



DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
6. Last Name and Suffix: Cornuelle , null	7. First and Middle Name: Bruce , D
8. Title: Researcher	
9. Email: bcornuelle@ucsd.edu	10. Phone Number: 858-534-4021
AUTHORIZING OFFICIAL	
11. Last Name and Suffix: Park , III	12. First and Middle Name: William ,
13. Title: Senior Contract and Grant Officer	
14. Email: wparkiii@ucsd.edu	15. Phone Number: 858-822-1350
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20. Recipient Name: UNIVERSITY OF CALIFORNIA SAN DIEGO	
21. Recipient Address: 8622 DISCOVERY WAY RM 116, LA JOLLA, CA 92093-1500 USA	
22. Recipient DUNS: 175104595	23. Recipient EIN: 956006144

ACCOMPLISHMENTS

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

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) is the world's longest multi-disciplinary ocean observation program. Its 69-year time series continues to elucidate the effects of interannual and decadal-scale variability on the southern California Current System (CCS) and its fisheries.

CIMEC plays key roles within U.S. and international Argo including instrumentation development, float production and deployment, communications and data management, and scientific analyses to demonstrate the value of Argo data. With CIMEC funding, SIO produces and deploys one-fourth of the U.S. Core Argo floats, carries out float technology development, participates in delayed-mode quality control, coordinates the U.S. Argo partnership, and provides leadership for international Argo.

The SIO High Resolution XBT (HRX) Network is a set of basin-spanning shipping routes (<http://www-hrx.ucsd.edu>) along which eddy-resolving temperature transects are collected four times per year at spatial separations of 10 to 50 km.

The HF Radar National Network Data Management Development is concerned with implementation and operation of the near real-time data system and supporting data distribution for research. The California Underwater Glider Network (CUGN) is maintaining sustained glider observations in the California Current System (CCS).

The Global Drifter Program provides a real-time data stream of drifter locations, SST, and other critical variables.

The Scripps O2 Program is continuing the longest ongoing flask time series of O2/N2 and Ar/N2 ratios at ten background air stations, which are being sustained by the Scripps O2 program.

The CLIVAR and Carbon Hydrographic Data Office (CCHDO) has core funding from both NSF (85% of support) and NOAA (15% of support). NOAA funds contribute to both the overall operation of the CCHDO and to goals and tasks of specific interest to NOAA.

CIMEC supported a variety of Passive Acoustic studies aimed at describing geographic variability of marine mammals and the impact of anthropogenic sound.

CIMEC machine vision researchers at UCSD have developed computer vision algorithms (CoralNet) that distinguish coral genera and other benthic cover components.

CIMEC also funded research aimed to enhance stock assessment and effective management of western Atlantic bluefin tuna (ABT) by improved understanding of the environmental factors that impact the success of larvae in spawning grounds in the Gulf of Mexico (GoM).

25. What was accomplished under these goals?

103 Core Argo floats were fabricated, shipped, and deployed by R/Vs Kaharoa, Thompson, Lasker, Tangaroa and Ride. 17 Deep Argo floats were fabricated, shipped, and deployed in regional pilot arrays by R/Vs Kaharoa and Tangaroa. Float technology was improved, including new batteries to increase float lifetime, improved calibration, and communications.

The HRXBT deployed >4500 XBTs with delayed-mode quality control of all profiles and dissemination.

The HF Radar National Network collected data as planned and disseminated them as noted below. Improvements were made in technology, acquisition, visualization, processing, and distribution.

The California Underwater Glider Network has been sustained for over twelve years, making it the longest-running underwater glider program in the world.

The Global Drifter Program array exceeded the target number of 1,250 drifters throughout the reporting period (+13.3% at the time of writing), due to technical innovations introduced by the Lagrangian Drifter Laboratory (LDL) at SIO and improved quality control. The count of drifters reporting sea surface temperature (SST) accuracy better than 0.05 deg has increased, and SVP drifters from the LDL can produce GHRSSST-compliant SST observations.

The Scripps O2 Program maintained time series at the ten flask sampling stations, improved measurement accuracy, error analysis, quality control, and did international intercalibration.

Seagoing projects were successfully executed aboard R/Vs Roger Revelle and Sally Ride.

Passive acoustic studies analyzed existing observations for beaked whale presence, made improvements to existing PIFSC equipment, and assisted PIFSC with data collection and monitoring equipment. They supplied a hydrophone mooring for a Northeast Fisheries Science Center Beaked Whale Cruise. They defined source levels for seal bombs, analyzed soundscapes at a site off Kona, Hawaii, and explored click patterns using machine learning.

During the spring and summer of 2017, a total of 8 HARPs were serviced. Acoustic tags were deployed and data collected on Gulf of Mexico Bryde's whales and SIO personnel collaborated for cruises and data analysis.

