



DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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RECIPIENT ORGANIZATION	
20. Recipient Name: WOODS HOLE OCEANOGRAPHIC INSTITUTION	
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ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

The Cooperative Institute for the North Atlantic Region (CINAR) is a regional CI that focuses on the Northeast U.S. Shelf Large Marine Ecosystem (NEUS LME), a critical region within the North Atlantic that spans from Cape Hatteras to Nova Scotia, encompassing the continental shelf from the continental slope to the northern wall of the Gulf Stream. The CINAR consortium is led by the Woods Hole Oceanographic Institution (WHOI), and includes the Gulf of Maine Research Institute (GMRI), Rutgers University (Rutgers), University of Maryland Center for Environmental Science (UMCES), University of Maryland Eastern Shore (UMES), University of Massachusetts Dartmouth - School for Marine Science and Technology (SMASST), University of Maine (UMaine), and University of Rhode Island (URI). Through our NOAA and academic partnerships, the CINAR consortium provides a mechanism for NOAA scientists to easily and rapidly obtain research assistance and facilities or infrastructure support for projects, and respond to technical needs through the development of instruments, models, and approaches that contribute to management decisions. This CI was established in 2019, and is completing its fourth year of a five-year award.

CINAR projects are carried out under five research themes: (1) Sustained Ocean Observations and Climate Research; (2) Ecosystem Research, Observation, and Modeling; (3) Stock Assessment Research; (4) Protected Species Research and Recovery; and (5) Ecosystem-Based Fisheries Management. Research carried out by CINAR investigators over the past year encompassed a variety of activities and programs under these five themes to address NOAA research and management needs in the Northeast region and beyond.

In addition to these activities, an important goal of CINAR is to promote education and outreach among member institutions and within the broader scientific community. To achieve this goal, we offer traineeships and fellowships at a variety of academic levels, including undergraduate internship programs, CINAR Minority Traineeships, participation in the Inclusive NOAA Fisheries InternSHIP (IN FISH) program, and early career faculty fellowships to help train future generations of NOAA marine scientists. Student participation in CINAR research is further facilitated through the NOAA Living Marine Resources Cooperative Sciences Center at the University of Maryland Eastern Shore. Our outreach programs span a diversity of topics, and include activities to foster better management of harmful algal blooms in the U.S., as well as a series of science and management workshops for commercial and recreational fishermen to foster improved cooperation and trust among fishermen, scientists, and managers.

25. What was accomplished under these goals?

Select research accomplishments from a subset of CINAR programs are highlighted below, organized under each of our CI's five major research themes. Figures cited in text can be found in Appendix 6. Education, outreach, and training activities are described in comment field #26.

Theme I – Sustained Ocean Observations and Climate Research. CINAR activities generated datasets and analyses that are critical to quantifying and modeling climate forcing and consequent ecological impacts, including efforts to: 1) maintaining the NTAS, Stratus and WHOTS Ocean Reference Stations, which provide sustained, climate-quality observing of the trade wind region (PIs: R. Weller/A. Plueddemann, WHOI; Fig. 1); 2) go-live of NOAA Fisheries DisMAP tool to visualize, analyze, and communicate climate-related changes to marine species distributions (PI: M. Pinsky, Rutgers); and 3) maintaining the Atlantic array of Argo floats (PI: S. Wijffels, WHOI), including use of 42 floats for rapid sampling before and during Hurricane Ida to examine hurricane dynamics (PI: T. Miles, Rutgers; Fig. 2).

Theme II – Ecosystem Research, Observation, and Modeling. CINAR projects used data from CINAR's ocean observing programs to understand and describe ecological parameters and processes in the NEUS LME, and developed tools and techniques to improve regional ecosystem forecasting, management, and policy decisions. Select highlights included: 1) development of Long Range AUVs with stereoscopic camera systems for benthic surveys near offshore wind farms (PI: A. Kukulya, WHOI; Fig. 3), 2) development of data products for analyzing decadal-scale trends in pH and impacts of ocean acidification (PI: G. Saba, Rutgers; Fig. 4), and 3) development of an in-situ dual-parameter carbonate chemistry profiling sensor for high resolution OA measurements (Z.A. Wang, WHOI; Fig. 5).

