Annual Progress Report
to
National Oceanic & Atmospheric Administration

NOAA Award# NA11OAR4320091A

Reporting period: 7/1/15 – 6/30/16

Oregon State University

Cooperative Institute for Marine Resources Studies

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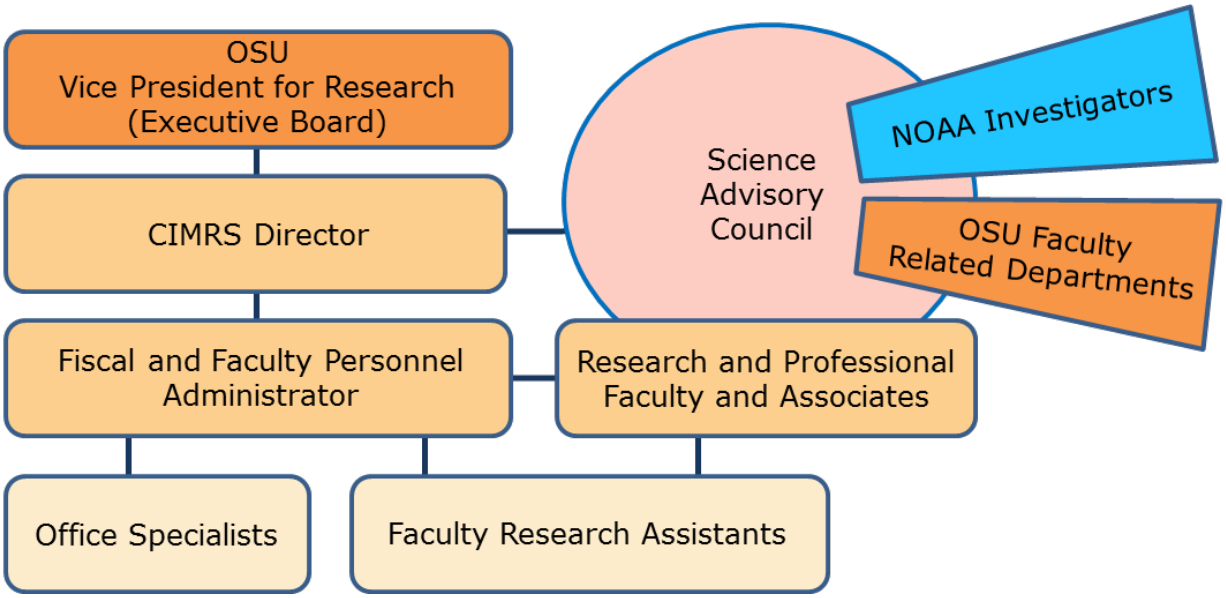
ORGANIZATION

CIMRS is administered through the OSU Research Office with oversight from an Executive Board made up of members from the participating NOAA laboratories and collaborating OSU colleges and programs under the terms of a Memorandum of Understanding between OSU and NOAA/NMFS. A Science Advisory Council (SAC) gives input on research directions, progress, and policy to the Director.



2015/2016 EXECUTIVE BOARD

Cynthia Sagers (Chair) Vice President for Research, Oregon State University	**Shelby Walker** Director, Oregon Sea Grant, Oregon State University
Roy Haggerty Interim Dean, College of Earth, Ocean & Atmospheric Sciences, Oregon State University	**Jeff Napp** Director, Resource Ecology and Fisheries Management Division, Alaska Fisheries Science Center, NOAA
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Dan Edge Dean, College of Agricultural Sciences, Oregon State University	**Chris Sabine** Director, Pacific Marine Environmental Laboratory, NOAA
Robert Cowen Director, Hatfield Marine Science Center, Oregon State University	**John Stein** Director, Northwest Fisheries Science Center, NOAA
Michael Banks (Ex Officio) Director, Cooperative Institute for Marine Resources Studies, Oregon State University	

2015/2016 SCIENCE ADVISORY COUNCIL

David Noakes (Chair) Professor, Department of Fisheries and Wildlife, Oregon State University	**Chris Parrish** Associate Professor, College of Engineering Oregon State University
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William Chadwick Professor Sr. Res., Cooperative Institute for Marine Resources Studies, Oregon State University	**Clifford Ryer** Fisheries Biologist, Resource Assessment and Conservation Engineering Division, Alaska Fisheries Science Center, NOAA
Louise Copeman Asst. Prof., Sr Res., College of Earth, Oceans, and Atmospheric Sciences, Oregon State University	**Paul Wade** Research Biologist, National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA
Kurt Fresh Estuarine and Ocean Ecology Program Manager, Fish Ecology Division, Northwest Fisheries Science Center, NOAA	**George Waldbusser** Assistant Professor, College of Earth, Oceans, and Atmospheric Sciences, Oregon State University
Sarah Henkel Asst. Professor Sr. Res., Department of Integrative Biology, Oregon State University	**Laurie Weitkamp** Research Fisheries Biologist, Conservation Biology Division, Northwest Fisheries Science Center, NOAA

Michelle McClure Director, Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, NOAA	Michael Banks (Ex Officio) Director, Cooperative Institute for Marine Resources Studies, Oregon State University

Research at CIMRS

CIMRS partnership brings university scientists together with scientists from NOAA Northwest Fisheries Science Center, Alaska Fisheries Science Center, and Pacific Marine Environmental Laboratory.

Current research themes are:

- Marine Ecosystems and Habitat;
- Protection and Restoration of Marine Resources;
- Seafloor Processes; and
- Marine Bioacoustics.

CIMRS' diverse and richly multidisciplinary range of applied and basic research investigations include marine chemistry and geophysics, ocean acidification and hypoxia, trophic dynamics and modeling, fisheries stock/habitat assessment and behavioral ecology, longer term prediction of physical (mesoscale/upwelling/plume/estuarine) and biological (predator/prey, lipid composition) inter-relationships and climate, zooplankton ecology, genomics, passive acoustic monitoring of marine mammals, socio-economic issues related to fisheries, and spatial planning.

The advancement of basic knowledge about ocean ecosystems from local to global scales, the conservation of endangered species, maintaining sustainable commercial and recreational stocks, and predicting and mitigating natural hazards associated with the solid earth (*e.g.*, earthquakes and volcanoes) and climate change (*e.g.*, changing weather, sea level rise, and ocean acidification) are in line with NOAA's mission. Over the next decade, CIMRS expects to assist NOAA in meeting existing and emerging environmental and ecological challenges through research, education and outreach. Our research efforts will promote technological and scientific advancements that lead to ecological health, marine geophysical dynamics, sustainable marine resources, and socioeconomic benefits.

In FY16, CIMRS researchers spent 124 days at sea. In addition, CIMRS researchers conducted 10 sampling days on the Newport Hydrographic Line.

RESEARCH PERSONNEL

The following table describes CIMRS research personnel in FY16

Position Category	# Staff	# B.S.	# M.S.	# Ph.D.
Research Scientist	4	--	--	4
Research Associates	1	--	--	1
Research Assistants	12	12	5	0
Total Support >50%	**18**	**12**	**5**	**5**
Research Scientist < 50%	**1**	**1**	**1**	**1**

2015-2016 PUBLICATIONS
ALL PEER-REVIEWED

Institute Lead Author	NOAA Lead Author	Other Lead Author
12	**5**	**6**

TASK 1: ADMINISTRATION, EDUCATION, AND OUTREACH

ADMINISTRATIVE STAFF

Position	FTE	Supported by Award
Director	0.4	Partial
Administrator	1.0	Partial
Purchasing Specialist	0.5	No
Travel Specialist	0.25	No

INSTITUTE DIRECTOR ACTIVITIES

National Service

National Cooperative Institute Directors' Executive Committee:

- Key participant in CI-21 deliberations (meetings June 17th, 2015 in DC , & Oct. 15th 2015 in Boulder)
- National CI Directors meeting, Washington DC, March 7&8, 2016 (resigned Exec Comm. Membership after 9 years (3 as chair))

University Service

- OSU Centers, Institutes and Programs meetings
- Conducted review of CIMRS faculty and staff – April 2016
- Convened meetings for CIMRS coordination and oversight:
  - CIMRS Seattle Labs and Director visits (Feb 9&10 2016)
  - CIMRS Executive Board, Corvallis, OR (4 April 2016)
  - CIMRS All Hands (5 Jan 2016)
  - CIMRS update with Bob Cowen, Director HMSC (13 Jan, 28 April 2016)
- Engaged in various HMSC/OSU Marine Studies Campus and Building meetings
- Engaged in HMSC Executive Committee meetings (monthly)

RESEARCH

The Institute Director's research was supported in 2015-16 through grants and state funds awarded through OSU's Coastal Oregon Marine Experiment Station, Department of Fisheries and Wildlife where he holds a faculty appointment at the rank of Professor.