A cruise (April-May 2018) was conducted during the peak Bluefin Tuna Gulf of Mexico spawning season and data from previous cruises was analyzed and submitted for publication.

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?

The Argo dataset provides a major resource for basic research and education of graduate and undergraduate students, post-docs, and young scientists. Over 300 PhD theses worldwide have utilized Argo data. SIO-Argo P.I.s serve as advisors and mentors for students, post-docs, and young scientists.

The datasets for the SIO O2 program have supported projects for two postdocs at Scripps, Eric Morgan and Yassir Eddebbbar. They have supported work by Scripps graduate student Benjamin Birner, the project provided laboratory and work experience for UCSD undergraduate Savannah Hatley.

A post doctoral researcher, Alba Solsona Berga, gained experience in development of interactive software as part of the project: An Interactive Machine Learning Toolkit for Classifying Species Identity of Cetacean Echolocation Signals in Passive Acoustic Recordings.

The Effects of Nitrogen Sources and Plankton Food-Web Dynamics on Habitat Quality for the Larvae of Bluefin Tuna in the Gulf of Mexico project has supported the career development of post-doc Rasmus Swalethorp, a technician, Jennifer Beatty, who entered a PhD program in marine science at the University of Southern California this fall, and two undergraduate students (Kelsey Fleming and Tabitha Hernandez), one from an underrepresented minority group, are also acquiring experience and training in analytical techniques for plankton food web studies.

The UC Santa Cruz Collaboration in Freshwater Ecology Research opportunities for professional development include leading workshops, giving oral and poster presentations at professional meetings, participating in the AFS student subunit, and participating in local outreach opportunities.

Several early career scientists (3 post-docs, 9 project scientists) and two UCSC graduate students were supported by and contributed to Climate ecosystem interactions/CA Current integrated ecosystem assessment/Species habitat modeling.

Multiple graduate and undergraduate students from UC Santa Cruz and elsewhere were trained in research methods as part of the Genetic monitoring and evaluation of CA salmon and steelhead project. Colleagues at the Autonomous University of Baja California (UABC) were trained on the black abalone population assessment and monitoring protocols.

Two HSU graduate students are developing thesis research based on TH-line observations; one of whom is building on previous training in statistical analysis gained while a technician on this project. Six undergraduate/post-graduate technicians have gained substantial training and experience in cruise operations, microscope analysis of zooplankton samples, chemical assays of zooplankton energy content, and chemical assays of seawater alkalinity and nutrients.

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

The CalCOFI program completed four quarterly cruises and the results were put online: <https://www.calcofi.org/cruises.html>. CalCOFI scientists regularly interact with media outlets and the general public to share findings of interest.

Delayed-mode quality control was carried out for all SIO-Argo profiles, approximately 18,000 per year and made available on the web. Operational models for ocean reanalysis and forecasting are dependent on Argo data, and the results of these data assimilating models are widely disseminated to interested communities.

All HR-XBT data were made available without restriction in near real-time through the GTSP and delayed mode versions through NCEI and at the SIO web site (www-hrx.ucsd.edu).

The HF Radar National Network published the data and long term averages through THREDDS Data Service and public listservs. Collaboration and harmonization is advanced through community forums and workshops as well as the global listserv.

The California Underwater Glider Network has established a website (spraydata.ucsd.edu) for public access of quality controlled delayed mode data. CUGN data continues to be provided to the GTS in real time, and to be used in several models of the CCS.

The SVP program is posting the drifter observations of the NOAA funded drifters that use the Iridium satellite system to the Global Telecommunication System (GTS).

The O2/N2 and CO2 data are made available without embargo on the ScrippsO2.ucsd.edu website. This data is also mirrored on the archival California Digital Library site, <https://library.ucsd.edu/dc/collection/bb3381541w>

The CLIVAR and Carbon Hydrographic Data Office (CCHDO) serves reference-quality repeat hydrography data and supporting documentation primarily by the website, cchdo.ucsd.edu.

All data collected aboard ships operated by Scripps Institution of Oceanography are provided to the NSF Rolling Deck To Repository program.

The site www.voicesinthesea.org has a page devoted to illustrating the sounds of Bryde's whales: <http://voicesinthesea.ucsd.edu/species/baleenWhales/brydes.html>

CoralNet is publicly available and used by over a thousand researchers.

UCSC Striped bass management/research results were included in the 2018 Annual Fisheries Report for Carmel River steelhead. Calls and meetings have been held regularly with stakeholders to initiate a tagging study of striped bass in the Carmel River.

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?