Theme III – Stock Assessment Research. CINAR research is working to improve stock assessments of species found in the NEUS LME through the development of data collection, modeling, and forecasting approaches. Highlights included: 1) evaluation of management procedures to resolve the identified mismatch in biological populations and management units of Atlantic cod (PI: L. Kerr, GMRI; Fig. 6); pairing of acoustic data and eDNA signals to assess biomass and distribution of herring and other commercially viable fish (PI: G. Sherwood, GMRI; Fig. 7); and 3) integration of multi-state tagging data for >500K striped bass and development of both a mark-recapture and population dynamics models (PI: M. Wilberg; UMCES).

Theme IV – Protected Species Research and Recovery. CINAR researchers developed new technologies and approaches for the assessment and recovery of protected species. These efforts contribute to improvements in defining, protecting, and restoring essential habitat for these species. Research highlights included: 1) development of innovative satellite-linked dorsal fin tags for coastal and continental shelf cetacean monitoring and tracking (PI: M. Moore; WHOI; Fig. 8); 2) use of a matrix of Slocum gliders, wave gliders, and moored buoys to monitor the occurrence and distribution of whales and commercially important fish (PI: M. Baumgartner; Fig 9); and 3) pairing of aerial photogrammetry and exhaled breath samples to monitor the body condition and

Attach a separate document if more space is needed for #6-10, or #24-50.

ACCOMPLISHMENTS (cont'd)

26. What opportunities for training and professional development has the project provided?

Over the past year, CINAR investigators provided research, training and professional development opportunities through direct participation of students and postdocs in research, as well as specific programs to connect with communities. Selected achievements and programs are highlighted below:

1. Undergraduate minority traineeship program: For many years, CINAR has supported an undergraduate minority traineeship program, which provides funding to each CI partner institution in support of summer fellowships for students from underrepresented communities. Over the past year, CINAR partnered with the newly developed NOAA undergraduate diversity internship program IN FISH (Inclusive NOAA Fisheries InternSHip), which provides internship opportunities for undergraduate students largely underrepresented in the marine science and resource management fields, as well as mentorship/training opportunities to the host investigators and institutions so that they learn together with the students. The goal of IN FISH is to build diverse talent to be the future workforce of NOAA, representative of our constituency. Under this partnership, CINAR supported five undergraduate students in 2022, who participated in coursework and cohort building activities along with a larger cohort of 15 IN FISH students. They then traveled to the CINAR partner that hosted them, and participated in an additional 8 week intensive mentor-led research project. Please visit the following webpage for more information about each participating student and their research: <https://website.whoi.edu/cinar/education-outreach/in-fish/>.

2. Graduate/undergraduate student, and postdoc participation in research: CINAR research programs offer many opportunities to engage graduate students, postdocs, and early career scientists, and provide career training to the next generation of NOAA scientists. Students are introduced to an active and collaborative research environment, interact with scientific leaders in ecosystem research, start building a network of contacts for advanced studies and a career in science or resource management, and gain experience with ecosystem-scale research, proposal writing and presentation skills. Over the past year, CINAR investigators included 29 graduate students, 34 undergraduate students, and 12 postdocs in their research programs, and expanding student and postdoc participation in research is an important priority going forward.

3. Quantitative Fisheries and Ecosystem Science faculty support: The goal of this program is to engage early career scientists in research to improve and enhance the assessment and management of fisheries resources in the region. With support provided by NOAA's Quantitative Ecology and Socioeconomics Training (QUEST) program, these two-year fellowships provide support to early career faculty at CINAR partner institutions that conduct research and educational activities related to stock assessment and quantitative fisheries science in the NEUS LME. Over the past year, CINAR supported five fellowships for early career faculty, and also held a competition to fund a second round of fellowships, which were awarded to four recipients. Complete information about this fellowship program, and current fellows and their research activities can be found on the CINAR website: <https://website.whoi.edu/cinar/people/fellows/>.

27. How were the results disseminated to communities of interest?

In addition to the educational and outreach programs described in comment box #26, results were disseminated through the numerous peer-reviewed publications, websites, and public presentations. These are too numerous to list here, but are described and detailed in Appendices 4 and 5, and comment field 32.