Marine Fisheries Genetics & Conservation				
Principal Investigators	**Funding Agent**	**Title**	**Term**	**Funds**
Banks	Oregon Department of Fish and Wildlife	AMS ODFW 617 Banks Colab Htchry Rsc	03/22/2016 – 06/30/2017	$456,000
Banks/Johnson/O'Malley	US ARMY CORPS OF ENGINEERS	Genetic pedigree analysis of McKenzie River spring Chinook salmon: An evaluation of adult outplanting strategies	11/30/2014 – 08/31/2016	$55,967
Banks	USDA	AMS - USDA Banks Gentcs Pac Oysters	09/28/2015 – 09/27/2017	$83,000
Ciannelli et al (Banks as core member)	NSF	NRT-DESE: Risk and Uncertainty Quantification in Marine Science and policy	FY16-FY21	$2,999,829
		TOTAL		$3,594,796

Grant and Journal Reviews:

CIMRS, *African Journal of Marine Science, Gene, KAUST, MEPS, WA Sea Grant panel member, J Fish Biology, Endangered Species Review, Population Ecology*

PUBLICATIONS:

MARINE FISHERIES GENETICS & CONSERVATION
*Papers by students or postdoctoral advisees, whom I offer first authorship as a matter of policy.

*Sard NM, DP Jacobson, **MA Banks.** Accepted. Grandparentage assignments identify unexpected adfluvial life history contributes offspring to a reintroduced population. *Ecology and Evolution*. (Submitted)

*Sard NM, KG O'Malley, DP Jacobson. M, Hogansen , MA Johnson, **MA Banks.** In Press. Genetic monitoring guides adaptive management of amigratory fish reintroduction program. *Animal Conservation. Version of Record online: 4 MAY 2016 DOI: 10.1111/acv.12278* *http://onlinelibrary.wiley.com/doi/10.1111/acv.12278/epdf*

* Bellinger, MR, MA Banks, SJ Bates, ED Crandall, JC Garza, G Sylvia, and PW Lawson. 2015. Geo-Referenced, Abundance Calibrated Ocean Distribution of Chinook Salmon (*Oncorhynchus tshawytscha*) Stocks across the West Coast of North America *PLoS ONE* 10(7): e0131276. doi: 10.1371/journal.pone.0131276

*Sard NM, KG O'Malley, DP Jacobson, M Hogansen, MA Johnson, **MA Banks.** 2015. Factors influencing spawner success in a spring Chinook salmon (Oncorhynchus tshawytscha) reintroduction program. *Canadian Journal of Fisheries and Aquatic Sciences* 72(9):1390-1397.

Other Reviewed Scholarship:

Lorenzen, Kai, Stephen Smith, **Michael Banks**, Chang Zhang, Zacharie Sohou, Mark Costello, V. N. Sanjeevan. 2016. United Nations World Ocean Assessment: Chapter 13: Fish Stock Propagation. ***http://www.un.org/depts/los/global_reporting/WOA_RegProcess.htm***

In Review:

*Hemstrom W, D Noakes, D Wilson, K Bucklin, **MA Banks.** Long Term Maintenance of Fine Scale *Oncorhynchus mykiss* Population Sub-Structuring and Genetic Diversity in a Hatchery Dominated System. *Transactions of the American Fisheries Society*

*Hemstrom W, **MA Banks**, S Van deWetering Causes and hatchery-based mitigation of hybridization between different steelhead salmon life-histories in the Siletz River, Oregon. CJFAS

Other Technical Writing, Progress, Completion Reports and Research archives:

Banks, MA, CIMRS Executive Board meeting agenda and director overview

Banks, MA, CIMRS Director response to 5-year review format questions

Avery SK, **MA Banks,** J.A. Koslow, A.J. Miller, S.G. Smith. External Review of JIMAR, UH, HI

Administrative Tasks

Dr. Banks and the CIMRS Administrator were responsible for submission of the proposal for the continuation of the Institute for the next five-year period as well as 22 proposals under the new Institutional award during the period 7/1/15 – 6/30/16. This exceeds the number of submissions from FY15. CIMRS Administrator Jessica Waddell retired Oct 1, 2016, but continued service on a limited hour appointment. A recruitment for her replacement was filled mid-October, but ended abruptly in mid-March. Ms. Waddell remains as the current Administrator. A second recruitment has been completed with an appointment date of August 1, 2016.

CIMRS Education

CIMRS Graduate Students Supported through Joint Projects

A small number of graduate student projects are being supported with contributed grant funds from NOAA Fisheries and Oceans and Atmospheric Research.

M.S. Candidates

Samara Haver	2015-2017
Project:	Measuring Soundscapes in the Atlantic Ocean
Major Professor:	Holger Klinck
NOAA Fisheries Rep:	Jason Gedemke, NMFS

Ph.D. Candidates

OSU Department of Fisheries and Wildlife

Linsey Arnold	2012-2017
Project:	Management Strategy Evaluations for Rockfish
Major Professor:	Selina Heppell
NOAA Fisheries Rep:	Grant Thompson, AFSC

OSU College of Earth, Ocean, and Atmospheric Sciences

Caren Barceló	2009-2017
Project:	Community dynamics of marine fish assemblages in northern neritic and pelagic environments
Major Professor:	Lorenzo Ciannelli
NOAA Fisheries Rep:	Ric Brodeur, NWFSC

Graduate Students Advised by CIMRS Faculty

CIMRS Faculty also advise students on projects independent of NOAA funding. The Hatfield Marine Science Centers offers a wide variety of scholarships, fellowships and awards that help supplement student research (http://hmsc.oregonstate.edu/academics/hmsc-scholarships-fellowships-and-awards) .

Selene Fregosi:	"Passive-acoustic monitoring of mid-frequency cetaceans using gliders and floats" Dept. Fisheries &Wildlife, Holger Klinck
Michelle Fournet:	"Humpback whale acoustic ecology and the impacts of large vessel noise on non-song vocal behavior in Glacier Bay National Park" Dept. Fisheries &Wildlife, Holger Klinck
Susan Schnur:	"Volcanic Construction and Destruction at the Summit of NW-Rota-1 Seamount: 2004-2010", College of Earth, Ocean, and Atmospheric Sciences, Bill Chadwick

CIMRS Undergraduate Students Projects

The Hatfield Marine Science Center has successfully received long-term funding from the National Science Foundation for a summer Research Experience for Undergraduates (REU) program (http://hmsc.oregonstate.edu/academics/internships/research-experiences-undergraduates-reu). Several CIMRS faculty have teamed up with undergraduate students from around the country who wish to explore research opportunities in the marine field. In the summer of 2015, Ross Meyer, University of Idaho returned for a second internship summer with Dr. Joe Haxel and Dr. Bob Dziak for a project: "Foreshock Analysis of Submarine Transform Fault Earthquakes along the Equatorial Mid-Atlantic Ridge"

CIMRS Outreach Activities

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. Two new blogs have been created by CIMRS investigators this year: www.blogs.oregonstate.edu/acoustics/ and Newportal: A gateway to oceanographic information from the Newport Line and beyond

CIMRS research efforts 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. "Patterns from Sound" 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. "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 depth, 3-D sculptures of crab larvae, and microscopes showing actual larvae. "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. Local radio station KYTE interviews scientists at HMSC. Jennifer Fisher was invited to talk about the Newport Hydrographic Line in March 2016.

Additionally, in the fall of every year, OSU's Department of Fisheries and Wildlife offers a class in coastal ecology and resource management. Usually at least one CIMRS researcher is asked to contribute a lecture.

> Lecture on developing an ecosystem approach to fisheries management. Oregon State University. Coastal Ecology and Resource Management class. October 14, 2015 (Jennifer Fisher)

TASK 2

(Projects support NOAA Strategic Plan Goal of Healthy Oceans and Climate Adaptation and Mitigation)

Theme: Marine Ecosystem and Habitat

Amendment 74: Indicators of Phenology in the northern California Current
Funded: $81,392

OSU RESEARCH STAFF: *Jennifer Fisher*, Faculty Research Assistant; *Xiuning Du*, Research Associate
NOAA TECHNICAL LEAD: *Bill Peterson*, FE/NWFSC

PROJECT BACKGROUND: The classical view of productivity in the California Current holds that production in the California Current depends largely upon the length and strength of the coastal upwelling season. However, this paradigm has been challenged recently in two respects: first, production events in late winter and early spring are critical for successful recruitment of winter-spawning invertebrate and finfishes including many that are fished commercially, including pink shrimp, rockfish, and sablefish. In addition seabirds such as the common murre, Cassin's auklets and Rhinoceros auklets have life history strategies that include reproduction during the winter and early spring because downwelling and poleward transport enhances larval retention. Thus any process that disrupts the timing of winter/spring reproduction events may affect subsequent recruitment of the winter spawners.

Interannual variations in the species composition of zooplankton in the NCC in spring and summer sets the efficiency at which productivity is transferred to higher trophic levels. A better understanding of the magnitude and timing of winter production and of efficiency of energy transfer during spring and summer is needed because the NCC is a feeding ground for numerous migrant species which come to the NCC in spring to fatten-up. Species such as Pacific hake, sardines and anchovies migrate northward from the warm waters of the southern California Current; stocks of salmonids from the Columbia, Snake, Sacramento and coastal rivers migrate to the sea in spring. Other species travel thousands of miles from breeding grounds throughout the Pacific Basin to feed in shelf and slope waters off northern California, Oregon and Washington –extreme examples include sooty shearwaters from New Zealand, black-footed and Laysan albatross from Hawai'i, humpback whales from Peru and grey whales from Baja California.