All continuing projects plan to maintain and, where possible, improve their planned operations. This includes: observing systems; data quality; timely, web-accessible data access; collaborations with national and international marine science, conservation, and management communities; to facilitate the use of their data locally, nationally, and internationally to advance science and inform decisions in marine resource management and policy. They will continue to teach, mentor, publish, and train the public and the next generation of scientists.

Some particular details include:

Argo will improve technologies in the SOLO-II and Deep SOLO floats for better performance and lifetime, facilitate the data stream for near real-time and delayed-mode users of Argo data.

The Global HF Radar Network will work to foster communication pathways between regional site operators and node operators, as well as among national node operators to ensure consistent processing. They will also work to develop HFR capabilities internationally to increase the number of coastal radars operating around the globe by maintaining a dialogue with organizations like the Group on Earth Observations (GEO), Intergovernmental Oceanographic Commission (IOC), Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) and Partnership for Observation of the Global Ocean (POGO)

The Passive Acoustic Recordings project will Build a user interface for their signal clustering and feature extraction tools, run their click detector on towed array data and begin classification efforts, and write documentation for the click detector.

Food-Web Dynamics in the Gulf of Mexico expect to finalize all cruise data (plankton biomass, phytoplankton growth and zooplankton grazing rates) from Y1 and Y2 cruises. These will be uploaded for public web access and integrated into the GoM model being developed by co-PI Stukel.

UCSC Ecosystem based fisheries management will develop models of migration for albacore covering the broader North Pacific. We will also collaborate with the NOAA-funded Future Seas project (<https://futureseas.github.io/>) to examine projections of future habitat, prey fields, and migratory corridors for this species under different climate change scenarios. Lastly, we will use the developed MSE framework to consider performance of a set of candidate harvest strategies for albacore, the robustness of potential management strategies for albacore to climate change, as well as the potential socioeconomic impacts on fishing communities. The Life history of pelagic fishes/Stock assessments for highly migratory fish species project will extend their diet database beyond 2014.

CoastWatch and PolarWatch will add a suite of satellite data products to the CoastWatch data server (<https://coastwatch.pfeg.noaa.gov/erddap/>) and PolarWatch server (polarwatch.noaa.gov/erddap) that are requested by our user base and the CoastWatch central office. CoastWatch and PolarWatch will instruct NOAA personnel on how to access ocean satellite data and incorporate it into their research and management efforts. CoastWatch and PolarWatch will develop online outlets to disseminate the results of NOAA fisheries management projects. CoastWatch will provide custom data products to NOAA projects with an aim to incorporate NOAA satellite data into ecosystem modeling products.

The Black abalone population assessment survey data will be used to estimate the population size of black abalone in southern California and the Channel Islands. Baja California survey data will be added to make a population estimate for northern Baja

PRODUCTS

29. Publications, conference papers, and presentations

We will provide an attached pdf document which will show all CIMEC publications. This list was submitted to the NOAA repository on July 9, 2019.

PRODUCTS (cont'd)

30. Technologies or techniques

- Directional Wave Spectra (Centurioni)
- Methods refinement and error-analysis for isotopic analyses of small sample sizes by CSIA-AA (Landry)
- High Frequency Radar HFR (Terrill)
- Development of new Dynamic Ocean Management frameworks (Raimondi/Palkovacs)
- The microhaplotype method for exponentially increasing statistical power has been validate (Raimonid/Palkovacs)

31. Inventions, patent applications, and/or licenses

Nothing to Report

PRODUCTS (cont'd)

32. Other products

California Cooperative Oceanic Fisheries Investigations: Ocean Observations to Inform Ecosystem- Based Management Each CalCOFI cruise generates a set of biological samples (from DNA to plankton) that are inventoried, catalogued, and enumerated during the process of integrating new samples into our long-term collections. These curated biological samples represent one of the richest and most comprehensive ocean monitoring inventories in the world.

The Argo Project: Global Observations for Understanding and Prediction of Climate Variability International Argo web site: <http://www-argo.ucsd.edu>

SIO High Resolution XBT Transects Intergovernmental Oceanographic Commission/IODE. 2018. Sixth International XBT Science Workshop, IOC Project Office for IODE, Oostende, Belgium, 18-20 April 2018. Paris, UNESCO, 25 pp. 2018. (IOC Workshop Report No. 283) (English). All XBT transect data are available on a cruise-by-cruise basis at <http://www-hrx.ucsd.edu/>

HF Radar National Network Data Management Development Surface Currents, Wave Height, Wave Direction, Wave Period, Wind Direction

NOAA Support for the CLIVAR and Carbon Hydrographic Data Office at UCSD/SIO All public CCHDO data, documentation, and data information are disseminated via the CCHDO web site <http://cchdo.ucsd.edu>.

