for the U.S. HAB community. The site is among the top three WHOI sites visited each month, with between 6,500 to 7,500 visits per month. In addition to maintaining the Web Site, conference announcements, funding opportunities, reports, etc. of interest to the HAB community are routinely posted and circulated through our numerous listservers.

Harmful Algae Facebook Page: In addition to maintaining the *Harmful Algae* Web Site, we maintain the Harmful Algae Facebook Page: (https://www.facebook.com/pages/Harmful-Algae/210160985681846). This site is updated on a near daily basis with news reports and other announcements related to HAB events and research. This is a very popular method for disseminating information to the HAB community, the general public, and Congressional staff. It is viewed between 4,000 and 20,000 times every month, and according to Facebook statistics accessed on May 20th, this site has received 1,269 total page "likes" since its inception. Over the

last 30 days alone, 5,800 people were "reached" by its posts. In February, a single post about whale deaths in Alaska was clicked on by over 1,000 people, 366 of whom then shared or forwarded the link, resulting in a total "reach" in excess of 22,000 people.

HAB community mailing lists: The National Office maintains a U.S. HAB community e-mail distribution list used for announcing meetings, funding opportunities, and other issues of relevance to the broad group of those involved in U.S. HAB research, monitoring, and management. Currently the list comprises over 600 individuals representing a growing HAB research community that has come to rely on us to distribute important messages to their colleagues. In conjunction with CSCOR HAB program managers, we continue to add individuals working in the areas of freshwater HABs, socioeconomic impacts of HABs, and endangered species and HABs. We have also been adding state, local and tribal managers who are still not familiar with national HAB efforts. We currently maintain listservers for ISSHA (the International Society for the Study of Harmful Algae**)**, SoundHAB (for HABs in the Puget Sound, WA area), Northeast PSP (for *Alexandrium* blooms in New England), GOMA HABs (for Gulf of Mexico Alliance HABs), NADSP (for North American Diarrhetic Shellfish Poisoning) and the National HAB Committee.

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

The National Office undertakes the unique role of compiling information on HAB events in the U.S. as the ICES *National Coordinating Center for Exchange of Information on Harmful Algal Blooms*. This involves annual efforts interacting with colleagues around the U.S. to compile reports of all national HAB events each year. We are responsible for the entry of these data into the HAEDAT database maintained by the ICES Science and Communications Center in Vigo, Spain. Presentations on these bloom reports are also given at annual working group meetings of the ICES Working Group on Harmful Algal Bloom Dynamics (WGHABD). National and international bloom reports are provided to all U.S. network participants, as well as to other interested parties. This is the only compilation of U.S. HAB incidents. Decadal maps for all U.S. HAB events are usually updated annually for ICES as well as posting on the Harmful Algae Web site (see http://www.whoi.edu/redtide/page.do?pid=14898&tid=542&cid=47893&c=3 for an example). In addition, PI Anderson presented a summary of U.S. events for 2015 at the 2016 WGHABD meeting. Recently the ICES Science and Communications Center in Vigo, Spain opened this database up to the public for browsing (http://haedat.iode.org/).

Intergovernmental Panel on Harmful Algal Blooms

Every two years, the IOC convenes the Intergovernmental Panel on Harmful Algal Blooms (IPHAB) to oversee the many aspects of the global HAB program. PI Anderson has attended these panel meetings since their inception, and participates as a scientific advisor and member of the US delegation. He has chaired several IPHAB task teams or activities in the past, and is currently chair of the Task Team on HABs and Desalination. The next IPHAB meeting will be in April, 2017.

Event Response Program

The National Office administers a Rapid Response Program for HAB Events in the U.S. in cooperation with CSCOR administrators. This involves advertising the availability of funds to the HAB community as well as accepting requests for funds and administering their dispersal. The National Office works with NOAA Program Managers who decide who receives funds and how much will be needed in each case. Additionally, we make arrangements and process travel, vessel charters, analyses, and other expenses associated with these rapid response activities.

During the past year this office worked with scientists and managers on the following unexpected or unique HAB events: an extensive and unprecedented bloom of *Alexandrium monilatum* in the lower Chesapeake Bay region; a mass mortality event of more than 100 adult diamondback terrapins in Flanders Bay, Long Island, NY; and the massive and widespread outbreak of domoic acid (DA) along the West Coast, which led to the closures of recreational and commercial fisheries for razor clams, and Dungeness and rock crab, and prompted Governor Brown to request the first-ever federal declaration of a fishery disaster and commercial fishery failure in California due to a HAB event. It is impossible to predict what the next year will bring in terms of HAB events, but the Office will be ready to assist NOAA CSCOR with administering the Rapid Response Program.