ACCOMPLISHMENTS (cont'd)

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

Work on all ongoing and new research and educational programs will continue under the last year of CINAR's current award. We recently announced an opportunity for CINAR investigators to propose workshops for CINAR scientists and NOAA partners to initiate scientific research on a particular topic, advance research in emerging and interdisciplinary fields, and/or create a community of practice for a new idea. These workshops will be convened in late 2023-early 2024. During the upcoming year, CINAR will also undergo a 5-year review of our administrative and science activities, and we look forward to the constructive feedback and assessment provided by the review panel. We will continue to seek opportunities to expand our partnership with the NOAA IN FISH program, and to support a greater number of summer student fellowships. We will continue to explore opportunities to augment programmatic funding for our education programs, and for expanded engagement of UMES undergraduate and graduate students in research at CINAR consortia via the LMRCSC. The second round of QUEST early career fellowship recipients will initiate their research activities, expected to extend to the end of our award period.

PRODUCTS

29. Publications, conference papers, and presentations

A comprehensive listing of all publications, conference papers, and presentations by CINAR investigators associated with the current reporting period are provided as Appendix 4 and Appendix 5. Please note that DOI numbers are provided for each peer-reviewed publication.

PRODUCTS (cont'd)

30. Technologies or techniques

Technologies and techniques associated with CINAR research are listed below:

- Anderson (WHOI) Imaging FlowCytobot for unprecedented resolution of the composition and abundance of primary producers in ecosystems.
- Baumgartner (WHOI): near real-time detections of whales from autonomous gliders and buoys.
- Cadrin (SMAST, Cod research): Acoustic receiver data continues to be shared with other researchers through the Atlantic Cooperative Telemetry Network (ACT), www.theactnetwork.com
- Foote (WHOI): Three-dimensional morphometric data derived from CT or MRI scanning of specimens of adult butterfish and Atlantic mackerel.
- Gerbi (UMaine): Development of an ARMS deployment system by the AK Fisheries Science Center and a collecting ARM for the ROV system owned by AK Dept. of Fish and Game.
- Grebmeier (UMCES): As part of our national and international activities, the DBO-NCIS is tracking identified Essential Ocean Variable (EOV) in relation to benthic populations in the Pacific Arctic.
- Jakuba (WHOI): Wave Glider operations fully integrated with AUV.
- Jayne (WHOI): Argo floats for physical and biogeochemical sensing.
- Kukylua (WHOI): Long-range AUV (LRAUV) with stereoscopic camera survey capabilities to conduct National Marine Fisheries Service benthic surveys in and around offshore wind farm developed areas.
- Miles (Rutgers): Analyses will be used to develop guidance for future use of Argo profiling floats in hurricane forecast operations.
- Rynearson (URI): Preliminary protocol for extracting DNA from Right Whale feces.
- Sherwood (GMRI): Preliminary model results indicate habitat, seasonal, and length-specific variation in cod indices of abundance.
- Wang (WHOI): CHANOS II has the capability to efficiently define the seawater carbonate system in studying and monitoring ocean acidification.
- Weller (WHOI): The Ocean Climate Observations and Analyses effort supports three Ocean Reference Stations (ORS), which are well-equipped surface moorings, deployed to provide sustained observations of the trade wind region.

31. Inventions, patent applications, and/or licenses

Nothing to Report

PRODUCTS (cont'd)

32. Other products

Other products developed by CINAR PIs are listed below:

- Anderson (WHOI): Cyst cruise data supports NOAA harmful algal bloom forecasting and modeling: <https://products.coastalscience.noaa.gov/hab/gomforecast.aspx>.
- Anderson and Richlen (WHOI): U.S. National Office for Harmful Algal Blooms website (<https://hab.whoi.edu/>), a “clearinghouse” for information related to national and international activities on HAB issues.
- Baumgartner (WHOI): The website <http://robots4whales.whoi.edu/> displays near real-time detections of whales from autonomous gliders and buoys.
- Fay (SMAST): GitHub repositories of Hydra estimation model development - https://github.com/thefaylab/hydra_sim; Hydra diagnostics - https://github.com/thefaylab/hydra_diag; Hydra simulation -<https://github.com/MaC-Perez/Hydra-self-testing>. Recordings of past quantfish workshops also available.
- Grebmeier (UMCES): DBO-NCIS is tracking identified Essential Ocean Variable (EOV) in relation to benthic populations in the Pacific Arctic -- <https://arctic.noaa.gov/Arctic-News/ArtMID/5556/ArticleID/385/Distributed-Biological-Observatory> and <https://dbo.cbl.umces.edu>
- Greig (UMaine): Van de Sande, J., V Watson, and C. Federico. October 2022. Narraguagus Restoration Project. Video, Instagram. <https://www.instagram.com/p/CjS8SqpsPTM/>
- Jayne (WHOI): The Argo database: <http://doi.org/10.17882/42182>
- Kerr (UMaine): GitHub central repository for Atlantic cod project enables collaborative model development and code review: <https://github.com/lkerr/Cod-Stock-Structure-MSE> . Northeast Climate Integrated Modeling project website: <https://gmri.org/projects/northeast-climate-integrated-modeling-nclim/> and GitHub central repository <https://github.com/Northeast-Climate-Integrated-Modeling>.
- Lohrenz (SMAST): Created a website to visualize oceanographic features and Illex catch. Includes satellite imagery; subsurface conditions via data from EMOLT (Environmental monitors on Lobster Traps) and The Pioneer Array (WHOI's coastal observatory); trends from the weekly size data from ILXSM and catch data from the Illex quota-monitoring website; and notable observations. Shiny app for viewing/assessing ILXSM paired length and weight data (in development).
- Mills (GMRI): VAST End-of-Century Projections Wiki. Online: <https://github.com/James-Thorson-NOAA/VAST/wiki/Projections> and Species Distribution Modeling Workflow: https://gulfofmaine.github.io/sdm_workflow/docs/index.html#preface
- Pickart (WHOI): Database of shipboard acoustic Doppler current profiler (ADCP) data for the Chukchi / western Beaufort Seas includes 58 cruises from June-November 2002.
- Pinsky (Rutgers): Contributed to <https://apps-st.fisheries.noaa.gov/dismap/>
- Schwartz (URI): Nutrient data have been merged with other physical and chemical data collected by NOAA and are available at NCEI's OCADS portal.
- Todd (WHOI): Todd, R.E., Owens, B. (2016). Gliders in the Gulf Stream [Data set]. Scripps Institution of Oceanography, 10.21238/S8SPRAY267575. Plots of real-time and post-processed glider data: <http://gliders.whoi.edu>

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

The CINAR PIs include Donald M. Anderson, CINAR Director, Woods Hole Oceanographic Institution; Paulinus Chigbu, University of Maryland Eastern Shore; Paula Bontempi, University of Rhode Island; Steve Lohrenz, University of Massachusetts Dartmouth School for Marine Science and Technology; Graham Sherwood, Gulf of Maine Research Institute; Oscan Schofield, Rutgers University; Michael Roman, University of Maryland Center for Environmental Science; and David Townsend, University of Maine. Additional CINAR personnel include Mindy Richlen (CINAR Associate Director), Claire Anacreon (Administrative Associate). A listing of project investigators is provided in Appendix 1.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to Report

35. What other organizations have been involved as partners?

Consortium members and subawardees include Woods Hole Oceanographic Institution, University of Maine, Rutgers University, Gulf of Maine Research Institute, University of Maryland Center for Environmental Science, University of Massachusetts Dartmouth School for Marine Science and Technology, University of Maryland Eastern Shore, University of Rhode Island, the Bermuda Institute for Ocean Sciences, and the World Meteorological Organization.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)

36. Have other collaborators or contacts been involved?

Nothing to Report

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

Impacts of CINAR research on the principal project discipline(s) are summarized below, organized according to research theme. Examples are drawn from progress reports provided by each CINAR investigator, which are distributed directly to project sponsors. Figures are provided in Appendix 6.

Theme I – Sustained Ocean Observations and Climate Research. CINAR activities under this research theme included supporting ocean observing programs critical to climate assessments and hurricane forecasting. These included autonomous collection of ocean measurements through the Stratus, NTAS and WHOTS Ocean Reference Stations (PIs: R. Weller/A. Plueddemann, WHOI; Fig. 1) and the global array of Argo floats (PI: S. Wijffels, WHOI), including focused rapid sampling in advance of and during hurricane events (PI T. Miles, Rutgers; Fig. 2). In addition to providing new approaches and datasets for hurricane forecasting, these efforts are contributing to our understanding of marine heatwaves and warming trends, and their impact on living marine resources and fisheries.