An Interactive Machine Learning Toolkit for Classifying Species Identity of Cetacean Echolocation Signals in Passive Acoustic Recordings, Open source software shared on github: <https://github.com/ScrippsWhaleAcoustics/DetEdit>; <https://github.com/ScrippsWhaleAcoustics/Triton>

Investigations in Fisheries Ecology [Groundfish ecology/stock assessments] The forementioned stock assessments of cowcod and gopher rockfish will be reviewed and published by the Pacific Fishery Management Council and unique findings will be prepared for publication in the peer-reviewed literature. Age and growth studies of pelagic juvenile rockfish are also ongoing and we expect a publication to be developed in the next CIMEC cycle. Efforts are also being initiated to evaluate trophic relationships and food habits of adult groundfish and their prey and predators, and a technical memorandum reporting on a forthcoming workshop will be developed. [Advanced survey technologies] Research continues in the following topics: 1) quantification of krill species to understand the dynamics of the base of the food web and its bottom-up effects in the California Current, 2) characterization of CPS target strength to produce more accurate fish abundances, 3) characterization of survey uncertainty, and 4) studying species and environmental interactions. [Climate ecosystem interactions/CA Current integrated ecosystem assessment/Species habitat modeling] California Current Integrated Ecosystem Assessment; WhaleWatch and EcoCast tools.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Bruce Cornuelle, Director of CIMEC, UCSD/SIO
Mark Brzezinski Partner Lead, UC Santa Barbara
Pete Raimondi, Partner Lead, UC Santa Cruz
John Largier, Partner Lead, UC Davis
James McWilliams, Partner Lead, UC Los Angeles
Brian Tissot, Partner Lead, CalState Humboldt State University
Pat Krug, Partner Lead, CalState Los Angeles

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?

No

35. What other organizations have been involved as partners?

California Polytechnic State University (CalPoly)
Cayman Island Department of Environment (CIDoE)
Center for Advancement of Population Assessment Methodology (CAPAM)
Center for Climate Change Impacts and Adaptation (CCCIA)
Center for Scientific Research and Higher Education of Ensenada (CICESE)
Channel Islands National Marine Sanctuary
CICESE
Cooperative Institute for Marine Resources Studies (CIMRS)
Connecticut Department of Energy and Environmental Protection

CSIRO Australia

Florida State University (FSU)
Georgia Aquarium
GO-SHP

Hoopla Valley Tribal Fisheries
Hopkins Marine Station (Stanford University)
Hubbs-SeaWorld Research Institute (HSWRI)
Humboldt State University

Intra-American Tropical Tuna Association (ATTTC)
Instituto Tecnológico de Bahía de Banderas (ITBB)

Monterey Bay Aquarium Research Institute (MBARI)
Monterey Peninsula Regional Park District
Monterey Peninsula Water Management District
Moss Landing Marine Laboratories (MLML)
National Marine Sanctuary Program
National Science Foundation (NSF)

NOAA AFSC
NOAA AOML

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?

G. Goni, (NOAA/AOML)
S. Dong, (NOAA/AOML)
M. Baringer (NOAA/AOML)
M. Goes (NOAA/AOML)
F. Bringas (NOAA/AOML)
P. Oke (CSIRO Australia)
R. Cowley (CSIRO Australia)
M. Feng (CSIRO Australia)
L. Krummel (Bureau of Meteorology, Australia)
Pierre Flament, University of Hawaii
John Largier, UC Davis
James O'Donnell, UCONN
Todd Fake, UCONN
Eoin Howlett, Applied Science Associates (ASA)
Eric Bernier, Applied Science Associates (ASA)
Julie Amft, Skidaway Institute of Oceanography
Anthony Kirincich, Woods Hole Oceanographic Institution
Cliff Merz, University of South Florida
Larry Atkinson, Old Dominion University
Harvey Seim, University of North Carolina
Bruce Lipphardt Jr., University of Delaware
Dave Ullman, University of Rhode Island
Greg Crawford, Humboldt State University
Steve Hankin, NOAA/PMEL
Roy Mendelssohn, NOAA/NMFS
Francisco Chavez, MBARI
Robert Key, Princeton University
Alex Kozyr, NOAA OCADS
Joel Bell, US Atlantic Fleet, Norfolk VA
California Department of Fish and Wildlife
Connecticut Department of Energy and Environmental Protection
Alaska Department of Fish and Game
Fisheries Resources and Marine Mammal Divisions of SWFSC

IMPACT

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

In addition to basic research, all projects have contributed observations, measurement techniques, peer-reviewed publications, courses, training programs, management plans and assessments, and outreach activities for marine sciences including climate. The publications are listed in the database and their breadth and diversity speak to the value of CIMEC programs.