Scientific Meetings/Workshops

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 *16th International Conference on Harmful Algae* (Korea) and the *Eighth Symposium on Harmful Algae in the U.S.* (California).

U.S. HAB symposia. Kleindinst served on the Steering Committees for the *8th Symposium on Harmful Algae in the U.S.*, which was held November, 2015 in Long Beach, CA. She worked closely with the organizers to plan the meeting, and to communicate updates and announcements to the U.S. HAB community. The National Office will also solicited and processed travel awards for students and managers for the HAB symposium. Richlen will serve on the Steering Committee for the *9th and 10th U.S. HAB Symposium*.

International HAB Conferences. Anderson serves on the Steering Committee for the *17th International Conference on Harmful Algal Blooms*, which will be held in Brazil in 2016, and will also serve on the Steering Committee for the subsequent ICHA meeting in 2018.

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 subcommittee on Education and Outreach. The National Office arranges and leads conference calls for the group as well as in-person meetings.

HIGHLIGHTS

- Assisted with the planning and organization of the *Eighth Symposium on Harmful Algae in the U.S.* (California), including soliciting and processing travel awards for students and managers.
- Soliciting and selecting travel awards for students and managers for the *17th International Conference on Harmful Algae* (Brazil).

SOCIETAL BENEFITS

All of the activity under this project relates to HABs, a serious and growing threat to the nation's fisheries, coastal ecosystems, and human coastal communities.

EDUCATION AND OUTREACH ACTIVITIES

- Anderson, D.M., U.S. Summary of HAB Events – 2015, ICES WGHABD, Brest, France, April, 2016)
- Harmful algae website: http://www.whoi.edu/redtide
- 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 communicates with journalists about HAB issues frequently (estimated 5 or 6 over the past year alone).

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

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 -March 31, 2016

CINAR Investigator: Alexa Dayton, GMRI

NOAA Sponsor: Earl Meredith, NEFSC

Related NOAA Strategic Plan Goals: Healthy Oceans

CINAR Theme: Education and Outreach

PROJECT OVERVIEW

For the period April 1, 2015 to March 30, 2016 the MREP Implementation Team proposed to carry out four initiatives:

- Deliver one MREP Science 100 module and one MREP Management 100 module in a Mid-Atlantic location;
- Develop and deliver a new MREP, covering both science and management, tailored to the needs of recreational fishermen;
- Develop and deliver a new MREP 200 module, focused on Ecosystem-based management, to be offered to MREP graduates; and
- Perform active outreach in building a fishing community network to support MREP training and recruiting throughout the Northeast 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.

ACCOMPLISHMENTS

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

- January 5-7, 2016 – MREP Science 100 in Norfolk, VA (three days).
- January 19-21, 2016 – MREP for Recreational Anglers in Baltimore, MD (three days).
- February 23-25, 2016 – MREP Management 100 in Norfolk, VA (three days).
- March 15-16, 2016 – MREP Ecosystems 200 at the NOAA/NEFSC Howard Lab at Sandy Hook, NJ and in Long Branch, NJ (two days).

Norfolk, VA was chosen as the venue for the MREP Science and Management 100 modules in an effort to engage communities of fishermen who have become reticent in participation in fishery management, based on input from multiple sources. The standard MREP 100 curricula were adapted to the information needs of these communities; for example, the Science 100 added presentations examining linkages between estuarine/bay environments and the productivity of open-ocean fish stocks, and the Management 100 included added information on the role of

ASMFC and a presentation given by NOAA Office of Law Enforcement.

MREP for Recreational Anglers was a new venture for MREP in the Northeast, added in response to strong demand by that community. We purposely structured it to provide a 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.

Both MREP for Recreational Anglers and MREP Management 100 included variations 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 the 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 communities in NC, VA and MD were the focus of MREP Science and Management 100, with a high percentage of "pier leaders" in attendance.
- 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, 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.
- Over 100 individual attendees and presenters participating in one or more of the four workshops, approximately 70% of who are new faces to the program.

EDUCATION AND OUTREACH ACTIVITIES

A general 3000-piece mailing went out to commercial and highly-migratory permit holders in the Mid-Atlantic region, followed by direct one-on-one recruiting through packing houses based in the Newport News area and key fishermen's associations (e.g., NC Fisheries Association and NC Watermen United).

