



## DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

*For instructions, please visit*

[http://www.osec.doc.gov/oam/grants\\_management/policy/documents/RPPR%20Instructions%20and%20Privacy%20Statement.pdf](http://www.osec.doc.gov/oam/grants_management/policy/documents/RPPR%20Instructions%20and%20Privacy%20Statement.pdf)

AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA16OAR4320152
3. Project Title: A Cooperative Institute to Support NOAA's N.W. Research Facilities in the Area of Marine Resources	
4. Award Period of Performance Start Date: 10/01/2016	5. Award Period of Performance End Date: 09/30/2021
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
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13. Title:	
14. Email: Patricia.Hawk@oregonstate.edu	15. Phone Number: 541-737-4933
REPORTING INFORMATION	
Signature of Submitting Official:  Vickie Watkins	
16. Submission Date and Time Stamp: 07/30/2019	17. Reporting Period End Date: 06/30/2019
18. Reporting Frequency:  <input checked="" type="radio"/> Annual <input type="radio"/> Semi-Annual <input type="radio"/> Quarterly	19. Report Type:  <input checked="" type="radio"/> Not Final <input type="radio"/> Final
RECIPIENT ORGANIZATION	
20. Recipient Name: OREGON STATE UNIVERSITY	
21. Recipient Address: 1500 SW JEFFERSON ST, CORVALLIS, OR 97331-8655 USA	
22. Recipient DUNS:053599908	23. Recipient EIN:611730890

## ACCOMPLISHMENTS

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

The OSU/NOAA Cooperative Institute for Marine Resources Studies (CIMRS) develops and offers opportunities for joint research, education and outreach to a growing community of University and NOAA scientists dedicated to marine science partnerships with regional industries and communities in the Pacific Northwest and beyond. The Institute's main mission is to bring together research partners from Oregon State University's full variety of colleges and departments to assist their NOAA colleagues address complex multidisciplinary issues relating to sustainable use and management of the marine environment, but our collaborations also extend to neighboring states (including AK) as well as international partners in agency, academic and private contexts. We thrive because of sustained vision and commitment of leaders from within the laboratories of our NOAA associates and the OSU Research Office. Increasing synergies realized over the past few years include: 1) fostering transdisciplinary working contexts to better address marine-related research problems owing to climate, environmental, economic and social changes, 2) extensive matching of NOAA support with research and education funds available for external partners (NSF, ONR, etc), 3) marked expansion in the distribution of research findings nationally and globally, and 4) diversification of post-doctoral and graduate student opportunities. CIMRS research projects are coordinated under six primary themes: Marine Ecosystems and Habitat, Protection and Restoration of Marine Resources, Seafloor Processes, Marine Bioacoustics, Coastal Mapping and Monitoring, and Coastal and Marine Natural Infrastructure. Diverse activities range from studies in physical oceanography, ecosystem, fisheries stock and habitat assessment, longer term prediction of physical and biological inter-relationships and climate, modeling, economics, mapping, spatial planning, genomics, ecology through to geology, marine chemistry, sound and human dimension issues such as flood risk and protection from natural resource valuing. Although our primary efforts are directed towards research that develops understanding, tools and technologies to assist and address NOAA's mission, economic and security advancement in the marine field, we also attend advancing education and outreach to foster marine related prosperity into the future. The eclectic collaborative structure of CIMRS strives to facilitate new and nimble ways to apply hard science and applied research in a quest to understand factors and fluxes impacting marine resources and better their management. Overall impacts arise from investment of our leaders and public in unique resources poised in the Pacific Northwest where four coastal states host sincere hard work and tremendous good will.