Some highlights include:

32 peer-reviewed publications used CalCOFI data, ranging from assessing the performance of marine protected areas, to ocean forecasting, to modeling marine mammal and seabird habitat.

Argo is widely viewed as having revolutionized large-scale physical oceanography. Over 3600 papers spanning a wide variety of topics have been published using Argo data. See <http://www.argo.ucsd.edu/Bibliography.html>. The community-service aspect of Argo is underlined by the fact that only 1/4 of publications using Argo data have an Argo P.I. in their author list.

The multi-decadal HR-XBT datasets are used for research in the ocean/climate system to understand the role of upper ocean circulation and variability in the mean and time-varying mass and heat balances and in air-sea interaction.

The network of data sharing for HF radar data is essential to NOAA goals of an integrated ocean observing system. It synthesizes physical data and builds relationships throughout the oceanography community.

The CUGN has demonstrated the ability of underwater gliders to sustain observations in the US EEZ within 200 miles of shore. This has motivated projects in the US and other countries.

The O2 project provides data that is fundamental to tracking global sources and sinks of carbon dioxide and long-term changes in ocean biogeochemistry.

CCHDO data are used for model testing, tracer and nutrient transport, and for calibration of autonomous sensors like Argo. GOSHIP has identified over 500 GO-SHIP scientific publications, and over 41,000 publications citing GO-SHIP or GO-SHIP data (CCHDO is the data repository for GO-SHIP).

Research vessels in the academic research fleet continue to contribute significantly to the U.S. ocean research effort.

Passive Acoustic Studies in the North Pacific has advanced our knowledge on the variability of Blainville's beaked whale (Md) echolocation clicks. Acoustic data for PIFL cruises document habitat use and animal densities of elusive beaked whale species in the Northwest Atlantic.

Echolocation click detection and labeling tools can be used by non-specialists. Passive acoustics in the Gulf of Mexico produced a better understanding of Bryde's whale behavior.

UCSD/SIO Food-Web Dynamics for the Larvae of Bluefin Tuna in the Gulf of Mexico uses an innovative broad ecosystem-based perspective (physics-to-fish) to understand larval ecology and recruitment dynamics of fish stocks.

UCSC Freshwater Ecology shows how ecology and evolution interact in nature, how such interactions respond to human disturbance, and how they can be utilized to help meet management objectives.

Groundfish ecology improved data and helped to refine methods for stock assessments and trophic interactions throughout the

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IMPACT (cont'd)

38. What was the impact on other disciplines?

The analytic methods developed for CalCOFI are used by a broad cross-section of STEM fields. In particular, the software tool MixSIAR (used for mixing model analysis of stable isotopes and other tracers) has seen adoption across plant sciences, ecology, soil sciences and hydrology.

Colleagues in ocean biogeochemistry are presently developing biogeochemical (BGC) sensors for Argo floats and mounting a global BGC Argo Program in parallel with the Argo Program.

The physical temperature and geostrophic velocity data from the XBT network have been used to interpret the patterns of biogeophysical properties in the world ocean (e.g. Freeman et al., 2019).

Information from the SIO HR-XBT network is used to assess models, and so produce better estimates of the coupled ocean/atmosphere variability. This is contributing to, for example, the redesign of the ENSO-Observing System as part of the Tropical Pacific Observing System TPOS-2020 effort.

The High Frequency HF Radar Network (HFRNet) supports operations and provides information for local and national entities such as U.S. Coast Guard Search and Rescue Optimal Planning System (SAROPS), NOAA Office of Response and Restoration (OR&R) Environmental Response Management Application (ERMA), National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS), and California Office of Spill Prevention and Response. The data feeds include numerous participating organizations and agencies.

Data from the CUGN is being used by NOAA SWFSC to help in their fisheries management responsibilities.

The atmospheric time series supported by the O2 program are intrinsically interdisciplinary, spanning climate sciences, and ocean and land biogeochemistry and ecology. The data are uniquely powerful at providing time series of high integrity that relate to very large-scale phenomena and thus are among the first places to look for indicators of global change.

Interactive Machine Learning tools are being made available for use in other areas of acoustic monitoring outside of marine mammals, including for analyzing human generated signals and terrestrial animal sounds.

The general approach of using a broad ecosystem-based perspective (physics-to-fish) to understand larval ecology and recruitment dynamics of fish stocks is still relatively new to the discipline. Our research is influencing that development, in particular, trying to find the linkages that relate ecosystem variability to the particular prey types that are preferred/selected by tuna larvae, and therefore most influence their feeding, growth, and survival.

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

CalCOFI's formal and informal student training has supported the development of many of the academic, state and federal scientists that are currently active in the field today. The Semmens lab is training new scientists on quantitative methods and techniques to support up-and-coming quantitative ecologists who can achieve the mission and goals of NMFS.