Most of the participants were recruited through word-of-mouth by these advisors and through consultation; priority was placed on engaging members of the recreational fishing community who are prominent, vocal, and positioned to inform other recreational anglers. The result was an

attendee list heavily weighted with fishing association leaders, tackle shop owners, and moderators of recreational blog-sites. Also attending as participants were a NOAA/Sliver Spring expert on MRIP reporting and GARFO Administrator John Bullard. The result was an average of 25 attendees at each module, from ports as far north as MA, but predominantly from NC, VA and MD.

Appended please find an article by Steve Cannizzo, graduate of the MREP for Recreational Anglers module. Steve is a blog moderator for *Fishing United*, the premier website for recreational fishermen on the East Coast, with over 10,000 subscribers. The article first appeared online in the *Fishing United* member's page.

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

Figure 1. MREP attendees participate in fish dissections.

Figure 2. MREP attendees engage in discussions during one of the workshops.

Marine Resource Education Program - Southeast

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Alexa Dayton, GMRI

NOAA Sponsor: Kim Amendola, NMFS

Related NOAA Strategic Plan Goals: Healthy Oceans

CINAR Theme: Education and Outreach

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, including one 3-day fishery science workshop and one 3-day fishery management workshop for commercial and recreational fishermen, tailored to the region by an 18-member Steering Committee.
GMRI proposed to recruit 20 program participants for the Management workshop during the reporting period, and also recruit an additional 20 participants for a Science workshop, with class compositions that reflect a high degree of diversity. The format of the workshop creates an open dialogue among participants and presenters in which they explore ways of fostering cooperation among fishermen, scientists and managers.
GMRI further proposed to reconvene the regional Steering Committee for a fourth annual meeting, engage them in a program review and evaluation of the third year, and foster industry leadership.

ACCOMPLISHMENTS

Fisheries Science Workshop
The second MREP Southeast Science Workshop was held April 14 - 16, 2015 in St. Petersburg, Florida. The 3-day workshop was held at the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWRI) facility. Participants in the workshop included fishermen, industry representatives, and a few others such as council members, drawn from the South Atlantic, Gulf of Mexico, and the Caribbean council regions. The Fisheries Science course was exceptionally well received, and ran according to plan. We had 28 attendees plus 20 presenters and other planning team members attend the presentations, small group break out sessions, research lab tours and meals together, creating an unparalleled networking and open dialog opportunity among fishermen, scientists and managers in the region. We observed trust building, increased cooperation, and myths were dispelled.

Fisheries Management Workshop
The second of the two-part workshop series, the MREP Management Workshop was held in Tampa, Florida September 22 – 24, 2015 and also included participants from the South Atlantic and Gulf of Mexico. A total of 31 participants attended the workshop, representing commercial,

recreational and charter fishermen as well as fish house owners/dealers and a representative from the marine manufacturing sector. 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.

In addition to the presentations, the always popular Council Case Study/Role Play Scenario, and the energizer 'Jeopardy' game introduced at the last Management workshop, we also included two new units not included in previous years: a presentation on the National Marine Sanctuary Program by Sean Morton, Superintendent of the Florida Keys National Marine Sanctuary, and an open discussion panel seated by Roy Crabtree, Regional Administrator, NMFS-SERO, Andy Strelcheck, Deputy Regional Administrator, NMFS-SERO, Bob Mahood, Executive Director, SAFMC, and Doug Gregory, Executive Director, GMFMC.

The newly developed National Marine Sanctuary Program overview provided attendees the opportunity to learn how the Sanctuary Program compliments regional fisheries management while giving participants one-on-one access to a key figurehead in that program in the Southeast/Gulf of Mexico region. The open discussion panel allowed attendees to engage regional leaders in discussions on topics of personal interest. The participants capitalized on this time by asking panelists to elaborate on concepts presented earlier in the MREP program, as well as addressing questions and issues not directly covered in the workshop but of key interest to their sector or livelihood.

Additionally, meals and break times continued to be invaluable moments for networking, asking questions, and allowing casual interaction among the presenters and attendees. Breaks were almost always longer than planned, as participants and presenters readily engaged in conversation during these periods. We observed that phone numbers were exchanged and follow-ups for post workshop contact were developed on an individual basis.

HIGHLIGHTS

- Fisheries science education program delivered for 28 fishermen and an additional 20 speakers and other guests, in St Petersburg, FL, April, 2015.
- Fisheries management education program delivered for 31 fishermen and an additional 20 speakers and other guests, in Tampa, FL, September, 2015.
- Reconvened MREP Southeast Steering Committee in November 2015, and with four new members selected from prior year workshop attendees.
- Reconvened MREP Puerto Rico Steering Committee in August 2015.
- Fisheries science education program refined based on prior year evaluations.
- Fisheries management education program refined based on prior year evaluations.
- Speaker's bureau was expanded and enhanced for science & management workshops.
- Performed extensive outreach and networking to generate a third year of program applicants.