### 25. What was accomplished under these goals?

Theme 1. Marine Ecosys. & Habitat: Several projects focus on the interactive effects of temperature, ocean acidification, oil pollution & prey quality on the growth, morphometric condition, lipid & fatty acid composition of several commercially important AK fish species: northern rock sole larvae, juvenile pollock, walleye pollock larvae, juvenile flatfish, yellow fin sole. Another AK project focuses on defining Essential Habitat of Flat Fishes in Chukchi Sea including yellowfin sole & Greenland halibut. An OR based Ecosystem Indicators of Ocean Conditions in the Northern CA Current project performs bi-weekly cruises to collect hydrography, zoo- (including RNA for genomics), & ichthyoplankton to enhance ocean ecosystem indicators (incl. salmon & other fishery prod. indexes). Work with fisherman in WA, & OR collected over 2,000 Chinook samples to Quantify Near-real-time Ecosystem Effects on Ocean Distribution of Chinook. Theme 2. Protect. & Rest. of Marine Res.: Comparison of Atlantic & Gulf of Mexico Kemp's ridley turtle used sequential isotopic analysis of inert tissues to determine cumulative prey consumption & habitat occupation. Stock Assessment Research Review of Pacific Hake contributed to the Scientific Review Group meeting (Simon Fraser Univ., BC). A Seabird bycatch project in West Coast At-Sea Hake Fisheries tested video monitoring equipment, & trailed potential mitigation options (76 sea-days). Theme 3. Seafloor Processes: Impacts of Submarine Volcanism & Hydrothermal Venting on the Global Ocean & Deep-Sea Ecosystem focused on long-term investigations at Axial Seamount (an active volcano offshore OR), along offshore Cascadia (w-coast continental margin that hosts 1000s of methane seeps) & on the Lost City hydrothermal vent field at the Mid-Atlantic ridge. Theme 4. Marine Bioacoustics: Ocean Noise Reference Station project maintains a network of hydrophones at 12 sites within the U.S. exclusive economic zone including an array in the Terra Nova Bay (Ross Sea Antarctica) monitoring acoustic signals radiated from ice shelves & sea ice. Technical engineering developed a portable, under-ice acoustic winch system for recording acoustic & environmental data (conductivity, temperature, depth) in remote polar areas. Baleen Whale Calls (blue, fin, sei & humpback) were Analyzed Comprehensively to assess calls missed by automatic detectors used by NWFSC. A Gray Whale Noise & Stress project is the first to combine multiple metrics (incl. fecal hormone data) of baleen whale physiology to understand physiological response to underwater noise. Theme 5. Coastal Mapping & Monitoring: Optimizing UAS Imagery Acquisition & Processing for Shallow Bathymetry Mapping uses unmanned aircraft systems (UAS) to map benthic habitats, including coral reef habitats, & inform coastal management decisions. Over 48,000 UAS images over St. Croix, U.S. Virgin Islands were used to develop seafloor orthomosaics & bathymetric digital elevation models (DEMs). Towards Optimizing Determination of Accurate Heights tests GNS positioning algorithms for multi-GNSS data used among geodetic communities worldwide. Theme 6. Coastal & Marine Natural Infrastructure: A Multidisciplinary, Integrative Approach to Valuing Ecosystem Services from Natural Infrastructure aims to understand nature of socially-optimal investment in coastal natural infrastructure in the Pacific Northwest from an economic perspective. Advancing the Analysis of Pacific Basin Coastal Flood Sensitivity under a Changing Climate advances application of statistical & other analytical techniques to assess vulnerability of built & natural environments to the impacts of coastal flooding in a changing climate. Our Timevarying Emulator for Short- & Long-Term Analysis of coastal flooding (TESLA-flood) is a methodology for producing robust estimates of coastal flooding risk while accounting for dependencies of local Total Water Level components on the fundamental drivers of large-scale climate.

*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?

Nothing to Report

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

Educational and scientific outreach is important in all aspects of CIMRS research. Websites are a venue that reach an enormous audience. CIMRS investigators feature their collaborative research efforts in the fields of fisheries oceanography, geophysical and acoustic monitoring of spreading centers, ocean exploration, and bioacoustic monitoring of marine mammals at several websites hosted by NOAA and CIMRS. Research activities, contributions, and news stories throughout the year are posted on CIMRS website, <http://hmsc.oregonstate.edu/cimrs/>. Owing to the collaborative nature of CIMRS, a large component of outreach provided by CIMRS investigators is on the award winning website, <http://www.pmel.noaa.gov/eoi>, which continues to feature educational curricula, video clips of in situ seafloor experiments, and animated 3-dimensional fly-through videos of seafloor ridges. CIMRS investigators continually update two blogs this year: [www.blogs.oregonstate.edu/acoustics/](http://www.blogs.oregonstate.edu/acoustics/) and Newportal: A gateway to oceanographic information from the Newport Line and beyond