Little work has been done on phenology in the marine environment due largely to the fact that most biological oceanographic sampling programs are not designed to look at this phenomenon (e.g., annual trawl surveys of fishes and quarterly surveys by CalCOFI clearly cannot capture any aspect of phenology). Biological observation programs that can or do produce phenological data are very rare and for the California Current include the 20-year time series of plankton and krill observations along the Newport Line, 30 year time series of plankton and krill off Vancouver Island (Mackas et al. 2007) and long-term surveys of seabirds nesting at colonies on

the Farallon Islands (for Cassin's Auklets),Yaquina Head (Newport) Oregon and Cape Flattery (for common murres), and Triangle Island BC (for Cassin's and Rhinoceros auklets).

PROJECT PROGRESS: The winter (January and February) phytoplankton bloom was examined for presence/absence and magnitude during the time period of 2001-2016. Empirical data analyses focus on in situ extracted chlorophyll concentration collected from a mid-shelf station off of Newport, Oregon and concurrent phytoplankton species composition and abundance. The preliminary results show that the bloom levels were highly variable interannually so were the major two micro-sized phytoplankton groups diatom and dinoflagellates. These complementary cell counts and chlorophyll dataset indicate whether the high biomass of phytoplankton from chlorophyll was due to the larger-celled diatoms and dinoflagellates (informing high-quality prey and efficient energy transfer to predators). Correlation analyses were conducted among phytoplankton and copepod variables and environmental variables. Preliminary analyses show that: diatoms are sensitive indicators of ocean condition changes; PDO has significant impacts on winter blooms (not local conditions); diatom abundance (not Chl *a* measurments) is significantly correlated with both northern (negative) and southern (positive) copepod biomass in winter and the following spring and summer.

Some analysis has been completed of biological spring transition as indexed by both copepods and phytoplankton in collaboration with Jessica Miller, OSU Fisheries and Wildlife. Preliminary analysis has begun using phytoplankton community analysis of longer time-series data as a parallel indicator of the biological spring transitions based on copepod.

PUBLICATIONS:

Peterson, W.T. and X. Du. 2015. Egg production of *Calanus marshallae* in relation to phytoplankton abundance and species composition in the Oregon upwelling zone. *Prog. Oceanogr*. 138: 32-44.

Amendment 66: Coast-wide Genetic Stock Identification – Ecosystem Effects on Adult Chinook Salmon Distribution and Abundance

Funded: $133,460

OSU RESEARCH STAFF: *Michael Banks*, Director, CIMRS; *Jonathan Minch*, Faculty Research Assistant, Hatfield Marine Science Center

NOAA TECHNICAL LEAD: *Peter Lawson*, Conservation Biology, NWFSC

PROJECT BACKGROUND: Genetic Stock Identification (GSI) is a uniquely useful tool for salmon management because it enables identification of nearly all hatchery and natural origin fish sampled and results are available in a few days. This is in contrast to the traditional Coded Wire Tags, which provide data on about 5 percent of hatchery fish only. Ages of GSI-sampled fish are determined from scales. GSI in combination with fine-scale at-sea sampling allows determination of which stocks are present in the fishery with a high degree of certainty and to map dynamic stock-specific distributions. It is anticipated that 2400 tissue samples will be analyzed from collections of Oregon Chinook salmon from three areas in August and September. Genetics labs

from Alaska to California have created a database of genetic microsatellites from Pacific salmonids through a consortium called Genetic Analysis of Pacific Salmonids (GAPS).

PROJECT PROGRESS: The work accomplished under the subaward to the Oregon Salmon Commission (OSC) for the period July 1, 2015 through June 30, 2016 included 1) fleet management, 2) fishermen charters, 3) sampling supplies, and 4) database maintenance. The OSC entered into contracts with the fleet manager, fishermen and Fish Trax Systems, Inc. (website maintenance) to perform the tasks for this project.

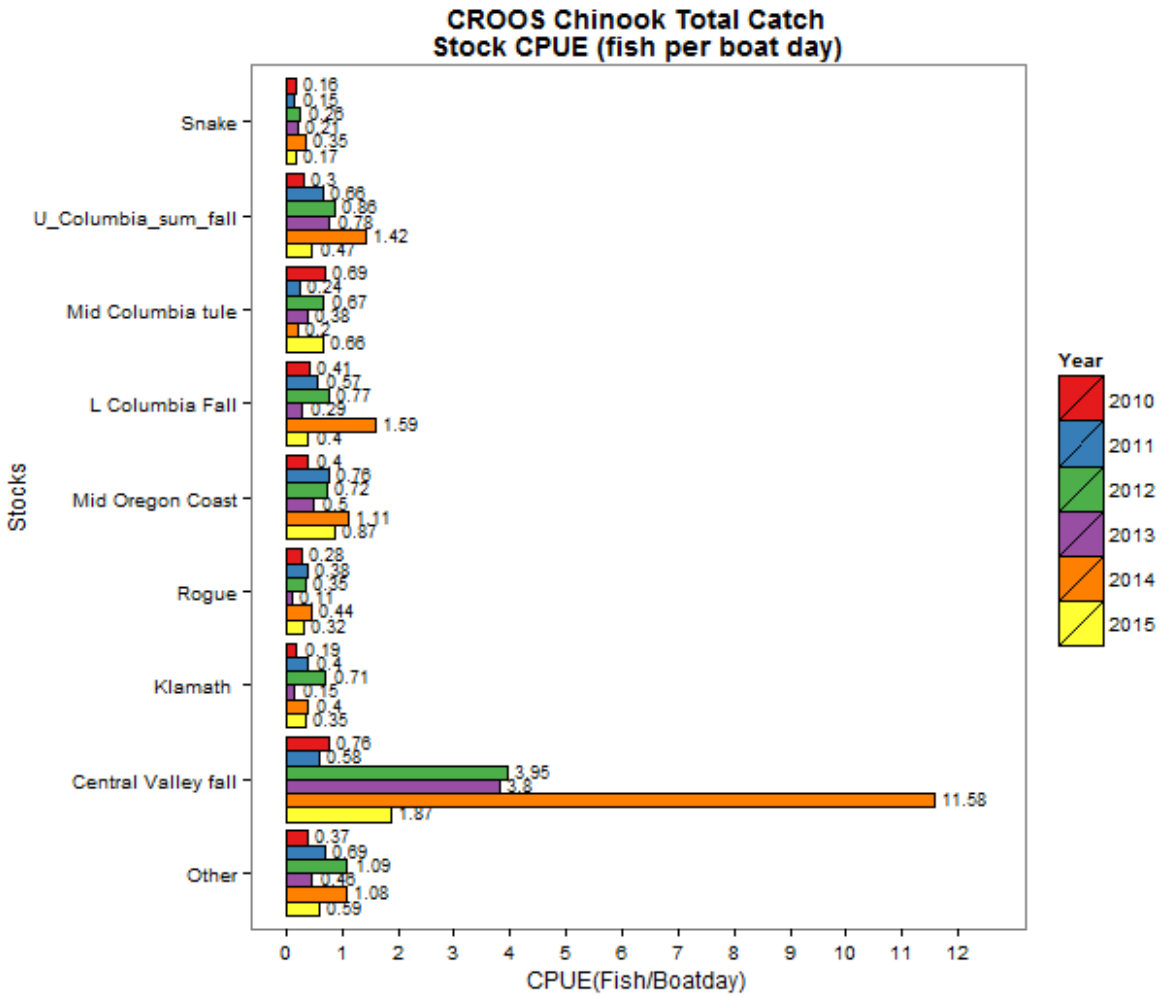
Fleet management: In 2015 the fleet manager coordinated with Newport area fishermen through one-on-one training to prepare fishermen and give them supplies for the sampling season. The fleet manager was in daily contact with fishermen for fish count updates and was also in contact with the OSC to ensure that all work stayed within budget guidelines. At the end of each fishing trip, the fleet manager met with each fisherman for an interview to download their GPS track logs, enter them in the database, and restock their supplies (barcode tags, envelopes, batteries, etc.). The envelopes with fin-clip samples were sent to the Coastal Oregon Marine Experiment Station (COMES) Marine Fisheries Genetics Laboratory for processing. Fishermen were sent to sea on a rotating basis to ensure that everyone had equal opportunity to participate. When at sea sampling, fishermen contacted the fleet manager daily with an update on the number of fish sampled. In 2016 the fleet was also equipped with Samsung tablets that had a built in application to record their GPS locations and logged any fish caught. The fleet uploaded their own data from the tablets to the Pacific Fish Trax (PFX) website (http://www.pacificfishtrax.org/). In 2016 project CROOS teamed up with Oregon Department of Fish and Wildlife (ODFW). Samplers from ODFW collected the fin-clip samples and sent them into the COMES Marine Fisheries Genetics Laboratory for processing. The fleet manager still met with each fisherman to deploy the tablets, upload new software patches and restock supplies.