Workshop evaluations were universally positive and indicated a significant increase in participants' likelihood to participate in fisheries science and management activities, such as cooperative research, data collection, and fishery management council activities. Five fishermen applied for Council Advisory Panel positions; of these, three were appointed. Two fishermen have engaged in new cooperative research projects. MREP Puerto Rico, evidence of the program's replicability in other regions, continues to bring forward new voices for the Caribbean

fisheries region, and lay a foundation of trust for alternate approaches to fisheries management in the region.

SOCIETAL BENEFITS

This education enables fishermen and others to participate productively in the fisheries science and management processes, and leads to improved cooperation and trust between fishermen, scientists and managers. Fundamentally, a co-learning approach is used in this program, where program developers, program participants and program presenters all learn from one another through their interactions and collaborations.

We fostered industry leadership through the Steering Committee construct, and workshop moderator opportunities, and saw new individuals become engaged in fisheries discussions, delivering increased leadership capacity for the region.

MREP Southeast has prepared industry members for meaningful engagement in the Council process, as articulated and envisioned by Magnusson Stevens Act.

EDUCATION AND OUTREACH ACTIVITIES

We performed a multi-faceted outreach campaign to generate workshop program applicants. We did this in part by creating a postcard mailer, which was circulated to a large randomly selected subset of 5,000 fishing permit holders in the Southeast region. We also mailed a small stack of 20 postcards and a few posters to each of our 18 Steering Committee members, encouraged them to hand these out and generate program referrals, and hang posters in their local ports, as well as submit opinion columns to their local fisheries newspapers, and post on discussion boards, and electronic forums. This yielded 71 applicants for a total of 32 program slots.

We then convened our industry planning team to review the applications and selected a group of 32 program participants to accept into the workshop, representing a balanced cross section of interest groups, with at least two thirds being a mix of recreational and commercial fishermen. We placed the other people on the waiting list for next year. We also included one council member from each of the three council regions, and these individuals were nominated by the Councils. In addition, we included several non-traditional stakeholders in the cohort, including a motor sales representative from Yamaha marine motors, to determine relevance of the program to this audience.

We recruited program presenters, many returning from prior years and some new presenters. They were coached by our industry planning team in ways to effectively communicate complex scientific concepts to a stakeholder/non-scientific audience, specifically the fishing industry. Program presenters were drawn from Southeast Fisheries Science Center, University of South Florida, Gulf of Mexico and South Atlantic Fishery Management Councils, Florida Fish and Wildlife Research Institute, and the Southeast Regional Office.

We have evaluated the workshop program delivery with post-program evaluations. The full Steering Committee was provided with periodic updates on curriculum development progress, which were written and sent by GMRI staff. They were engaged in sub-committees and the planning team as a way to directly shape the program content.

A unique website page was developed for this effort. We used photos provided by Steering Committee members, and NOAA staff to ensure the proper look and feel for the Southeast region.

FIGURES/PHOTGRAPHS/ILLUSTRATIONS

Figure 1. MREP Southeast has now achieved a scale and level of industry awareness, which has increased the number of program applicants significantly leading to a substantial waiting list.

Figure 2. 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. The program culminates in a fictitious council scenario, which generates lively discussion, debate and allows application of material learned to real work concepts.

Figure 3. Fisheries stakeholders from a variety of regions and sectors (Recreational, Commercial, Charter) work together in small groups during hands-on otolith ageing activity.

Figure 4. One-on-one conversations and small group interactions between participants and presenters help to establish relationships, and build trust with fisheries stakeholders outside the regulatory arena.