Theme II – Ecosystem Research, Observation, and Modeling. The NOAA scientific community is using data collected by CINAR's ocean observing assets and programs to understand and describe ecological and environmental parameters and processes in the NEUS LME. State-of-the art ecological models and data assimilation methods developed by CINAR investigators have been applied to practical problems facing key ecological and commercial species. One example is development of OA data synthesis products that describe decadal-scale trends in pH, particularly in bottom water where potentially vulnerable commercially important species reside (PI: G. Saba, Rutgers; Fig 4).

Theme III – Stock Assessment Research. CINAR activities have contributed valuable technologies and datasets to advance our understanding of critical species in the NEUS LMS, and for effective management and resource stewardship in the region. Examples include successful testing of paired ASV-ROV operations for enhanced efficiency for offshore science operations (PI: M. V. Jakuba; WHOI; Fig. 12), and development of molecular approaches for assessing herring biomass and distribution (PI: G. Sherwood, GMRI; Fig. 7).

Theme IV – Protected Species Research and Recovery. CINAR activities under this theme are developing new technologies and approaches for the assessment and recovery of protected species in the NEUS LME, including, the critically endangered North Atlantic right whale (NARW). Examples include integrating autonomous aerial photogrammetry with genetic sequencing of respiratory microbiota to quantify whale health (M. Moore, WHOI; Fig. 10), and use of Slocum gliders to monitor the occurrence and distribution of whales and commercially important fish, share near real-time data for NOAA's Slow Zones program, and help motivate a reassessment of NOAA ship speed rules (M. Baumgartner, WHOI; Fig. 9).

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT (cont'd)

38. What was the impact on other disciplines?

The impact and value of CINAR research extends beyond the scientific disciplines encompassed by this CI's research themes. Humans are an integral part of approaches to EBFM; therefore, human dimensions research is an important part of support EBFM and other ecosystem-based approaches to management. These activities provide a fuller understanding of interactions and interconnections within the NEUS LME, and support efforts to integrate economic, social, and cultural considerations in EBFM. For example, CINAR investigators are working to sentinel indicators of resilience for the lobster industry that are designed to detect early signs of vulnerability within the fishing fleet. The result of this work is a set of beta indicators that can be used to evaluate the resilience of the fishery industry in the face of rapid socioeconomic and environmental change. The indicators, and our approach to developing them, has the potential to be a model for other fisheries in Northeast U.S. Shelf Large Marine Ecosystem and beyond (PI: J. Stoll, UMaine).

CINAR investigators are also involved in efforts to identify research priorities for the effective management of harmful algal blooms (HABs) and their impacts on human health and economies. Over the past year, CINAR investigators were involved in a significant collaborative effort to update "Harmful Algal Research and Response National Environmental Science Strategy" document, also known as HARRNESS. Activities included participating in the committee that is writing this document, and providing significant administrative and logistical support throughout this process. HARRNESS describes research and management recommendations for multiple HAB-related activities, and when complete, this national plan will be used by federal agencies to identify research and funding priorities (PIs: M. Richlen & D. Anderson, WHOI).

Finally, CINAR investigators continued to engage fisheries stakeholders through the highly successful Marine Resource Education Program (MREP). MREP is a stakeholder engagement and education program designed by fishermen, for fishermen, to cultivate industry leadership and enable effective collaborative management of fisheries. MREP engages stakeholders directly in the federal fisheries science and management systems in multiple regions of the U.S. MREP offers fishermen the opportunity to learn about the complex fisheries science and management processes, and equips these fishermen with tools to effectively participate in these processes (Figs. 13 & 14). The MREP program held multiple science and management workshops this year, covering areas on the both West and East U.S. coasts. MREP alumni continue to represent more than half of the new council member appointments nationwide, thus strengthening the capacity of industry leaders to engage in the highly complex issues of fisheries science and management.

39. What was the impact on the development of human resources?

Over the past year, CINAR programs supported 124 research scientists and staff, postdocs, and administrative staff, as well as 63 students. A complete personnel listing is provided in Appendix 3, and additional details regarding the impact of teaching and educational programs is described in comment field #40, below.