Active CIMRS research projects are featured at OSU Hatfield Marine Science Center's (HMSC) Visitor Center, which is dedicated to the lifelong exploration and discovery of coastal and marine sciences and resources. Many educational exhibits and programs at the Visitor Center correspond with current research conducted by the multiple federal labs co-located with HMSC and may be viewed by 150,000 attendees annually. CIMRS investigators have collaborated with Oregon Sea Grant educational staff to design and prepare interactive exhibits, covering the entire range of CIMRS research. Among the permanent exhibits, "Ring of Fire" demonstrates submarine volcanism research on the seafloor. "Mysteries of the Deep" and "Burning Ridge" bring the seafloor to life with real volcanic rock specimens and a 3-D mid-ocean ridge model. "CIMRS Acoustic Display" exhibit educates visitors on marine acoustics research. In addition to these permanent exhibits, a real hydrophone and an interactive earthquake/seismic kiosk are on display. "Sensing the Sea" describes various technological methods of monitoring ocean conditions, from satellites to hydrophones. "Endangered Species of Pacific Northwest" exhibit educates visitors on the various regional endangered species. "Riding the Ocean Currents" is a multimedia exhibit that illuminates the relationship between ocean currents and plankton larval dispersal off the Oregon coast; the exhibit includes digital screens depicting ocean currents at various depths. "Sustainable Fisheries" includes an overview of project CROOS which has a goal to improve salmon management through developing near real-time tracking of genetic stocks.

CIMRS researchers provide valuable volunteer hours at K-12 Science Fairs and related activities throughout the year including Marine Science Day that draws over 3,000 visitors to the Hatfield Marine Science Center to discover current research projects at the campus.

CIMRS Acoustics personnel visited classrooms at a native American charter school (Siletz Valley Schools) in February 2019 to introduce students to underwater acoustics and pictures and sounds from a recent expedition to Antarctica

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

**ACCOMPLISHMENTS (cont'd)**

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

CIMRS has and will continue to seek funding commitment from NOAA as well as matching support from OSU and external funding agents such as NSF and ONR to further our research, education and outreach under each of CIMRS's 6 themes. This in combination with several projects that have pending funding decisions mean that we are well poised to continue realizing our goals supporting the NOAA mission as originally proposed. Through attendance at annual and local science & professional meetings, we remain engaged with agency, academic and public partners working in the marine and atmospheric arena and continue to interface with other Cooperative Institutes and Sea Grants to collectively seek, enable and realize synergies.

**PRODUCTS**

29. Publications, conference papers, and presentations

CIMRS list of publications will be submitted to NOAA Institutional Repository on/or before July 31, 2019. More information about CIMRS publication, papers, and presentation is included in the attachment.

## PRODUCTS (cont'd)

### 30. Technologies or techniques

New CIMRS technologies and techniques include:

Theme 1. Marine Ecosystems & Habitat:

1. Condition screening histology technique to assess physiological effects of fish larvae exposed to Ocean Acidification conditions.
2. Tagseq, a novel form of gene expression analysis applied to copepod RNA samples taken from the Newport Hydroline to provide new information to better assess physiological and productivity status in relation to environmental conditions.
3. Salmon fisherman were equipped with Samsung GSI tablets using software we developed to efficiently gather at-sea catch, effort and associated environmental data.

Theme 2. Protection & Restoration of Marine Resources:

4. Electronic monitoring through use of video equipment & mitigation options to reduce seabird bycatch in West Coast at-sea hake fisheries.