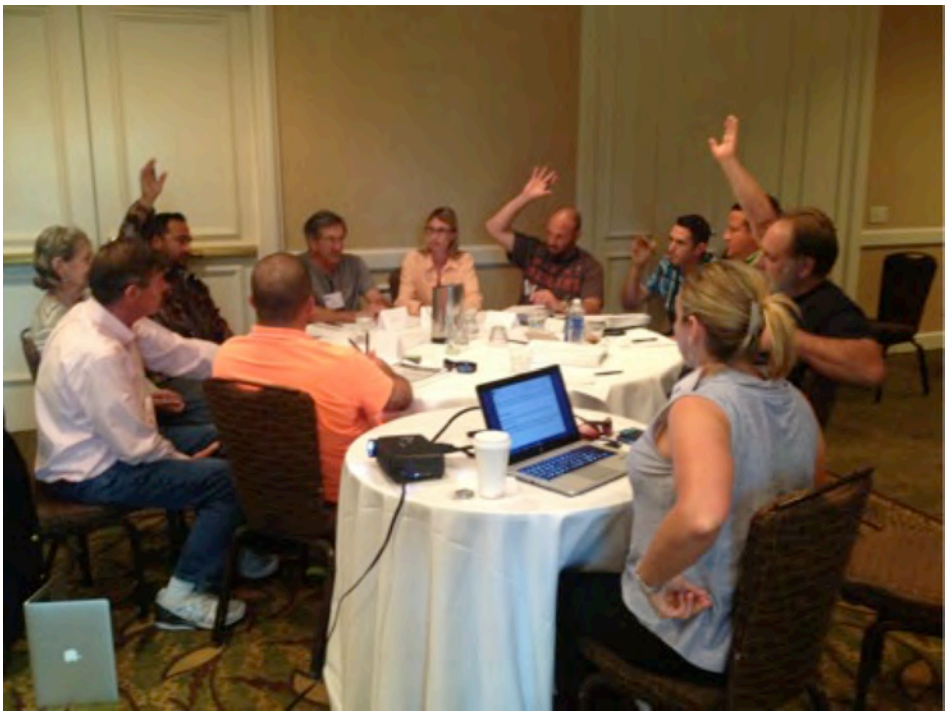

Figure 5. MREP cohorts bond with each other and maintain contact with each other and program presenters even after the workshop concludes.

Advancing the International Deep-Sea Coral Symposium

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Timothy Shank, WHOI

NOAA Sponsor: Martha Nizinski, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

PROJECT OVERVIEW

Understanding the role, function, and value of deep-sea coral ecosystems has become a priority topic for many national governments and international regional resource management bodies. Continuing in the tradition of past Symposia in Halifax, Canada and Erlangen, Germany (see Table below), the 6th International Symposium on Deep-Sea Corals (ISDSC) will facilitate global exchange of current scientific knowledge and rapidly developing hypotheses on deep-water corals and their associated fauna and to discuss potential statutory means available to conserve and protect deep-sea habitat.

In the last decade, the global presence of deep sea, cold-water corals in a range of ocean margin settings has been established, and is still being expanded. Associated with the corals is the presence of huge carbonate mound structures and deep-sea reefs, which contain unique records and a detailed history of ambient ocean water conditions over periods of rapid climate change. The coral reefs and mounds form very rich benthic habitats of spectacular biodiversity, housing more coral species in deep cold-waters than in tropical coral reefs. Because of their function as a nursery for commercially important fisheries, in combination with increasing environmental pressures, the cold-water corals, reefs, and mounds are seriously threatened and management and policy making is a must. The 6th International Deep Sea Coral Symposium addresses new developments and knowledge through a range of themes and topics and will take place at the Boston Marriott Long Wharf in Boston, MA, USA from Sept 11-16, 2016.

The 6th International Symposium will provide attendees from around the world with an opportunity to share their research results, identify information gaps, and discuss if deep-sea corals need special protection and if so, the statutory means available to do so. Being international and inter-institutional in nature, the symposium also allows scientists to develop collaborative partnerships for future projects. A public forum presented by selected deep-sea coral researchers will be held one evening. Given the Northeast US location for this Symposium, we anticipate potentially more than 500 participants (the last US ISDSC in Miami in 2005 hosted more than 300 attendees) and covering a broad range of ongoing and upcoming topics. The 6th ISDSC will bring together new developments and knowledge through a range of themes (1-4) and associated topics that will include: (1) Biology, Demography and Ecology, (2) Habitat and Environmental Settings, (3) Oceans Past/Future and Climate Change, (4) Threats, Management and Conservation Policy Strategies

ACCOMPLISHMENTS

Andy Daly and Tim Shank visited and surveyed more than a dozen possible venues in Boston in 2015. Through comparisons of available facilities, proximity to Boson resources, and costs, it was decided that The Marriot Long Wharf Conference Hotel will be the site of the Symposium, and a contract was being finalized.

HIGHLIGHTS

The 6th International Deep Sea Coral Symposium, addressing new developments and knowledge through a range of themes and topics, will take place from Sept 11-16, 2016 at The Marriot Long Wharf Conference Hotel in Boston, MA, USA.