During the review period, 3 graduate students in Dr. Semmens lab defended their dissertations. Joshua Stewart and Brian Stock transitioned into postdoctoral research appointments at Southwest and Northeast Fisheries Science Centers, respectively. Lynn Waterhouse took a career position as a research biologist at Shedd Aquarium.

QUEST funds supported two postdoctoral researchers during the review period, both focusing on SWFSC/SIO collaborative science, and both sit half-time at the SWFSC. One, Peter Kuriyama, was hired at the SWFSC as a full-time stock assessment scientist during the review period.

The Global Drifter Program is training skilled technical personnel in ocean engineering.

Anne Simonis was a graduate student working on Passive Acoustic Studies in the North Pacific. She received her Ph.D. during this period and transitioned into a post-doctoral researcher role. She has taken on contract work with several NOAA Fisheries Science Centers in the domain of cetacean passive acoustic monitoring.

The Bluefin Tuna in the Gulf of Mexico project has enhanced the career development of a post-doctoral researcher.

Three UC Santa Cruz Freshwater Ecology postdoctoral researchers have secured positions in academia. Two graduate students have secured positions in academia. One graduate student has secured a job with NOAA Fisheries.

Groundfish ecology/stock assessments internships and training helped to develop human resources (e.g., staff, graduate students, undergraduate students)

Ecosystem-based fisheries management enabled the two-way transfer of knowledge between scientists and the fishing community via webinars, workshops, and more informal discussions.

Genetic monitoring and evaluation of CA salmon and steelhead staff and students working on this project were able to learn new research methods and skills in both laboratory molecular genetics and data analysis.

HSU Ocean Observing and Fisheries Oceanography Research has positively contributed to the development of next-generation

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

IMPACT (cont'd)

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

Each year 6-12 graduate and/or undergraduate students participate in ship-based sciences as part of the CalCOFI program. CalCOFI scientists (both at SIO and SWFSC) work closely with undergraduate and graduate students on scientific projects that leverage CalCOFI data.

PI Semmens taught an undergraduate course in oceanography field techniques for ~50 students, including undergraduate cruises on the RV Gordon Sproul. Activities included CTD casts, plankton tows, Otter tows, and IKMT tows.

The Argo dataset provides a major resource for basic research and education of graduate and undergraduate students, post-docs, and young scientists. Over 300 PhD theses worldwide have utilized Argo data. SIO-Argo P.I.s serve as advisors and mentors for students, post-docs, and young scientists.

HR-XBT PI Sprintall co-advises a PhD student using HR-XBT data as part of his research. PI Sprintall also co-mentors a postdoc. Near real-time surface currents and related products are available in public repositories and online visualizations providing opportunities for education.

The CUGN supported 2 female graduate students using data from the CUGN. One earned a Ph.D. in 2018. UCSD undergraduates work on the project and the CUGN is used in the PI's undergraduate physical oceanography course.

Dr. Centurioni taught a graduate seminar course covering observational and analysis methods.

The data from the O2 project has fueled multiple projects by graduate students and postdocs, both at Scripps and elsewhere.

CCHDO has 2 students working with an experienced physical oceanographer and a technical team to handle data and documentation and present them in easy to use understandable form.

A graduate student finished her PhD working on Passive Acoustic Studies in the North Pacific and received funding from the project. Passive Acoustic Studies trained a graduate student to analyze echolocation clicks with machine learning tools which she will now apply in her doctoral thesis.

A graduate student, gained experience in research using towed array recording data for dolphin monitoring.

A graduate student and an undergraduate student participated in research cruises to the Gulf of Mexico on the NOAA Ship Gordon Gunter.

One undergraduate and two masters students started research projects related to CoralNet.

The Bluefin Tuna project has provided hands-on experiential learning opportunities for three female undergraduate students who seek careers in marine science. One, who worked as a tech on the project during the first cruise is pursuing a PhD in grad school.

The Rockfish project hosted three graduate students, nine undergraduate students, and 23 volunteer citizen scientists.

A short course on the use of acoustic systems to monitor protected areas was held in La Paz, Mexico, exposing graduate and undergraduate students to a discipline that is still relatively unused outside of large research institutions.

The UC Santa Cruz Freshwater Ecology PI mentored 10 graduate students, 4 postdoctoral researchers, and 26 undergraduate students. The PI taught a freshwater ecology course to a class of 90 students and taught an undergraduate research writing course to 25 students.

Across all years, this project has supported 12 graduate students (8 complete, 4 current), including 7 women and 2 students from

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

CalCOFI supports ship based observational science (and the ships that carry out such observations) along the west coast of the US.