IMPACT (cont'd)

40. What was the impact on teaching and educational experiences?

CINAR research programs offer a variety of opportunities to involve undergraduate and graduate students, postdocs, and early career scientists in research programs related to our research themes, and provide career training to the next generation of marine scientists. Below we highlight selected achievements and programs:

1. Graduate student and postdoc participation in research: CINAR research programs offer many opportunities to engage graduate students, postdocs, and early career scientists, and provide career training to the next generation of NOAA scientists. Students are introduced to an active and collaborative research environment, interact with scientific leaders in ecosystem research, start building a network of contacts for advanced studies and a career in science or resource management, and gain experience with ecosystem-scale research, proposal writing and presentation skills. Although student participation was impeded by the COVID pandemic, CINAR investigators included 29 graduate students and 7 postdocs in their research programs, and expanding student and postdoc participation in research is an important priority going forward.
2. Undergraduate student participation: The ability of our consortium to host undergraduate students was significantly impacted by COVID-19; however, undergraduate participation in CINAR research expanded significantly over the past year from 26 students during the 2021-2022 time period to 34 students in 2022-2023.
3. Undergraduate Minority Trainee program and NOAA IN FISH Partnership: For many years, CINAR has supported an undergraduate minority traineeship program, which provides funding to each CI partner institution in support of summer fellowships for undergraduate students from underrepresented communities. Over the past year, CINAR also began partnering with the newly developed NOAA undergraduate diversity internship program IN FISH (An Inclusive NOAA Fisheries Internship Program), which provides internship opportunities for undergraduate students in the marine science and resource management fields, as well as mentorship/training opportunities to the host investigators and institutions so that they learn together with the students. The goal of IN FISH is to build diverse talent to be the future workforce of NOAA, representative of our constituency. Under this partnership, CINAR supported five undergraduate students in 2022, who participated in coursework and cohort building activities along with a larger cohort of IN FISH students, followed by an additional 8 week intensive mentor-led research or resource management project. Information on these students and their activities can be found on the CINAR website: <https://website.whoi.edu/cinar/education-outreach/in-fish/>.
4. Over the past year, CINAR supported five early career scientists at our partner institutions through funding from NOAA's Quantitative Ecology and Socioeconomics Training (QUEST) program. An important goal this program is to engage early career scientists in research to improve and enhance the assessment and management of fisheries resources in the region. Support provided by these two-year fellowships will enhance research, teaching, and advising activities and will help to establish laboratories and programs that can develop and implement new technologies to improve the assessment and management of fisheries resources in the NEUS LME. Complete information about this program, current fellows, and their research activities can be found on the CINAR website: <https://website.whoi.edu/cinar/people/fellows/>. Over the past year, CINAR supported five fellowships for early career faculty, and also held a competition to fund a second round of fellowships, which were awarded to four recipients.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

CINAR researchers continued to support the international Argo program, a global array of autonomous profiling floats, and provided leadership in technology improvement, sensor testing and validation, production and acquisition of floats, deployment logistics, float communications, data analysis and management, international coordination, and education. Contributions to physical, institutional, and information resources under this program included the preparation and deployment of 48 floats in 2022-2023 and continued operation of a fleet of 425 active floats (PI: S. Wijffels, WHOI). Over the past year approximately 15,000 profiles were obtained and distributed via the Argo data system. In addition, a subset of Argo floats in the Gulf of Mexico, Caribbean, and Tropical Atlantic were used in a pilot project to improve hurricane forecasts (PI: T. Miles, Rutgers; Fig. 2). This work assessed the impact of these rapidly cycled floats on the Real Time Ocean Forecast System (RTOFS) that is used to initialize the coupled operational hurricane forecast models. The results of these analyses will be used to develop guidance for future use of Argo profiling floats in hurricane forecast operations.

Additional contributions to infrastructure included continued operation and maintenance of three Ocean Reference Stations (ORS), which are used to collect sustained, climate-quality observations in the trade wind regions and drive improvements in understanding and modeling at these sites. Over the past year, CINAR PIs R. Weller & A. Plueddemann (WHOI) continued to maintain the Stratus, NTAS and WHOTS ORS, which provide sustained observing of the trade wind region. Data produced by these CINAR-supported ORS are essential to critical climate assessments worldwide.