Fishermen: Chinook salmon and associated fine-scale at sea environmental data were collected in Oregon, during the 2015 fishery season in accordance with the West Coast Salmon Genetic Stock Identification Collaboration sampling plan. Twelve fishermen were contracted from the Coos Bay area and 13 fishermen from the Newport area participated. These fishermen collected 939 samples from May 1st through September 30th, 2015. A similar sampling strategy, but only off of Newport, has been coordinated for 2016 where fishermen were furnished with Samsung tablets that have a mapping function to help enable them to fish and participate with project CROOS. This application charts out the course the fisherman has taken, allows the fisherman to log all fish caught through digitizing information on the barcoding each individual fish, depth the fish was caught and if there was an adipose fin clip present or not. Upon coming into port the fisherman used Wi-Fi hotspots to uploads there data to the PFX website. When fisherman bring their catch to the processor, ODFW samples all of the first 20 fish but takes a subsample from the >20 quota if more than 20 fish are caught in a given trip.

Database Maintenance: In 2015, the fleet manager accessed the database regularly to enter the fishermen information. These data were then available for the lab to access and connect with the biological samples. Fishermen were able to access their own fishing data and compare findings with the aggregate throughout the season. Project managers and scientists accessed the data to compare with findings from previous years and to see if any patterns were developing. An in-season report was prepared and included a summary of each time period from May through September with the number of fish sampled and their genetic river of origin.

Central Valley Fall Chinook were the dominant component of harvest for each time period with the exception of August in the southern Oregon coast where Mid Oregon Coast was the dominant component of harvest. This report has been posted to the Pacific Fish Trax website. This site also includes the public portal for viewing aggregate data by time, regions, fish size and river of origin. Individual fishermen data is available through a specific log-in allowing them to view their own fishing data. Ongoing 2015 and 2016 sampling adds to the work that has been completed since 2006. Collecting several more years of data will strengthen the database and should improve our understanding of the ocean ecology of salmon by integrating stock-specific distribution patterns over space and time with biological and environmental data. A three-dimensional sub-settable depiction has been created which visualizes the bathymetry off the Oregon coast overlaid with 2010 to 2013 CROOS catch data. The image can be subset queried based on stock, month and year. This 3D graphic will be available at pacificfishtrax.org. where plans include updating with 2014 through 2016 CROOS catch data.

Genetic Characterization using the GAPS database: Work accomplished in this reporting period includes DNA extraction and polymerase chain reaction amplification of the GAPS13 microsatellites to identify most likely source of sampled Chinook. Further analysis includes assessing encounter rates of different stocks as a function of effort and evaluating trends over location, time and years sampled since 2010. For Oregon waters in 2015, a total of 939 samples were collected and provided to the genetics laboratory by Project CROOS participants. Starting 5/1/15, and through the full season, DNA was extracted from all 939 of these Oregon tissue samples using a silica-based method that utilizes multichannel pipettes, PALL glass fiber filtration plates, and buffer, centrifuge and transfer protocols as described in Ivanova et al. (2006). A panel of 13 microsatellites known as GAPS13 (from Seeb et al. 2007) were amplified from these DNA samples using the polymerase chain and utilizing protocols detailed in Seeb et al. (2007) and multiplex modification protocol developed by Jonathan Minch. This panel includes: *Ogo-2, -4* (Olsen et al. 1998); *Oki100* (Canadian Department of Fisheries and Oceans, unpublished); *Omm1080* (Rexroad et al. 2001); *Ots-3M* (Greig and Banks 1999); *Ots-9* (Banks et al. 1999); *Ots-201b, -208b, -211, -212, -213* (Greig et al. 2003); *OtsG474* Williamson et al. (2002); and *Ssa408* Cairney et al. (2000). Most likely region and run of origin were assessed utilizing the 'assign individual to baseline population' option available in the statistical package ONCOR (Kalinowski 2008 www.montana.edu/kalinowski/Software/ONCOR.htm) and each individual was assigned to the reporting group in which it had the greatest probability. Data for most likely region of origin for Oregon samples were deposited in the Pacific Fish Trax database in near real-time. Catch per unit effort (fish/boat day) for the complete 2015 sampling season is presented against comparatives for five preceding year seasons (Figure 1).



PUBLICATIONS:

Bellinger M.R, M.A. Banks, S.J. Bates, E.D. Crandall, J.C. Garza, G. Sylvia, P.W. Lawson. ·2015. Geo-referenced, abundance calibrated ocean distribution of Chinook salmon (*Oncorhynchus tshawytscha*) stocks across the west coast of North America. PLOS ONE 22 JUL 2015, doi.org/10.1371/journal.pone.0131276

Amendment 64: Improving Ecosystem-based Fisheries Management and Integrated Ecosystem Assessments by Linking Long-term Climate Forcing and the Pelagic Nekton Community in the NCC

Funded: $25,040

OSU RESEARCH STAFF: *Lorenzo Ciannelli*, Professor, CEOAS; *Caren Barcelo*, GRA, CEOAS
NOAA TECHNICAL LEAD: *Ric Brodeur*, FE/NWFSC

PROJECT BACKGROUND: The California Current Integrated Ecosystem Assessment (CCIEA) lays out a long-term plan to evaluate the status of a wide variety of ecosystem components. In recent years, the CCIEA has been bolstered by the augmentation of the availability of leading ecosystem indicators for the pelagic ecosystem given our efforts to analyze and summarize the existing pelagic fish data for the Northern California Current region.

Both fine-scale remotely sensed oceanographic data as well as forecasted climate change scenarios are being used to generate species distribution models for forage fish species (herring, mackerel and sardine) off the Oregon and Washington coasts. By integrating habitat, prey and predators over space and time, this research will lay the groundwork for integrated ecosystem models between predators and prey species that can be used to assess human impacts, the permeating effects of climate change through the food web and management strategies.

PROJECT PROGRESS: This project aims to develop new indicators that will describe how the pelagic nekton communities in the NCC have responded to climatic forcing during the period 1998-2011, with the twin goals of providing critical ecosystem information for fisheries management and expanding the availability of indicators for Integrated Ecosystem Assessments put together by NOAA. Additional funds allocated to the project were to continue providing updates to the time series and to further ongoing diversity, community analysis as well as species distribution modeling.

In the past FY, Ph.D. student C. Barceló, provided data products to NOAA's Integrated Ecosystem Assessment sections, specifically, the Coastal Pelagic Fishes. This updated a time series of abundance data for top abundant species captured in NOAA-NWFSC's survey sampled along the Oregon and Washington coasts. Barceló also ran multivariate analyses to track the change in overall community composition through the years, which was included in the 2015 State of the California Current report. Professor Lorenzo Ciannelli assisted in the interpretation of results, development of code for analysis, and presentation preparation.

Amendment 63: Habitat Use Database for the California Current
Funded: $131,600

OSU RESEARCH STAFF: *Chris Goldfinger*, Professor, College of Earth, Ocean, and Atmospheric Sciences; *Chris Romsos*, Faculty Research Assistant, College of Earth, Ocean, and Atmospheric Sciences
NOAA TECHNICAL LEAD: *Waldo Wakefield*, NWFSC; *Mary Yoklavich*, SWFSC; *Joseph Bizzarro*, SWFSC

PROJECT BACKGROUND: The NMFS NWFSC, SWFSC, and WCR are updating the Habitat Use Database (HUD) for the California Current. The HUD was specifically designed to address the need for habitat-use analyses in support of groundfish EFH, HAPCs, and fishing and non-fishing impacts components of the 2005 EFH EIS. Since 2005, there have been opportunistic updates to the database. However, software incompatibilities and lack of maintenance has significantly diminished the utility of the HUD, in particular the online query tool. The HUD

also contains ecological information on federally managed fish species on the West Coast. It is important that this information be updated with the most recent information to ensure that the best information is available to users of the HUD (e.g., EFH consultations, NOAA scientists, resource managers, etc). OSU's Active Tectonics and Seafloor Mapping Lab will assist NMFS to fully integrate the data entry, quality control, and reporting capabilities from the original HUD Access database with a web-based and programmatic interface to the current Oracle HUD database.

PROJECT PROGRESS: The initial planning for this year's work on the Habitat Suitability Project (HSP) consisted of a series of conference calls between the HUD (Habitat Use Database) team at the North West Fisheries Science Center (NWFSC) and Oregon State University's (OSU) Active Tectonics and Seafloor Mapping Lab (ATSML) focused on parameterizing the Bayesian modeling products the NWFCS sought as outcomes of this project and delineating what practical steps were required to create the maps in question. The models produced according to this plan are intended to replicate the 2005 Essential Fish Habitat (EFH) project's efforts to generate habitat suitability maps, which were based primarily on latitude, depth, and preference for varying habitat types inputs that were then incorporated into a Bayesian Belief Network (BBN). During this past year, the HUD group has worked extensively to error check and update their original database with newly available literature. These resulting updates have formed key input for the new rendition of the HSP models.