Theme 3. Seafloor Processes

5. Hydrate sampler: A new gas-tight sampler was designed, built, and used for the first time to collect small samples of methane hydrate on the deep seafloor with a remotely operated vehicle and keep the sample hermetically sealed at high-pressure until it can be chemically analyzed. This sampler was developed to test whether methane gas released from the ice-like hydrate can be chemically distinguished from free methane gas.

Theme 4. Marine Bioacoustics:

1. Continued development of a pseudo-real-time, portable, battery-operated under-ice acoustic winch system for bio-acoustic and water column monitoring (conductivity, temperature, depth) in remote polar areas.
2. Continued development of mobile autonomous platforms for acoustic detection of marine mammal sounds, including optimization for detecting both low-frequency species (e.g., fin whales) as well as high-frequency ones (e.g., dolphin and porpoise species).
3. Development of new statistical methods, and corresponding code, for estimation of animal population density using mobile autonomous platforms.
4. New and first methods to determine hormone status of whales from the whale fecal samples.

Theme 5. Coastal Mapping & Monitoring

5. We develop and vet standard operating procedures that will enable efficient, cost-effective use of unmanned aircraft systems for mapping nearshore waters in support of a range of NOAA programs.
6. The Cycle Slip (CS) simulator is an independent MATLAB routine, which adds CSs to a GNSS observation file for an experimental purpose.

Theme 6. Coastal & Marine Natural Infrastructure:

7. A dune conceptual model that considers the relative importance of dune ecosystem services in natural & managed systems and a new numerical modeling framework to better understand the evolution of beaches & dunes.
8. Timevarying Emulator for Short- & Long-Term Analysis of coastal flooding (TESLA-flood) is a methodology for producing robust estimates of coastal flooding risk while accounting for dependencies of local Total Water Level (TWL) components on the fundamental drivers of large-scale climate

### 31. Inventions, patent applications, and/or licenses

Nothing to Report

## **PRODUCTS (cont'd)**

### **32. Other products**

CIMRS website and data results are:

Data has contributed to the Newportal Blog:  
[https://www.nwfsc.noaa.gov/news/blogs/display\\_blogentry.cfm?blogid=1](https://www.nwfsc.noaa.gov/news/blogs/display_blogentry.cfm?blogid=1).

Data has been contributed to updates on "Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current" website:  
<http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/index.cfm>

Biological and physical data were uploaded to the California Current IEA ERRDAPP server:  
<https://www.integratedecosystemassessment.noaa.gov/regions/california-currentregion/indicators/climate-and-ocean-drivers.html>

Near-real-time data is available at Pacific Fish Trax website through public, fisherman, scientist portals at  
<https://fp.pacificfishtrax.org/>

The SRG report, available at: [https://www.westcoast.fisheries.noaa.gov/fisheries/management/whiting/pacific\\_whiting\\_treaty.html](https://www.westcoast.fisheries.noaa.gov/fisheries/management/whiting/pacific_whiting_treaty.html).

Live ROV video from ship to shore:  
<https://nautiluslive.org/>  
[https://schmidtocean.org/cruise/seeping\\_cascadia\\_margin/](https://schmidtocean.org/cruise/seeping_cascadia_margin/)  
<http://axial2018.blogspot.com/>  
<https://schmidtocean.org/cruise/methane-seeps-at-edge-of-hydrate-stability/>

Results of this project have been included in a NOAA NCCOS web publication: "NCCOS Tests Drones to Map Coastline and Nearshore Waters":  
<https://coastalscience.noaa.gov/news/nccos-tests-drones-to-map-coastline-and-nearshore-waters/>

## **PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

### **33. What individuals have worked on this project?**

CIMRS have 52 researchers, students and staff that work on various project under this award. A detailed outline is included in the attachment.

**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?

Project: Advancing the Analysis of Pacific Basin Coastal Flood Sensitivity under a Changing Climate

Dr. Fernando J Mendez  
Fundacion Leonardo Torres Quevedo  
University of Cantabria, Santander, France  
www.flq.com

Provided to project assistance in the development and application of Time-varying Emulator for Short- and Long-Term Analysis of coastal flooding (TESLA-flood) as a methodology for producing robust estimates of coastal flooding risk while accounting for the dependencies of local TWL components on the fundamental drivers of large-scale climate.