CINAR infrastructure also included development and use of diverse autonomous instruments for monitoring, including the development of Long Range AUVs with stereoscopic camera systems for benthic surveys in and around offshore wind farms (PI: A. Kukulya, WHOI; Fig. 3); use of a matrix of Slocum gliders, wave gliders, and moored buoys to monitor the occurrence and distribution of whales and commercially important fish and share near real-time detections of the critically endangered North Atlantic right whale for NOAA's Slow Zones program (PI: M. Baumgartner; Fig 9); successful testing of paired ASV-ROV operations away from the primary scientific vessel for enhanced efficiency for offshore science operations (PI: M. V. Jakuba; WHOI; Fig. 12), development of an in-situ dual-parameter carbonate chemistry profiling sensor for high resolution OA measurements (PI: A. Wang, WHOI; Fig. 5); and use of a variety of autonomous platforms for acoustic monitoring, including Slocum ocean gliders, wave gliders, and moored buoys.

Finally, CINAR investigators maintain multiple websites and informational resources, which are listed in comment field #32.

IMPACT (cont'd)

42. What was the impact on technology transfer?

CINAR investigators are pioneering multiple new tools, models, and approaches to collecting, analyzing, modeling, and disseminating biological and physical data in the NEUS LME. Additional information on some of these products is provided in comment fields #25 and #30. As mentioned above, CINAR investigators maintain multiple websites and informational resources, which are listed in comment field #32.

43. What was the impact on society beyond science and technology?

Data and analyses carried out by CINAR investigators are supporting efforts to integrate human interactions and socioeconomic considerations into marine species and ecosystem management, thereby promoting sustainable coastal development and community resiliency. Engagement of fisheries stakeholders by CINAR researchers through the MREP program promotes the involvement and participation of the general public and commercial sector in fisheries science and management in a productive way. In addition, CINAR research is contributing to better management of harmful algal blooms in the region, which contributes to human health disciplines and aquaculture management. These activities support efforts to integrate human interactions and socioeconomic considerations in EBFM, and contribute to a better understanding of interactions and interconnections within the NEUS LME.

IMPACT (cont'd)

44. What percentage of the award's budget was spent in foreign country(ies)?

4 , Our estimates indicate that <5% of our budget was spent in foreign countries.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Several projects experienced significant and ongoing disruptions and delays due to the COVID-19 pandemic. These problems and delays are included in comment field #46 a

CHANGES/PROBLEMS (cont'd)

46. Actual or anticipated problems or delays and actions or plans to resolve them

Fay (SMASST, Workshops): Delay in workshops last year caused further delays. Extension allowed work to be completed and to continue with a graduate student.

- Fay (SMASST, fishery data): Project was extended to defer Carpentries training until AY22-23.
- Foote (WHOI): The need to secure fresh specimens from a seasonal fishery and scan these at a private institution with sufficient veterinarian capabilities has contributed to delays in the timely completion of tasks. A second no-cost extension was granted.
- Gerbi (UMaine): No fieldwork occurring in 2021 due to COVID.
- Greig (UMaine): Our project has been extended to 8/31/2023 because processing invertebrate samples took longer, which delayed data analysis and writing. Laboratory processing is complete, and data analysis is well underway.
- Grebmeier (UMCES): Jakuba (WHOI): The project was executed on schedule; however, the shortened cruise provided only a single opportunity to link up the AUV and Wave Glider. A key objective, operating an ROV simultaneously with the ASV tending the AUV was consequently not attempted.
- Jayne/Wijfells (WHOI): Impacts on manufacturers by COVID-19 both for parts supply, parts quality and workforce turnover. The price of floats supplied is increasing (by ~30%) and the quality of the float supply has decreased. From a rejection rate of 5% in pre-COVID times, we are facing one of 20%, which slows down float production at WHOI.
- Kerr (UMaine, Groundfish): PI changed institutional affiliations in October 2022 moving from the GMRI to UMaine. Transfer of award delayed hiring of a postdoc.
- Kerr (GMRI/UMaine, Atlantic Cod): Our spending of the award has been slower which reflects delays in postdoc hiring.
- Kukulya (WHOI): Due to supply issues, team chose to use an existing LRAUV in our lab to develop on while we build the new survey LRAUV. Our schedule is currently on target for field testing the camera system. The new LRAUV platform is expected to be complete by the end of January 2024.
- Maas (WHOI): Less cruises due to COVID, and delays in data processing of environmental and biological variables have hampered the comparison of pteropod shell condition to broader ecosystem health metrics. We expect those to be available next year.
- Mills (GMRI, Salmon): Funding remaining in this project are quite low, so we slowed work on it this year. We have several research elements that have been started but not completed; in addition, we planned to do a more rigorous growth-ecosystem analysis.
- Pinsky (Rutgers): A no-cost-extension was requested to allow continuing support of the DisMAP team, including on the Distribution and Mapping Working Group.
- Rose (UMCES): NCE was granted due to COVID to enable timely completion of the project.
- Sherwood (GMRI, Herring): Not a single spawning school of herring was observed in this area (over 17 trips in 2020/2021) in what we described as a herring spawning hotspot in our previous work (2012-2016). This observation itself is a major contribution to understanding the extent of the herring collapse – that is, it appears to have disrupted normal spawning behavior in coastal Maine waters.
- Sherwood (GMRI, Spatial footprint): While we are on track to achieve our goals, an extension may be needed due to recruiting challenges delaying hiring of staff.