Model Alterations:

During the early project planning meetings it was decided that two sets of outputs would be modeled for each species where sufficient literature was present to create reliable data input; both adult and juvenile lifestages. It was also determined that in addition to the "5-point" input based on the absolute minimum, preferred minimum, optimal, preferred maximum, and absolute maximum values for the latitude and depth conditions noted for these species in related literature (as was utilized in the 2005 models), species with sufficiently dense trawl data would have an alternate set of latitude and depth preferences derived from this second data source. Two sets of models outputs would then be created for both lifestages (trawl data quality permitting); one produced from the 5-point curve of latitude and depth inputs, and the other from the trawl data derived latitude and depth data. Another new addition to the 2016 models is the inclusion of a data quality node, which permits the evaluation of areas with lower vs. higher data quality in the depth and habitat type datasets.

Data and Model Input Preparation:

After the initial project planning stage was completed, the NWFSC produced a small series of compilations describing individual species and lifestage preferences for both latitude and depth (yielding the input for the 5-point curve input data) and habitat type based on their extensive literature review and expert opinion. During that intervening period, the HUD and HSP groups worked together to create a habitat classification scheme that would serve both groups' purposes. While the HUD group focused on implementing the new habitat classification scheme into their database and producing descriptions of species preferences for latitude, depth, and habitat type, the HSP group built a crosswalk table capable of "converting" the HUD habitat codes to the Surficial Geologic Habitat (SGH) codes used in the ATSML's habitat maps. The most recent of the ATSML's habitat maps extends from the Strait of Juan de Fuca to the Ft. Bragg area off northern California and had not yet had the newly classified habitat maps from the Olympic Coast National Marine Sanctuary (OCNMS) amalgamated into it, nor did it include data for

central and southern California. The OCNMS data was duly combined with the existing habitat dataset, and the most up-to-date version of the ATSML's habitat classification for central and southern California was utilized in the region south of Ft. Bragg in order to create a coherent habitat classification dataset acceptable for use throughout the West Coast in the HSP.

Model Creation:

Once the latitude, depth, data quality, and habitat type data had been prepared for the model and the crosswalk table completed, data were converted into a specific format (case files, a type of specially formatted text file) suitable for use in Netica 5.02, the software that the 2016 Bayesian models were created in. The model's Conditional Probability Tables (CPTs), which are numerical representations derived from the HUD group's input on the degree to which the species and lifestage in question would likely be associated with all possible combinations of modeled conditions (latitude, depth, habitat type), were then constructed.

Map Product Production:

Netica 5.02 is a useful program for running Bayesian analysis, but is not capable of map production or creating other cartographic products. Upon the completion of a model run, which results in a text-based output file listing the results of Netica's Bayesian analysis, it is necessary to convert this text file to a format that can be loaded and displayed into GIS prior to mapping. Toward that end, a script created for a similar project was modified, automating the process of generating rasters from the output data created by Netica. After extensive streamlining, CPT construction for each model (a step that must only be completed once) takes approximately one hour. From start to finish, model runs and results mapping require roughly 10 - 15 minutes at 500 m resolution for the entire West Coast study area, a process that would take a minimum of one and a half hours to two hours without the script. It should be noted, however, that higher resolution model runs and mapping will require greater processing time.

Current Model Results and Future Work:

To date, model results from one species (Longnose Skate, *Raja rhina*) for both adult and juvenile lifestages have been completed and submitted to the HUD group for review. These results were produced fairly recently and not all of the HUD group have yet had the opportunity to express their opinion on their validity; however, newly received input from the HUD group has so far indicated a fairly high degree of satisfaction with the applicability of the model results and the level of agreement between the Longnose Skate HSP maps with what they, in their expert opinion, would expect a map representing habitat suitability to be for this species. In particular, depth and latitude trends appear to match well with their expectations, although there are two subregions where it appears that the habitat classification requires further verification and examination to ensure the map results are correct. Plans have been made to begin mapping another skate species with greatly differing habitat preferences (California Skate, *Raja inornata*) in the near future to serve as a counterpoint comparison. Future work will also involve the extraction of latitude and depth preferences and their input into related CPTs based on trawl data for relevant species, as CPTs have to date been only produced from the original 5-point curve method.

Once the error checking is completed on the early skate models, it is expected that further model runs for additional species will progress at a much faster rate than they have proceeded at during the initial "debugging" stages of this project.

Amendment 59: Climate and Habitat Effects on Productivity of Important Alaska Fishery Species
Funded: $126,839

OSU RESEARCH STAFF: *Louise Copeman*, Asst. Professor, Sr. Res., CEOAS/CIMRS,
NOAA TECHNICAL LEAD: *Tom Hurst, Cliff Ryer, Ben Laurel*, RACE/AFSC

Effects of ocean acidification on Alaskan fishes

PROJECT BACKGROUND: This project directly addresses NOAA Ocean and Great Lakes Acidification Research Plan's goal of evaluating the ecological effects of ocean acidification. Walleye pollock, Pacific cod, and northern rock sole are principle components of the nation's most valuable fisheries. This work evaluates the physiological effects of ocean acidification that could lead to changes in population productivity of these critical resource species.

PROJECT PROGRESS: Research Technician Summer Meredith successfully reared live-food (*Brachionus plicatilis*) and Pacific cod (*Gadus microcephalus*) larval under varying conditions in the laboratory. Larvae were reared under either high pH or ambient pH and fed either unenriched or lipid enriched rotifers in order to examine the interactive effects of pH and prey nutritional quality on larval Pacific cod. Larvae were raised in 100L black cylindrical flat-bottom upwelling tanks for 6 weeks under experimental conditions and measurements of larval weights as well lengths were taken at weeks 2, 4, and 5.

Larval and rotifer samples were collected for lipid and fatty acid analyses at time-0 and at weeks 2, 4, and 5. Kalyn Hubbard (Research Technician) and Dr. Louise Copeman (Asst. Prof) have completed a modified Folch lipid extraction on all samples as well as lipid class analyses by TLC-FID and fatty acid analyses by GC-FID. Methods for all extractions, lipid class analyses and fatty acid analyses are described in Copeman *et al.* (2016). Statistical analyses and preparation of manuscripts will occur during the summer and fall of 2016.

Optimal Thermal Habitats of Alaskan crabs

PROJECT BACKGROUND: The degree to which crab species respond to changing temperatures depends on their thermal preferenda, i.e., the temperature at which physiological processes are optimal. These physiological processes include a suite of cellular activities (e.g., biochemical homeostasis, energy conversion efficiency, muscle performance, etc.) but are manifested collectively in terms of growth and condition of the animal (Amara et al. 2007). The thermal habitats for snow crab (*Chinoecetes opilio*) and Tanner crab (*Chonoecetes bairdi*) have not been fully described nor have they been consolidated into a single reference for the purposes of science and management. A document combining EFH information for crabs, gadids and flatfish would provide readily accessible habitat information for regions where bottom temperatures are available, as well as a framework and repository for additional FMP species. While focused on cold pool effects in the southeastern Bering Sea, this project will have utility for understand crab habitat in the greater Bering, Chukchi and Beaufort Seas as bottom temperatures rise.

PROJECT PROGRESS: Dr. Copeman (OSU) and Ms. Hubbard (OSU) along with NOAA-AFSC staff have completed the crab morphometric sampling as well as the lipid class and fatty acid analyses of 100 crabs collected in 2012 and 2014 from the Bering Sea cold-pool. These crabs were collected on the NOAA-BASIS survey and will be used to examine the effect of variability in temperature and food quality on the condition of both juvenile tanner and snow crabs. Dr. Louise Copeman and Dr. Cliff Ryer (NOAA) will be collaborating on manuscript preparation over the summer of 2016.

Experiments on the effects of temperature on the growth and lipid storage of snow crabs in the laboratory have also been completed. Dr. Copeman and Ms. Hubbard have analyzed 51 crabs reared at temperatures ranging from 0.5 °C to 9 °C for total lipids and storage lipid classes.

Several papers written are in pre-publication internal review at this time:

Hurst, T.P., B.J. Laurel, **E. Hanneman**, S.A. Haines, M. Ottmar. in review. Elevated CO2 does not exacerbate nutritional stress in larvae of a Pacific flatfish.

Copeman LA, Laurel BJ, Spencer M, Sremba A, in review Temperature-dependent lipid allocation among juvenile gadids from Boreal and Arctic Ecosystems.

Laurel BJ, **Copeman LA**, Spencer M, Iseri P. in review Temperature-dependent growth as a function of size and age in juvenile Arctic cod (*Boreogadus saida*).

PUBLICATIONS:

Copeman LA, Laurel BJ, Sremba A, Klinck K, Heintz R, Vollenweider J, Boswell K (2016) Ontogenetic variability in the lipid content of saffron Cod (*Eleginus gracilis)* from the Western Arctic and Northern Chukchi. *Polar Biology* 39 (6): 1109–1126.