The Argo partnership has created a global array of 3800 profiling floats spread every 3-degrees of latitude and longitude over the global deep ocean, providing a snapshot of the physical state of the ocean every 10 days.

The XBT network leverages extensive ship resources through partnerships with the ships, companies and international academic community and in doing so, also providing a degree of public outreach.

HF Radar Central repository nodes have been deployed and are maintained on the east coast (Rutgers University), west coast (Scripps Institution of Oceanography [SIO]), and at the National Data Buoy Center (NDBC) to demonstrate an end to end distributed data system which links multiple regions to a central data repository. Data aggregators are currently deployed at nine institutions (California Polytechnic State University; Monterey Bay Aquarium Research Institute (MBARI); Oregon State University, College of Oceanic and Atmospheric Sciences; Rutgers University; Scripps Institution of Oceanography; University of California, Santa Barbara; University of Maine; University of Miami, Rosenstiel Schools of Marine and Atmospheric Science; University of Southern Mississippi).

The CUGN is made possible by the Spray underwater glider fleet infrastructure at the Instrument Development Group at Scripps Institution of Oceanography. Data management activities are proving influential, particularly in our use of the DOI to identify data sets from the CUGN.

The O2 program sustains physical resources (instrumentation, facilities, computer hardware, and software) pertinent to long-term O2/N2 and CO2 measurements. These resources are relevant also for additional programs making these and similar gas measurements.

CCHDO represents an enhancement of research information infrastructure. While the CCHDO does not generate new data, it makes the data better and more usable, thus more far-reaching and ultimately more scientifically and socially relevant.

A capable and reliable fleet of academic research vessels is vital to the health of the U.S. oceanographic research community.

PIFSC instrumentation pool was kept up to date and improved.

PIFSC acoustic data collection with autonomous recorders was made possible through the continued support of instrumentation. Older datasets were screened and missing data or faulty data was replaced and fixed, respectively, when possible.

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?

In the past year, CalCOFI's observations continued to support model validation for applications in remote sensing products, fisheries and ecosystem modeling, and physical ocean models. Each of these model products represents technologies that improve our understanding of current and future ocean state. SIO-Argo works with MRV Systems to provide commercial versions of the Argo floats developed at Scripps. Recently a system to transmit XBT observations in real-time using Iridium satellites was developed and implemented on all cargo ships with XBT transects operated by NOAA/AOML and SIO. The use of the Iridium network reduced the cost of XBT data transmissions by 95% over the previous system using Inmarsat. Additionally, the recent implementation of FTP protocols instead of SMTP (email) facilitated a more reliable, faster and highly efficient transmission of large datasets. Although originally developed to be used for XBT observations, the adaptability and portability of the FTP data transfer system have been expanded to allow transmission of other types of observations, such as ThermoSalinoGraph (TSG), pCO₂, and marine weather reports. In addition to Iridium transmissions, the new FTP data transfer system can also be configured to transmit data over telephone landlines or computer networks. These innovative systems, as well as continuing development of best practices, have improved the success rate of the XBT probe deployment. In 2018, over 98% of XBT deployments returned good data. The translation of these technological systems to other components of the global observing system is similarly likely to improve their successful deployment rate. There are three primary surface current mapping systems from manufacturers: CODAR Ocean Sensors; WaveE RAdar (WERA); Least Expensive RAdar (LERA) that are installed for measuring surface currents. PIFSC instrumentation was improved to the newest version of our long-term acoustic recorders. Interactive graphical user interfaces for interactive machine learning software tools for classifying species identity of cetacean echolocation signals in passive acoustic recordings were developed for non-expert government users. UCSC Fisheries Ecology Carmel River steelhead project: Local fisheries staff of Monterey Peninsula Water Management District learned to deploy and maintain a PIT tag detection system and corresponding infrastructure within the Carmel River basin. The analytic products developed by members of the Semmens lab are made freely available over software sharing portals such as Github. As detailed above, these software tools have found a broad audience, including many scientists in the NMFS. The acoustic-trawl method developed by SWFSC and UCSC scientists was reviewed by a panel of international independent experts, which attested the survey quality by endorsing its use in the assessment of four coastal pelagic (CPS) trans-national species: Pacific sardine, Pacific mackerel, jack mackerel, and northern anchovy. UCSC and SWFSC scientists produced a detailed methods and results report of the acoustic-trawl that is in open-source format. This document will be updated annually to report both changes in methodologies and the evolution of the CPS community. The survey results have been adopted by the Pacific Fishery Management Council to be used in the assessment and management of Pacific sardine, Pacific mackerel, and the central subpopulation of northern anchovy. This serves as an advancement in ecosystem-based approaches to fisheries management (EBFM) for highly migratory species in the eastern North Pacific.