47. Changes that had a significant impact on expenditures

- Alexander (WHOI): In 2021, The A13.5 cruise was cancelled (after equipment, supplies, and people had made their way to the ship). This has impacted our spending and budgeting. However, we are happy that the A13.5 cruise is now slated to be run again in 2023.
- Weller (WHOI): Funding pressures are evident. We make cuts to budgeted items each year to keep the bottom line of the budget at the target figure set by the Global Ocean Monitoring and Observing (GOMO) program. We three years ago year ended surface wave observations at Stratus and NTAS due to the cost of replacing obsolete National Data Buoy Center (NDBC) wave measurement systems. In the last two years we have increased risk by eliminating most of the spare mooring materials that we would normally take to sea. We have not, more generally, been able to budget to replace aging instruments and have carried no permanent equipment items in our budgets. Nor are we able to have every instrument calibrated for every deployment, as the manufacturers' calibration charges exceed what we can budget. The results are an increased data loss and increased turn-around cost each year. For instrumentation that we have designed in house, especially the ASIMET (Air-Sea Interaction Meteorological package) that we rely on to obtain surface meteorology and air-sea fluxes, obsolescence of components and ongoing industry transitions in data storage (for example, from PCMCIA cars to Compact Flash Cards, to SD Cards) require us to redesign and fabricate new circuit boards. A planned replacement program for older instrumentation and a healthy calibration budget are needed to support our ability to continue to meet project metrics. The tight budgets also constrain our ability to provide support for technical staff to attend workshops and training classes. Informal exchanges of hands-on experiences between technical staff of different groups and with manufacturers' engineers are important means to maintain the currency of staff and avoid problems encountered by others. Ability to support travel to such meetings by technical staff would better support progress. Dialog with our program manager is planned to plan ORS activities now that the NTAS site is no longer being maintained.

CHANGES/PROBLEMS (cont'd)

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to Report

49. Change of primary performance site location from that originally proposed

Nothing to Report

PROJECT OUTCOMES

50. What were the outcomes of the award?

Outcomes of this award are captured in the aforementioned "Accomplishments", "Products", and "Impact" sections, and in Appendices 1-6.

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

<p>Gender:</p> <p><input type="radio"/> Male</p> <p><input type="radio"/> Female</p> <p><input type="radio"/> Do not wish to provide</p>	<p>Ethnicity:</p> <p><input type="radio"/> Hispanic or Latina/o Not</p> <p><input type="radio"/> Hispanic or Latina/o Do not wish to provide</p>
<p>Race:</p> <p><input type="radio"/> American Indian or Alaska Native Asian</p> <p><input type="radio"/> Black or African American</p> <p><input type="radio"/> Native Hawaiian or other Pacific Islander</p> <p><input type="radio"/> White</p> <p><input type="radio"/> Do not wish to provide</p>	<p>Disability Status:</p> <p><input type="radio"/> Yes</p> <p>[] Deaf or serious difficulty hearing</p> <p>[] Blind or serious difficulty seeing even when wearing glasses</p> <p>[] Serious difficulty walking or climbing stairs</p> <p>[] Other serious disability related to a physical, mental, or emotional condition</p> <p><input type="radio"/> No</p> <p><input type="radio"/> Do not wish to provide</p>

Attach a separate document if more space is needed for #6-10, or #24-50.