Laurel BJ, Spencer M, Iseri P, **Copeman LA** (2016) Temperature-dependent growth and behavior of juvenile Arctic cod (Boreogadus saida) and co-occuring North Pacific gadids. *Polar Biology* 39 (6): 1127–1135.

MEETING PRESENTATIONS:
Copeman LA, Laurel BJ, Spencer M, Iseri P, Sremba A (2016) Temperature-dependent lipid storage of juvenile Arctic cod (*Boreogadus saida*) and co-occurring North Pacific gadids. Oral presentation, Ocean Sciences Meeting, New Orleans, Louisiana, Feb 21-27, 2016.

Copemana LA, Ryer C, Spencer M, Ottmar M, Sremba A (2016) Determining the importance of food quality and temperature on the growth and condition of juvenile southern tanner crab (*Chionoecetes bairdi*) using complimentary field and laboratory based approaches. Poster presentation, Ocean Sciences Meeting, New Orleans, Louisiana, Feb 21-27, 2016.

Copeman LA, Laurel BJ (2016) Temperature-dependent lipid storage in juvenile Arctic and boreal cod species. Poster Presentation, Alaska Marine Science Symposium, Anchorage, Alaska, January 24-28 2016.

Laurel B, **Copeman LA** (2016) Juvenile growth and lipid dynamics of Arctic cod (Boreogadus saida) and other Alaskan gadids under variable environments. Oral Presentation, Alaska Marine Science Symposium, Anchorage, Alaska, January 34-38, 2016.

Koenker B, **Copeman LA**, Laurel BJ (2016) The effect of temperature and food availability on the growth, condition and survival of larval gadids. Poster Presentation, Alaska Marine Science Symposium, Anchorage, Alaska, January 24-29, 2016.

Amendment 56: Ecological Indicators of Ocean Conditions in the northern California Current

Funded: $25,419

OSU RESEARCH STAFF: *Jennifer Fisher*, Faculty Research Assistant, CIMRS; *Xiuning Du*, Research Associate, CIMRS

NOAA TECHNICAL LEAD: *Bill Peterson*, Fisheries Ecology, NWFSC

PROJECT BACKGROUND: The northern California Current (NCC) is an ecologically important region supporting numerous fish, bird and marine mammal populations. Based on long-term data sets focused on the hydrography and lower trophic-level dynamics within the NCC, it is clear that variations in climate, basin-scale forcing and regional and local processes all influence the food-web. Ocean ecosystem indicators provide information on the 'condition' of the ecosystem and have been successfully used to help predict future returns of culturally and economically important species (salmon) as well as provide an understanding of what factors may control the success of other managed fish species (e.g., sablefish, sardine) and top predators such as sea-birds.

PROJECT PROGRESS: Eight research cruises along the Newport Hydrographic (NH) Line were conducted over the last year. Because of personnel issues reducing the availability of the research vessel (RV Elakha), fewer trips were conducted compared to previous years. Seven stations from 1 to 46 km from shore were sampled during each cruise. At each station, measurements of hydrography (temperature, salinity, depth, dissolved oxygen, fluorescence) were made throughout the water column using a CTD (Seabird Model 25); water samples were collected for analysis of chlorophyll and nutrient concentrations, as well as phytoplankton community composition including Harmful Algal Bloom species detection; and zooplankton were sampled using a vertically towed plankton net as well as a larger, obliquely-towed, bongo-style net. All the water and net samples were pre-processed at sea and then brought back to the lab for final analysis. The past year sampling effort provided valuable information for an unusual year when the pelagic ecosystem has been strongly influenced by anomalously warm ocean conditions (the "Warm Blob") impacting the entire West Coast and by a developing El Niño event in the equator.

All physical and biological data are archived in a Microsoft Access database at the Northwest Fisheries Science Center's Newport, Oregon location. Ocean Ecosystem Indicators of Salmon Marine Survival in the Northern California Current.
http://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/index.cfm

A new blog site Newportal (https://www.nwfsc.noaa.gov/news/blogs/display_blogentry.cfm?blogid=1) was launched in June 2015 to keep people up to date about the anomalous ocean conditions. To date, the site has over 22,000 hits.

CONFERENCES:

Participation in the 2014-2015 Pacific Anomalies Science and Technology Workshop, University of Washington, Jan 20-21, 2016.

Oral Presentation at the Eastern Pacific Oceans Conference Fallen Leaf Lake Sept 21-23, 2015. **Jennifer L. Fishe**r, William T. Peterson, and **Jay O. Peterson**. "Changes to the hydrography and zooplankton in the northern California Current in response to 'the blob."

PUBLICATIONS:

Fisher J.L, Peterson, W.T. and R.R. Rykaczewski .2015. The impact of El Niño events on the pelagic food chain in the northern California Current. *Global Change Biology* 21, 4401-4414, doi: 10.1111/gcb.13054

Leising, A.W., Schroeder, I.D., Bograd, S.J., Abell, J., Durazo, R., Gaxiola-Castro, G., Bjorkstedt, E.P., Field, J., Sakuma, K., Robertson, R.R., Goericke, R., Peterson, W.T., Brodeur, R.D., Barceló, C., Auth, T.D., **Daly, E.A.**, Suryan, R.M., Gladics, A.J., Porquez, J.M., McClatchie, S., Weber, E.D., Watson, W., Santora, J.A., Sydeman, W.J., Melin, S.R., Chavez, F.P., Golightly, R.T., Schneider, S.R., **Fisher, J., Morgan, C.**, Bradley R. and Warybok P. 2015. State of the California Current 2014-15: Impacts of the Warm-Water "Blob". *CALCOFI Rep*, 56: 31-68.

Amendment 55: Survey of Pelagic and Demersal Habitats

Funded: $45,873

OSU RESEARCH STAFF: *Jennifer Fisher*, Faculty Research Assistant, CIMRS
NOAA TECHNICAL LEAD:*Bill Peterson*, Fish Ecology, NWFSC

PROJECT BACKGROUND: This project aims to examine both the nearshore and the offshore habitats of fish and their food resources off the Oregon coast. CIMRS investigators continue to conduct a fishing vessel-based survey of YOY groundfishes along the NH-Line along with the plankton and physical oceanography sampling program. The project provides valuable information on the status of pelagic habitat relevant to early life history stages of many commercially and ecologically important species. Further, the project builds upon a long-term data set critical for detecting trends over time scales relevant to climate variability.

PROJECT PROGRESS: A series of pelagic and demersal habitat surveys were conducted quarterly from August 26-27, 2015 and Nov 3-4, 2015 aboard the FV Timmy Boy and May 24-25 aboard the FV Michelle Ann. The surveys sampled 12 stations along the Newport Hydrographic (NH) Line out to 85 nautical miles from shore. The sampling for pelagic habitat

included full water column hydrography (temperature, salinity, dissolved oxygen, transmissivity, fluorescence) using a CTD; water samples for nutrients, chlorophyll and phytoplankton species; and net samples for mesozooplankton and krill. Additionally, bottom trawl samples were conducted at 6 stations to quantify demersal fish and characterize the demersal habitat. The hydrographic data have been processed and entered in an MS Access database along with several of the biological and nutrient samples. A 'fish processing' work party was conducted to speciate, length, and weigh a backlog of juvenile fish collected during these cruises. Remaining samples are preserved and being stored until resources become available to process them. The sampling opportunity provided a valuable chance to combine resources and capabilities of the commercial fishing fleet with those of the scientific community. The information gathered comes during a period of an El Niño and anomalously warm conditions (the "Warm Blob") impacting much of the West Coast marine ecosystem. Data from these surveys will provide important information as to the impacts of extremely anomalous conditions on the northern California Current ecosystem.

Amendment 50: Long-term Observations of Physical and Biological Oceanographic Conditions in Coastal Waters off Oregon: Hydrography and Zooplankton

Funded: $94,000

OSU RESEARCH STAFF: *Jennifer Fisher* Research Assistant, CIMRS
NOAA TECHNICAL LEAD: *Bill Peterson*, Fish Ecology, NWFSC

PROJECT BACKGROUND: This project which monitors ocean conditions and zooplankton communities continues to produce a combined northern California Current copepod anomaly index annually. In addition, copepod abundance anomalies are calculated on a seasonal basis (spring, summer, fall) for comparison to sablefish, whiting, rockfish and Chinook and Coho salmon time series of recruitment and survival. CIMRS investigators monitor ocean conditions off the coast of Oregon sampling hydrography and plankton along the Newport Hydrographic Line (44.6°N) on a biweekly basis.