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

The multi-decadal, multi-variate ocean data sets taken, maintained, and served by CIMEC are used for basic research in the ocean/climate system to understand the dynamics of the coupled ocean, atmosphere, land, and ecosystem and assess the state of the global and regional oceans. This basic research is applied in global and regional models for understanding and prediction of the economic and human impacts related to variability in the state of the oceans, such as carbon, sea level, hurricanes, or ecosystem-based management of fisheries. In the longer term, these observations will help us to understand the earth system under climate change, including habitat changes for important fisheries and threatened species. National and international climate assessments (e.g. IPCC) depend on CIMEC data and results to quantify and clarify policy discussion.

Better management of marine resources directly impacts all consumers. The research and subsequent dynamic ocean management products provide a framework for maintaining sustainable and healthy marine ecosystems. Through the reduction of by-catch species in fisheries, CIMEC is helping protect important non-target species while maintaining the intrinsic beauty of our marine environments. Quantifying catch will help to understand each fishery's impact on target populations, enabling better management.

NOAA is developing a conservation and hatchery program for threatened and endangered species, such as salmonids and white abalone. CIMEC science will support these efforts, and contribute to the recovery of economically and socially important species. These species and resources have great social and cultural value throughout the USA, including to indigenous and Native American communities, and support economically valuable tourism.

Outreach presentations and media engagement enhance public understanding of marine ecosystems and climate. Education, outreach and teaching efforts at CIMEC have reached thousands of students over the last few years alone, spanning students from the K-12 to the graduate level, and including interested members of the general public.

CIMEC personnel have led workshops on Equity, Diversity, and Inclusion (EDI) topics and hosted various panels on EDI topics and participated in groups that work towards a more equitable, equal, and inclusive community, within science and in the broader world.

Some specific highlights are below.

CalCOFI's 'omics observations have provided insight into the spatial microbiome of the California Current, with direct application to understanding and predicting harmful algal blooms (human health and food security).

400 HF radars make real time measurements of surface currents for pollution and rescue operations. 34 countries are making measurements of their coastal waters and 10 countries are sharing data via the global network <http://global-hfradar.org>.

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

IMPACT (cont'd)

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

1 , The Argo Project: Global Observations for Understanding and Prediction of Climate Variability: 1%

SIO High Resolution XBT Transects: Approximately 5% primarily on accommodations for ship riders when their XBT cruise ends in a foreign port.

NOAA Support for the CLIVAR and Carbon Hydrographic Data Office at UCSD/SIO: Approximately 6% of the award was spent in a foreign country. This represents the meal and accommodation costs incurred during travel to international science meetings and conferences

Effects of Nitrogen Sources and Plankton Food-Web Dynamics on Habitat Quality for the Larvae of Bluefin Tuna in the Gulf of Mexico: About 1%. With prior rebudgeting approval, Landry and Swalethorpe attended an international conference (ECOLATUN Meeting, Tenerife, Spain, March 2019) on comparative studies of ABT larvae in the Mediterranean Sea and Gulf of Mexico.

Investigations in Fisheries Ecology: Less than 5%

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

NOAA Support for the CLIVAR and Carbon Hydrographic Data Office at UCSD/SIO:

The CCHDO Director, Dr. James Swift, retired at the end of June 2018, and Dr. Karen Stocks, Director of the Geological Data Center at Scripps, was appointed as the new CCHDO Director. Swift is remaining active as an unfunded co-PI and advisor in his "Return To Active Duty" retiree status, ensuring a smooth transition. Dr. Sarah Purkey acts as an additional scientific advisor to the CCHDO.

Training the Next Generation of Marine Population Dynamics Scientists:

This year saw a large turnover in graduate students in the lab, with associated challenges in ensuring research continuity and appropriate archiving of data and samples prior to student departures. Funding to support CAPAM continues to present a challenge, particularly in terms of dedicated staff time to support the program

CHANGES/PROBLEMS (cont'd)

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

See Attached RPPR

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

There were only minor alterations in some sampling programs due to logistical considerations.

PROJECT OUTCOMES

50. What were the outcomes of the award?

See Attached RPPR

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- Male
- Female
- Do not wish to provide

Ethnicity:

- Hispanic or Latina/o Not
- Hispanic or Latina/o Do not
- wish to provide

Race:

- American Indian or Alaska Native Asian
- Black or African American
- Native Hawaiian or other Pacific Islander
- White
- Do not wish to provide

Disability Status:

- Yes
 - Deaf or serious difficulty hearing
 - Blind or serious difficulty seeing even when wearing glasses
 - Serious difficulty walking or climbing stairs
 - Other serious disability related to a physical, mental, or emotional condition
- No
- Do not wish to provide

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