SOCIETAL BENEFITS

The vast majority of deep-ocean resources, specifically coral ecosystems that support commercially-important fisheries and endemic biological diversity, are currently unknown. Only through the communication, exchange, and advancement of scientific information will the first order discovery and characterization of these resources be known for the subsequent and effective ability to protect and manage such resources, and the impacts of climate change on these resources and their stewardship.

UMaine Cooperative Education

NOAA Cooperative Agreement No. NA14OAR4320158
April 01, 2015 – March 31, 2016

CINAR Investigator: Gayle Zydlewski, UMaine

NOAA Sponsor: Richard Langton, NMFS

Related NOAA Strategic Plan Goal: Healthy Oceans

CINAR Theme: Education and Outreach

PROJECT OVERVIEW

The main objective in Year 2 was to hire additional undergraduate students to continue work previously started and conduct new internships with the local NOAA-Fisheries Office. Two previously established undergraduate continued with these project funds.

ACCOMPLISHMENTS

- Two students continued from previous internships at the Maine Field Office and UMaine.
- Six more internships were developed between UMaine and NOAA-Fisheries.
- Applicant solicitation occurred in mid-September 2015.
- Applicants were interviewed at the beginning of October; nine applicants representing two different departments at the University of Maine were interviewed.
- Eight interns were hired.
- In April 2016 a solicitation for four summer and fall internships were advertised.
  13 applications from two UMaine departments were received.
  All were interviewed.
  8 internships were filled, 6 for the summer and 2 for the fall.

HIGHLIGHTS

John Carlucci: I read, cited, and summarized several scientific papers and developed a literature brief. These papers were related to biological and migratory related effects of trapping and trucking migratory fish around hydroelectric barriers. The end goal of this review was to establish a current knowledge base to support the development of a Biological Opinion in regards to trapping and trucking of endangered Atlantic salmon in the Kennebec and Penobscot Rivers. These systems were formerly some of the most productive Atlantic salmon rivers in the US. This issue has received attention from federal, state, and non-government organizations considering this practice as a viable restoration tool for Atlantic salmon in rivers impacted by hydroelectric facilities. We are trying to better understand how trapping and trucking programs could be beneficial, negligible, or detrimental to the overall success of Atlantic salmon restoration.

Audrey Dean: I cleaned, mounted, imaged, and measured Atlantic salmon scales collected as part of the Carlin tag project from 1962 to 1992. I began working on this project in the fall of 2014, and I examined scales from 1000 fish in the summer of 2015. By the end of this semester, I, along with fellow intern Sameera Salame, will have examined scales from another 1000 fish. The goal of this project is to see how the marine phase of growth changed as a result in changes in productivity in the Northeast Atlantic Ocean in the 1990s. Although the larger project will not be finished by the end of the semester, the initial processing of the scales will be complete.

Alexandra Alterman: I greatly valued my time as an Intern for NOAA and UMaine during the fall of 2015. I gained key skills in using Excel and Access to analyze datasets. I know I will have a job in the future that will use one or both of these programs, so I am very glad I have a basic understanding of how both of them work. Also, this internship involved both collaborative and independent work. I spent a lot of time entering data and creating queries on my own. I also worked very closely with my project leader Christine during data analysis, and the interpretation of those findings. This internship was my first exposure to scientific research, as I am sure it will be for many other students in the future. Christine and the other project leaders recognized this and created an amazing learning experience. This opportunity has made me a competitive candidate for other professional opportunities. I hope the program continues for students in the future so they can have an equally beneficial experience.

Erin Mercier: I revised and prepared a survey originally created by a former graduate student at UMaine. The survey builds on efforts to determine current preferences and practices influencing the participation of a group or an individual when sharing acoustic telemetry data through a formal network. Formal networks provide scientists with the ability to build partnerships with other scientists using acoustic telemetry, and enable them to share detection data for future projects; however, some researchers choose not to participate. Our survey asked researchers about their involvement with data sharing and the factors determining whether or not they are willing to collaborate. Each of the questions was designed to give a better understanding about what researchers want in an acoustic data sharing network, with the hope that changes in network policies will increase participation and benefit the scientific community and species management.

Jamie Fisher: I cleaned and mounted smelt scales. I learned the proper technique of cleaning scales by following a protocol where the scales were placed in a sonicator and further cleaned using a paintbrush. I mounted scales on a slide and then aged the scales using a microscope. I learned how to look for an annulus in order to determine age. I also learned how the data will be analyzed. Length measurements were recorded for each fish. Graphs of length measurements and the corresponding age were created. I also had the chance to participate in hydroacoustic trips. I learned how this process operates and how it is used to map the fish distributions.