PROJECT PROGRESS: Eight research cruises along the Newport Hydrographic (NH) Line were conducted over the last year. Because of personnel issues reducing the availability of the research vessel (RV Elakha), fewer trips were conducted compared to previous years. Seven stations from 1 to 46 km from shore were sampled during each cruise. At each station, measurements of hydrography (temperature, salinity, depth, dissolved oxygen, fluorescence) were made throughout the water column using a CTD (Seabird Model 25). Water samples were collected for analysis of chlorophyll and nutrient concentration. Zooplankton were sampled using a vertically towed plankton net as well as a larger, obliquely-towed, bongo-style net. The zooplankton samples were preserved and brought back to the lab for analysis. Live samples were collected at a nearshore station and brought back to the laboratory for experiments investigating copepod egg production in relation to changing ocean conditions. At least 20 individual *Calanus pacificus* or *Calanus marshallae* were isolated into small jars with ambient seawater. Eggs were enumerated following a 24 hours incubation period. These data are entered into a database and await analysis with environmental variables. All CTD data and a selection of the zooplankton samples, chlorophyll and nutrient samples have been processed and analyzed and entered into a

Microsoft Access database located in Newport, Oregon. All remaining samples are archived until resources become available for processing.

The data have 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 and the Newportal Blog https://www.nwfsc.noaa.gov/news/blogs/display_blogentry.cfm?blogid=1.

Theme: Protection & Restoration of Marine Resources

Amendment 76: A Pilot Project toward Measuring Physiological Effects of Noise Exposure on Pacific Gray Whales (*Eschrichtius robustus*)
Funded: $74,999

OSU RESEARCH STAFF: *Joe Haxel*, Asst. Professor, Sr. Research, CEOAS; Leigh Torres, Asst. Prof., Sr. Res., Marine Mammal Institute
NOAA TECHNICAL LEAD: *Robert Dziak*, OERD/PMEL

PROJECT BACKGROUND: Long-term, deep ocean acoustic measurements from fixed hydrophone stations have documented a steady increase in low frequency ambient noise levels (10-12 dB) in the Northeast Pacific since the 1960s, primarily associated with increased commercial shipping traffic throughout the basin. In contrast, long-term trends in underwater noise levels within shallower waters of the continental shelf region remain largely unknown due to a lack of adequate time series measurements. These shallow water coastal areas may be more susceptible to rising levels of anthropogenic noise generated from expanding commercial activities and coastal development (e.g., fishing, marine renewable energy, tourism). The threat of rising anthropogenic noise levels in the oceans has raised concern for many marine species that rely on acoustic sensitivity for a variety of ecosystem functions including baleen whales (*Mysteceti*) whose functional range overlaps with low frequencies commonly generated by anthropogenic sources. The effects of long-term exposure to increasing ambient sound levels resulting from anthropogenic sources are not well known, and may not be easily recognized from short-term observation of behavioral changes. Rather, chronic stress effects may potentially manifest as a physiological response within animals.
Using Pacific Coast Feeding Aggregation (PCFA) gray whales along the Oregon coast as our study species, CIMRS researchers will develop methods and collect data aimed at addressing the following questions:

1. Are whales exposed to significantly different anthropogenic and naturally influenced ambient noise environments depending on location and time?
2. Do individual GC hormone concentrations vary relative to individual, body condition, prey availability or habitat (location)?
3. Relative to samples collected in low-noise environments, do fecal samples from whales in noisy environments have higher GC concentrations, indicative of elevated stress?

Furthermore is there an observed difference in GC concentrations between environments dominated by anthropogenic verses natural sound sources?

4. What is the time scale of recovery for fecal stress hormone concentrations to baseline levels after an increased noise event?

PROJECT PROGRESS: Data collection efforts have been separated into an early (May-Jun) and late (Aug-Sep) field season in order to collect comparative data between early-season conditions when whales will likely be malnourished and have higher stress levels due to the long migration and fast periods, relative to the late-season after significant feeding has occurred. During our early field season efforts from May 23 – June 24, 2016 the project team spent 72 hours on the water over 11 sampling days, with 47 gray whale encounters, 13 fecal samples collected, 26 UAS flights and 13 hydrophone drifter deployments totaling 16:42 hours of passive acoustic recordings. Details are summarized below:

Date	**Port**	**Departure time**	**Return time**	**Total Time**	**# of gray whale sightings**	**# fecal samples**	**# of UAS* flights**	**# drifter deployments**
23-May-16	Port Orford	9:32	17:00	7:28	6	0	0	0
24-May-16	Port Orford	6:23	13:15	6:52	5	0	3	4
9-Jun-16	Newport	6:30	16:40	10:10	6	2	5	4
10-Jun-16	Newport	6:45	9:25	2:40	3	1	0	0
12-Jun-16	Newport	9:00	11:50	2:50	2	3	3	0
13-Jun-16	Newport	6:55	14:25	7:30	3	0	2	0
16-Jun-16	Newport	13:35	17:30	3:55	2	1	0	0
17-Jun-16	Newport	7:00	12:45	5:45	5	0	3	0
18-Jun-16	Newport	7:30	15:22	7:52	6	2	3	0
22-Jun-16	Newport	8:00	17:45	9:45	5	1	3	0
24-Jun-16	Newport	7:30	14:50	7:20	4	3	4	5

* UAS = Unmanned Aerial System (‘drone’).

Preliminary analysis of the early season data is underway and the next period of data collection efforts is scheduled to begin August 4, 2016.

Amendment 62: Ecotoxicogenomic Analysis of polybrominated diphenyl ether (PBDE)-exposed Chinook Salmon

Funded: $26,966

OSU RESEARCH STAFF: *Michael Banks*, Professor, Department of Fisheries and Wildlife
NOAA TECHNICAL LEAD: *Mary Arkoosh*, EC/NWFSC

PROJECT BACKGROUND: Polybrominated diphenyl ethers (PBDEs) are a class of persistent and brominated flame-retardants that bioaccumulate in Chinook salmon. PBDE exposure can alter endocrine and immune systems in fish and aquatic mammals. Unfortunately, the mechanisms of PBDE metabolism and toxicity, and their full effects on Chinook salmon are still unknown. This information is critical to assessing PBDE risks to ESA-listed salmon stocks. The objective of the proposed study is to identify the effects of PBDE exposure on Chinook salmon at the transcriptome level using high-throughput RNA sequencing (RNA- seq), in order to identify mechanisms of PBDE toxicity. This study will have tissue samples analyzed by RNA-seq. RNA-seq data and will be used to quantify differential expression between treatment groups; a functional enrichment analysis will be used to determine if certain gene functions (e.g., immune response) are statistically over-represented in the differentially expressed genes. Researchers will specifically investigate the functional categories (endocrine and immune systems) that were likely involved in the organism-level endpoints significantly affected by PBDE exposure. Consequently, we will be linking transcriptome-level effects with observed organism-level effects.

PROJECT PROGRESS: The research effort has been focused on identifying stored tissues with RNA quality that is adequate for sequencing. Four salmon tissues were stored following PBDE exposures and necropsies, i.e. liver, kidney, spleen, and brains. In order to have methods comparable to other published ecotoxicogenomic studies, the liver was initially selected. However, after evaluating the RNA integrity from a subset of 192 RNA extracts, we have determined that the liver RNA quality is insufficient. The integrity analysis indicated that RNA degradation had occurred. In response, 40 RNA extracts from the remaining tissues were compared. Spleen tissues were found to have the most consistent RNA integrity values (RIN > 6.0), based on the bioanalyzer results. In order to complete the project objectives, the following tasks must be completed:

1. RNA extraction from tissues;
2. Evaluation of RNA quality using a bioanalyzer;
3. Sequencing of the RNA using RNA-seq; and
4. Data analysis, which includes transcriptome assembly and differential expression.

To date, RNA from all of the spleen tissues have been extracted (Task 1 complete), and the integrity has been determined in about half of those samples (Task 2). The RNA quality needs to be determined in the remaining extracts before the final sample selection is made and the RNA sequencing is begun.

In addition to the laboratory analysis, project personnel have also completed courses and workshops focused on the techniques for data analysis required in Task 4. This instruction has been provided by Oregon State University's Center for Genome Research and Computing (CGRB).

Amendment 60: Stock Assessment Research Review of Pacific Hake
Funded: $16,279

OSU RESEARCH STAFF: *David Sampson*, Professor, Department of Fisheries and Wildlife
NOAA TECHNICAL LEAD: *Michelle McClure*, FRAM/NWFSC

PROJECT BACKGROUND: The coastal stock of Pacific hake (*Merluccius productus*), known commonly as Pacific whiting, annually migrates between U.S. and Canadian waters. The stock is managed jointly by the U.S. and Canada under provisions of the Pacific Whiting Treaty, which established a Joint Management Committee that sets the annual total allowable catch of whiting, a Joint Technical Committee (JTC) that conducts stock assessments and other technical analyses to provide the scientific basis for harvest management decisions, and a Scientific Review Group (SRG) that provides independent peer review of the technical work of the JTC. The SRG includes two members appointed by the U.S. government, two members appointed by the Canadian government, and two members nominated by the Treaty's Industry Advisory Panel. Dr. Sampson was appointed to the SRG as one of the industry-nominated reviewers.