Dr. Melisa Menéndez García  
Fundacion Instituto De Hidraulica - IH  
University of Cantabria, Santander, France

Provided to project assistance in the development of methods for estimation of sea level returns and data analysis.

Project: WA & OR Coast-wide GSI - Quantifying Near-real-time Ecosystem Effects on Ocean Distribution of Chinook

Nancy Fitzpatrick, Executive Director  
Oregon Salmon Commission  
Lincoln City, OR

Provided to project assistance in the sample collection with local fisherman in Oregon and Washington. Additionally, provided periodic update to FishTrax database.

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

**PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)**

36. Have other collaborators or contacts been involved?

Oregon State University Marine Mammal Institute  
Hatfield Marine Science Center  
2030 SE Marine Science Dr  
Newport, Oregon 97365

In-Kind Collaborator: Provide use of equipment and permits for data collection on Measuring physiological effects of changing noise levels on Pacific gray whales (*Eschrichtius robustus*) project.

Oregon Sea Grant  
Oregon State University  
Hatfield Marine Science Center Visitor Center  
2030 SE Marine Science Drive  
Newport, OR 97365-5229

In-Kind Collaborator: Provide educational exhibit space for CIMRS research projects; Impacts of Submarine Volcanism and Hydrothermal Venting on the Global Ocean and Deep-Sea Ecosystems and Ecosystem Indicators of Ocean Conditions in Northern California Current

**IMPACT**

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

Theme 1. Marine Ecosystems & Habitat: Because much of CIMRS's Ocean Acidification (OA) research focuses on juvenile life history phases of fish of commercial importance to AK, findings have relevance to assessments of OA effects on future fisheries as these fish mature as well as to other regions experiencing OA. Likewise, but from perspectives gained of plankton (and their RNA) at an even more basic levels of marine food-webs, research on the Newport Hydroline continues to inform and enable predictions on impact of climate change on fisheries sustainability and provides updates to ocean ecosystems indicators of the California Current Integrated Ocean and the Pacific Fisheries Management Council. Returning to higher trophic levels, the Chinook project informs on ecosystems effects to salmon fisheries, as well as enables fin-scale stock-specific spatial resolution to enable sustainable execution of this fishery given a number of threatened or endangered stocks contained therein.

Theme 2. Protection & Restoration of Marine Resources: Primary impact of Kemp's Ridley turtle, Hake Stock assessment and Seabird bycatch reduction is that findings are used to guide and enable management towards most sustainable utilization of resources while maintaining protection & restoration of a fully functioning marine ecosystems.

Theme 3. Seafloor Processes: Findings on Submarine Volcanism, Hydrothermal Venting, & Deep-Sea Global Ocean & Deep-Sea Ecosystem studies are updated to NSF's Interdisciplinary Data Alliance, Marine Geoscience Data System. It thus provides observational geoscience data of critical importance to Ocean, Earth, and Polar Sciences prediction and security because it addresses the largest component of earth's habitat.

Theme 4. Marine Bioacoustics: Key impacts include: climate change assessments, tsunami and earthquake warning, port security, assessment of anthropogenic impacts on ambient marine noise levels, and information to enhance marine mammal biology, management and conservation.

Theme 5. Coastal Mapping & Monitoring: Applications of unmanned aircraft systems to map benthic marine habitats provides and develops methods to enable unprecedented resolution in regions of critical relevance to sea-level rise, coastal planning, security and other management decisions. Likewise advancement Multi-GNSS data enables standardization of Precise Point Positioning (PPP) at standards applied in geodetic communities worldwide. Improving the PPP solution with multi-GNSS will contribute to aero and space navigation, space flight management and risk.

Theme 6. Coastal & Marine Natural Infrastructure: Value assessment of ecosystem services attained from Natural Infrastructure given impending sea-level rise continues to inform planning, utilization and conservation efforts across the state of OR. The TESLA-flood model advances assessment of total water level contributions to sea level variability and extreme flooding owing to compound events.