Sameera Salame: In summer 2015 I worked with Ruth Haas-Castro in Woods Hole, imaging and aging Atlantic salmon scales from various Maine Rivers. I learned how to mount scales properly, how aging is shown on salmon scales, how to use image analysis software, and how to identify the difference between a salmon that was wild caught or a hatchery reared fish. Through this we can see the age differences in the salmon that return to the river after spawning. In fall 2015-spring 2016, I worked with the Carlin Scale Project at the NOAA Maine Field Station. I learned how to properly clean adult salmon scales and mount them on slides, and enter the Join-ID into the database. I will be returning to Woods Hole this summer to continue this internship.

Tal Kleinhause-Goldman: I started my internship with Christine Lipsky in January 2016. While it has only been about 3 months, I have already learned a lot about the environmental effects on river fishes, as well as new data analysis techniques. One of the most exciting opportunities thus far has been connecting the theories from my coursework to real data in the lab. For example, after learning in my Evolution course about the different time periods that might be needed for changes in a population to accrue, I take a look on the data in the lab and saw firsthand how the length of Alewife fish is getting smaller over the course of only five years.

SOCIETAL BENEFITS

These internships are giving undergraduate students the opportunity to interact with NOAA scientists concerning societally-relevant marine science issues. These experiences could be instrumental in the students' career paths and their active involvement in fisheries issues.

EDUCATION AND OUTREACH ACTIVITIES

Several of these students, Audrey Dean and Erin Mercier, have presented this work at the UMaine School of Marine Sciences capstone symposium and the Atlantic Salmon Ecosystem Forum (below).

Dylan S. Whitaker, James P. Hawkes , Joe Zydlewski , and Timothy F. Sheehan 2016 Do we hit to the target? Evaluation of thermal exposure of river- and hatchery-reared juvenile Atlantic salmon prior to migration on the Narraguagus. Presentation at 2016 Atlantic Salmon Ecosystems Forum

Mercier, E., Zydlewski, G.B., Johnson, T. 2016 Improving data sharing in acoustic telemetry networks. Presentation for UMaine SMS capstone symposium

Dean, A. 2016. Sea Pens of Maine 2016 Presentation for UMaine SMS capstone symposium