**IMPACT (cont'd)**

**38. What was the impact on other disciplines?**

Theme 1. Marine Ecosystems & Habitat: Research about Ocean Acidification effects on lipid content among juvenile life history phases of AK fish and plankton at the base of marine food-webs (Newport Hydroline Research) has relevance to human (and other) diet threats owing to climate change. Change of spacial, temporal and depth locations among Chinook capture owing to changing environmental conditions is important to assessment of economic futures of this fishery given climate change predictions.

Theme 2. Protection & Restoration of Marine Resources: Kemp's Ridley turtle, Hake Stock assessment and Seabird bycatch reduction findings are relevant to other animal and human behaviour research.

Theme 3. Seafloor Processes: Findings on Submarine Volcanism, Hydrothermal Venting, & Deep-Sea Global Ocean & Deep-Sea Ecosystem studies are updated to NSF's Interdisciplinary Data Alliance, Marine Geoscience Data System have critical relevance to national and global economic and global security futures.

Theme 4. Marine Bioacoustics: Likewise study of natural and anthropogenically derived marine sound has critical relevance to national and global economic and global security futures.

Theme 5. Coastal Mapping & Monitoring: Methods and procedures developed in applications of unmanned aircraft systems map marine benthic habitats, as well as advancement Multi-GNSS data have relevance to precise position assessment in other remote habitats such as freshwater lakes, other terrestrial based systems and space. In addition, multi-GNSS Precise Point Positioning software is capable of extracting various atmospheric quantity parameters while processing data for GNSS positioning. These atmospheric measurements can be applied in atmospheric science and space weather that will impact human travel in space, potential human residence on other planets, space station security, early warning for natural hazards (e.g., earthquake, tsunamis, hurricane).

Theme 6. Coastal & Marine Natural Infrastructure: Although findings for value assessment of ecosystem services attained from Natural Infrastructure given impending sea-level rise as well as near-shore flood risks are based from studies specifically in Oregon, many are relevant to similar habitat types that exist throughout the nation and globally. They have important bearing on economic, planning, utilization and conservation considerations for these risks globally.

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

Under this award, CIMRS supported 13 graduate students, two undergraduate student, and one high school during this reporting period (details from each student is included in the attached reports question 33).

CIMRS with funding from Task 1 provided its first 1st YEAR Graduate Fellowship.

Project: Ecosystem indicators of ocean conditions in the northern California Current

Student: Kirsten Steinke, PhD Student

CIMRS' Faculty mentor several undergraduate students over the summer at a part of the Oregon State University's Research Experience for Undergrads (REU) Program funded by NSF. Oregon State University students unless noted

Project: Ecosystem indicators of ocean conditions in the northern California Current

Students: Charles Leal and Jessica O'Loughin

Project: Climate and Habitat Effects on Productivity of Important Alaska Fisheries

Species

Students: Annabella Aguirre, from California State University Monterey Bay, and Hillary Thalmann

**IMPACT (cont'd)**

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

Nothing to Report

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

Nothing to Report

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

**IMPACT (cont'd)**

**42. What was the impact on technology transfer?**

This past decade has involved substantial advancement of marine technologies evidenced by near-real-time availability of continuous big-data for most marine parameters from enterprises and organizations such as OOI, NANOOS etc. These engage a number of academic and industry partners to equip, sample and synthesize findings and make them available to as broad an assemblage of society as possible. CIMRS research focuses more on the discovery/innovation side of technologies engaged in this arena than actual transfer to industry, but the line between when innovation stops and where transfer to industry takes place is hard to draw precisely. For example many electronic innovations now used in hydrophones produced commercially and distributed globally result from engineering innovations that arose in the CIMRS Marine Acoustics program where unique combinations of individual electronic and sensing components (often invented elsewhere) are put together and tested in the rigorous marine environment where powering, pressure and corrosion present significant challenges. CIMRS innovations from this past year include the methane hydrate sampler; tagseq, an RNA gene expression technique for sampling biological response among plankton to extreme conditions; tablets and software for electronic data sampling and upload of data from the Chinook fishery; hormone assessment from whale fecal samples; histology techniques to determine OA response among fish larvae; electronic control of video monitoring to assess sea-bird bycatch; a battery-operated under-ice winch for acoustics and environmental data sampling in remote areas; methods for estimation of marine mammal population density from mobile acoustic platforms; techniques for efficient mapping using unmanned aircraft systems; a MATLAB routine which adds Cycle Slip simulation to a GNSS observations; other web and R applications; numerous human-dimension ecosystem service value models; and a Time-varying Emulator for Short- & Long-Term Analysis of coastal flooding (TESLA-flood) methodology. All these are described in more detail under section 30.

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

CIMRS provides agency, academic and industry engagement within a working port where scope and size of our context are perfect for incubation of unique human resources for vibrant citizenry and leadership in the marine and atmospheric arena. As examples, our alumni include the lead of an acoustic program at Cornell, several NOAA scientists serving in Silver Spring, leadership in fisheries oceanography at Univ. Maryland, plankton ecology at UW and even a private industry working with natural gas production from algae in Scotland! These folk and the enterprises they engage with add vitality and also rigor to ongoing wellbeing of a human and natural ecosystems because they integrate effectively with earth's largest habitat – the ocean, and remain keenly linked to messages. It is abundantly clear that CHANGE is now an increasingly obvious an uncertain feature of everything marine, and CIMRS's fishery, ocean acidification, extreme weather, temperature and climate research has direct bearing on impacts this will have on economic futures for national and global society. Because CIMRS research and findings are on direct experience at the center of the world's large ocean, they provide direct reflections of real-time adaptive capacities of human and natural ecosystems, as we negotiate these changes. Seafloor processes research and mapping here informs society on key features of this sector of earth's largest habitat, which has strong bearing on national and global security. Lastly human dimension research in valuing of natural infrastructure bolstering given sea-level rise and flood risks has direct bearing on economic planning for most prosperous human and marine natural ecosystem futures.

**IMPACT (cont'd)**

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

1 , During this reporting period CIMRS had 16 trips to foreign countries. Travel was for the following purpose:

11 trips for conference travel to Japan, France, and Canada = .69 of the 1%

2 trips for collaboration with project sub-awardees in Spain = .02 of the 1%

3 trips for research related data/equipment collection on research vessel travel to Antarctica, the Axial Seamount and Lost City = .19 of the 1%

No foreign collaborator's travel to the US.

**CHANGES/PROBLEMS**

45. Changes in approach and reasons for change

Nothing to Report

**CHANGES/PROBLEMS (cont'd)**

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

Nothing to Report

47. Changes that had a significant impact on expenditures

Nothing to Report

**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?**

Research, education and outreach achievements at CIMRS continue to address and reveal features of how physical and biological (including human) derived forces interact in concert or dissonance to from the marine and atmospheric experiences of today and make best predictions for the future. As possible we seek, train and use findings, human resources and outreach venues to inform on questions arising from the NOAA mission, so that society and natural systems can thrive towards a mutually prosperous and safe future for all. We continue to: 1) Quantify the effects of changes (e.g. ocean acidification, the Pacific Marine heatwaves, etc.) upon marine ecosystems and habitat futures. 2) Establish best practices for protection & restoration of marine resources (e.g. Plankton, a host of Alaskan and PNW fishes including Hake, salmon, as well as marine mammals). 3) Quantify basic structure and stability of the ocean core through geology and acoustics. 4) Map and value ecosystem services of nearshore and natural infrastructure. Because of CIMRS, society is better equipped to sustain prosperous futures in concert with marine change including sea-level rise and increasingly extreme weather and flooding conditions.

**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 style="padding-left: 20px;"><input type="checkbox"/> Deaf or serious difficulty hearing</p> <p style="padding-left: 20px;"><input type="checkbox"/> Blind or serious difficulty seeing even when wearing glasses</p> <p style="padding-left: 20px;"><input type="checkbox"/> Serious difficulty walking or climbing stairs</p> <p style="padding-left: 20px;"><input type="checkbox"/> 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.*