PUBLICATIONS

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

FIGURES/PHOTOGRAPHS/ ILLUSTRATIONS

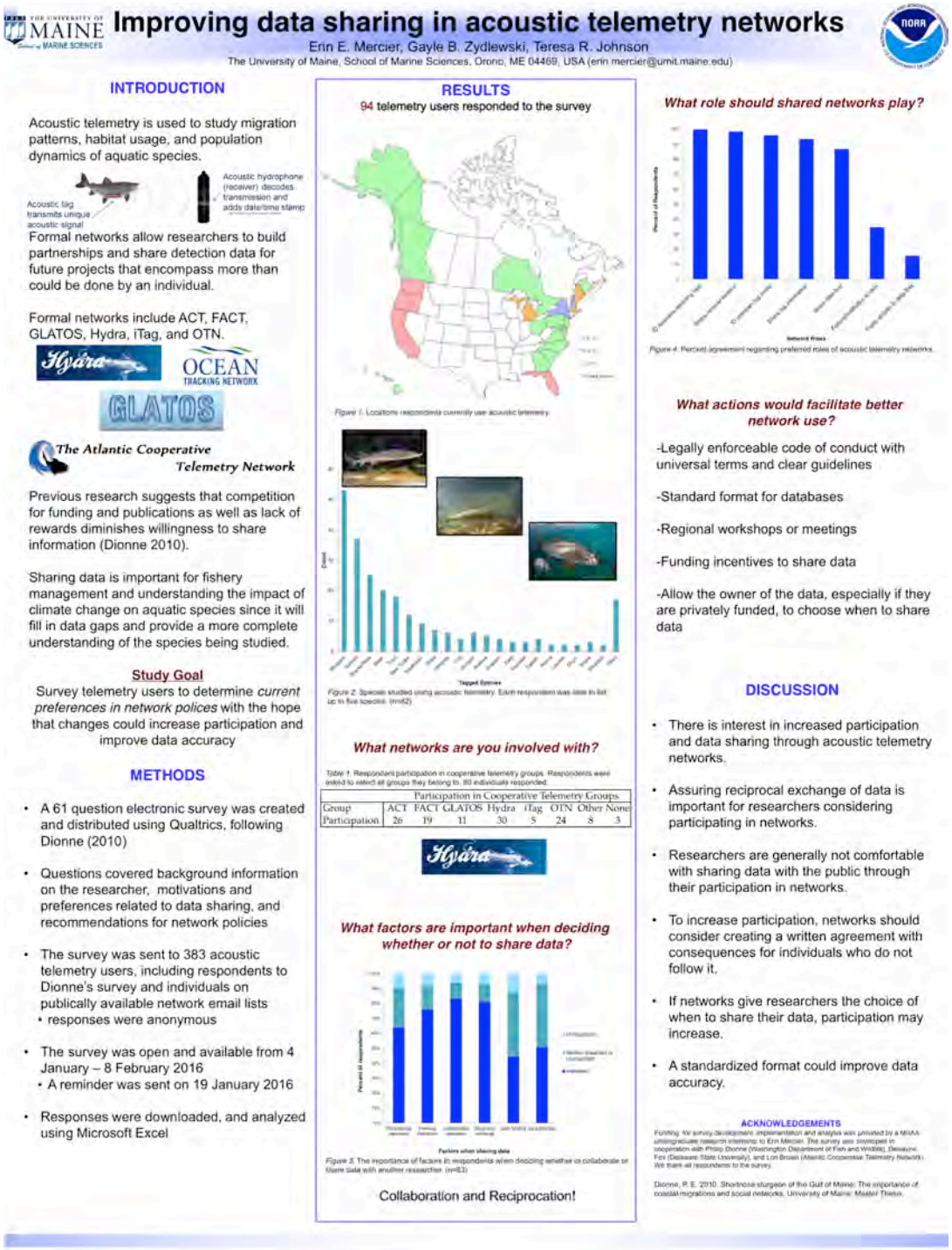

Figure 1. Poster presented by Erin Mercier at the UMaine School of Marine Sciences capstone symposium.

APPENDIX 1: CINAR Personnel Summary

NA14OAR4320158
July 01, 2015– June 30, 2016

Task 1 Support

Employees	**Appt. Dates**
Don Anderson, CINAR Director	7/01/09 - present
Judy Kleindinst, CINAR Administrator	7/01/09 – 7/31/2015
Mindy Richlen, CINAR Associate Director	6/01/15- present
Ann Stone, CINAR Administrative Professional	9/26/09 - present

Postdoc	**CINAR Theme**	**Appt. Dates**	**Advisors**
Dr. Joel Llopiz University of Miami	Ecosystem Monitoring	Fall 2010 (18 Month appt.)	Simon Thorold Carin Ashjian
Dr. Robert Todd University of California, San Diego	Sustained Ocean Observations and Climate	Fall 2011 (18 month appt.)	Fiammetta Straneo Glen Gawarkiewicz Steven Lentz Albert Plueddemann
Dr. Ke (Kevin) Chen North Carolina State University	Sustained Ocean Observations and Climate	Fall 2012 (18 Month appt.)	Glen Gawarkiewicz Steven Lentz
Dr. Sarah Bender University of Washington	Ecosystem Monitoring	Fall 2013 (18 Month appt.)	Max Saito
Dr. Andrew Jones	Ecosystem Monitoring	Fall 2014 (18 Month appt.)	Joel Llopiz

APPENDIX 2: CINAR Personnel Summary Chart

April 1, 2015 – March 31, 2016

Category	Number	B.S	M.S	PhD.
Employees who receive ≥ 50% NOAA Funding (not including Students)				
Research Scientist	0	0	0	0
Visiting Scientist	0	0	0	0
Post Doctoral Fellow	0	0	0	0
Research Support Staff	0	0	0	0
Administrative	0	0	0	0
Total	0	0	0	0

Category	Number	B.S	M.S	PhD.
Employees who receive < 50% NOAA Funding (not including Students)				
Research Scientist	41	2	0	39
Visiting Scientist	0	0	0	0
Post Doctoral Fellow	1	0	0	1
Research Support Staff	10	6	3	1
Administrative	11	10	0	1
Total	63	18	3	42

Students	-	-	-	-
Undergraduate Students	10	0	0	0
Graduate Students	2	2	0	0
Total	12	2	0	0

Obtained NOAA employment within the last year	0	0	0	0

APPENDIX 3: CINAR Publications for Reporting Period

	2014-2015	2015-2016
CI Lead Author	8 peer-reviewed 3 non peer-reviewed	17 peer-reviewed 3 non peer-reviewed
NOAA Lead Author	0 peer-reviewed 0 non peer-reviewed	8 peer-reviewed 1 non peer-reviewed
Other Lead Author	3 peer-reviewed 0 non peer-reviewed	31 peer-reviewed 6 non peer-reviewed

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