PROJECT PROGRESS: Dr. Sampson's primary activity for this project was participation in a three-day meeting of the SRG held at the Watertown Hotel in Seattle, Washington on 23-25 February 2016. Additional activities included preparing for the meeting by reading the draft 2016 stock assessment document, contributing text to the SRG's report to the Joint Management Committee, and subsequently finalizing the SRG report by email correspondence.

The 2016 assessment for the coastal Pacific hake stock and related analyses had been conducted during the summer and fall of 2015 and early winter 2016 by the members of the JTC, consisting of three U.S. stock assessment biologists (Allan Hicks, Ian Taylor, and Aaron Berger) from the Northwest Fisheries Science Center, National Marine Fisheries Service, three Canadian stock assessment biologists (Chris Grandin, Nathan Taylor, and Andrew Edwards) from the Pacific Biological Station, Fisheries and Oceans Canada, and a consulting academic (Sean Cox) from Simon Fraser University. The assessment was more or less an update of the 2015 assessment, with the addition of one more year of landings and age-composition data for the commercial fishery and an additional biomass estimate from the acoustic survey and associated age- composition information. However, in response to requests in 2015 by the SRG the acoustic survey team reprocessed the survey data (from 1998 to the present) and revised most of the survey biomass index and age-composition series used in the assessment. The JTC made no changes to the fundamental structure of the stock assessment model.

Stock Assessment Review

The review of the stock assessment, which occurred during the first two days of the meeting, was structured around a series of presentations by JTC members and members of the research survey team who were involved in conducting the hydro-acoustic surveys and working up the survey data for the assessment. The formal presentations included an overview of the 2015

hydro-acoustic survey, a summary of research conducted during 2015 by the hydro-acoustic survey team, a technical description of the revised approach taken for developing the survey biomass index estimates, an overview of the data used in the 2016 assessment, an overview of the draft 2016 assessment results, a summary of sensitivity analyses for the 2016 assessment, a summary of simulations conducted within the JTC's previously developed management strategy evaluation (MSE) framework that explored the utility of an age-1 survey index, and an overview of some possible future work related with the MSE. Following the presentations there were general discussions between the members of the SRG and JTC and acoustic survey team regarding potential issues associated with either the data inputs or how the JTC had chosen to structure the Stock Synthesis assessment model.

As had been the case during the 2014 and 2015 SRG meetings, much of the discussion at the 2016 review again focused on the approach taken for developing the biomass index values from the acoustic survey data. The process involves interpolating between the survey transects and extrapolating from the data into the regions at the transect ends. There was also review and discussion of the survey team's efforts to develop an age-1 index, as requested by the SRG in 2015. If a sufficiently accurate age-1 index could be developed it would provide earlier confirmation of the strength or weakness of incoming year-classes and reduce the uncertainty surrounding projections of future trends in stock biomass and how they are influenced by different fishery harvests.

During the morning of the third day of the review the SRG, JTC and Advisory Panel advisors discussed the findings and conclusions of the review, formulated recommendations to the Joint Management Committee (JMC) on harvest management advice and future research activities, and prepared some of the SRG report.

SRG Report Preparation

The SRG report summarizing the review meeting was prepared jointly by the members of the SRG, with Michelle McClure, the US co-chair, taking the lead on assembling the draft report and circulating it to the rest of the SRG. The report was finalized by email correspondence following the SRG meeting and was sent to the JMC on March 1st.

Dr. Sampson is in full agreement with the findings and conclusions as stated in the Joint U.S.-Canada Scientific Review Group Report, which can be obtained on-line from the following web-site,
http://www.westcoast.fisheries.noaa.gov/fisheries/management/whiting/pacific_whiting_treaty.html

Amendment 57: PNW Fishing Community Oral Histories: A Collaborative, Educational Project for Researchers, Students, and Community Members

Funded: $25,000

OSU RESEARCH STAFF: *Flaxen Conway*, Professor, Department of Fisheries and Wildlife
NOAA TECHNICAL LEAD: *Suzanne Russell*, NWFSC

PROJECT BACKGROUND: Oral histories are a methodology to collect previously undocumented and unique, in-depth information. Oral histories capture and preserve the heritage and culture of an individual, family, community of place, or a community of interest that spans over several places. Oral histories can identify key issues and concerns, identify and record an individual's or a community's inherent and observed knowledge, and inform the public, local community leaders and members, and management entities. In the first part of this project, one of the themes that emerged was the changing role of women. The previous student who worked on this project focused her MS research on this theme while conducting oral histories.

Another theme that emerged was the "graying of the fleet." This year, while gathering oral histories and seeing what additional themes arise, a student will focus their MS research on the intergenerational transfer of fishing family businesses and how this impacts the resilience of the fleet (thus the term "graying") and the coastal community in two ports in Oregon: Port Orford and Newport. Thus this project continues to be a collaborative process that engages students, faculty, agency researchers, and community partners thereby providing an educational experience to a broad range of project participants and community members.

PROJECT PROGRESS: The goal of this project is to identify and collect oral histories from coastal communities in Port Orford and Newport, Oregon, focusing but not limited to intergenerational fishing family businesses. The ability to collect and document oral histories before fishermen and other key community members retire or are no longer accessible is critical to preserving local knowledge and heritage. The oral histories will be obtained from various perspectives for the most complete representation of the culture and heritage. Efforts will be made to capture oral histories from fishermen, processors, wives/partners, suppliers, and possibly even state and federal fisheries managers. These stories about how the management of many fisheries in these communities is changing rapidly as a result of recent or forthcoming fisheries and environmental management efforts will become part of the Voices from the Fisheries.

- One student (Sarah Calhoun) worked on this project last summer (7/1/15 – 9/1/15). She gathered six oral history interviews.
- Two additional new students joined the project during the 2015-16 academic year
  - Deanna Caracciolo, Marine Resources Management student, began interviewing Spring 2016 quarter. She's completed 3 interviews.
  - Courtney Flathers, Masters of Public Policy student, began interviewing Spring 2016 quarter. She's completed 2 interviews.

Both students will conduct most of their research during the summer months.

MEETING PRESENTATIONS:Dr. Flaxen Conway presented an oral presentation at the 2016 Annual Meeting of the Society for Applied Anthropology, Vancouver, BC (Spring 2016). "The Old(er) Men of the Sea: Graying of Oregon's fishing industry and its impact on local community resilience."

Theme: Seafloor Processes

Amendment 65, 71, 73: Impacts of Submarine Volcanism and Hydrothermal Venting on the Global Ocean and Deep-Sea Ecosystem

Funded: $1,677,879

OSU RESEARCH STAFF: *William Chadwick*, Professor, Senior Research, CIMRS; *Holger Klinck*, Assistant Professor, Sr. Res., *Haru Matsumoto*, Assistant Professor, Senior Research, CIMRS; *Andy Lau*, Professional Faculty, Applied Mathematician, CIMRS; *Joe Haxel*, Assistant Professor, Senior Research; *Andra Bobbitt*, *Susan Merle*, Senior Faculty Research Assistants, CIMRS; *Leigh Evans*, *Matt Fowler*, Faculty Research Assistants, CIMRS; *Samara Haver* Graduate Student

NOAA TECHNICAL LEAD: *John Lupton*, *Bob Embley*, *Chris Sabine*, PMEL

Volcanic and Hydrothermal Event Detection in the Northeast Pacific

PROJECT BACKGROUND: The efficient propagation of sound in the oceans highlights the beneficial use of underwater acoustics for studies involving geophysical seafloor processes, assessing the health of marine ecosystems, marine mammal and fish behavior, and climatic processes near the Polar Regions. Project analysis of hydroacoustic recordings from fixed and mobile platforms provides information on submarine volcanic events, long-term ambient noise levels, marine mammal vocalizations, signals radiated by sea ice and glacial decomposition, as well as anthropogenic contributions to regional soundscapes all in support of NOAA's Goal for Healthy Ocean and Ecosystems.

PROJECT PROGRESS: Assistant Professor Haru Matsumoto continued development of innovative acoustic technologies for use on fixed and mobile platforms. He continues to lead development of a hydrophone mounted on a winch buoy that can remain submerged for extended time periods, then come to the sea-surface to transmit data back to shore in real-time. The system is planned for an initial test deployment of the coast of Newport, OR in September of 2016. Additionally, he has been developing a near real time acoustic detection and monitoring system using a surface buoy connected through an acoustic modem link to sensor packages on the seafloor. This system (RAOS, Real-time Acoustic Observing System) was deployed off Newport in September of 2015 for a week long test. It is currently (June 2016) in the Strait of Juan de Fuca undergoing additional testing. Dr. Matsumoto is also developing hydrophone and data acquisition systems on buoyancy driven gliders and floats for acoustic marine mammal detection and ambient noise level measurements. Assistant Professor Joseph Haxel participated in 2 expeditions to

Challenger Deep in the Marianas Trench to deploy and recover the first long-term passive acoustic recordings of the deepest ocean abyss. He presented initial results from the Challenger Deep project as well as an acoustic study using an ocean glider mission off the Washington coast at the IEEE/MTS Oceans '15 meeting in Washington D.C. in October 2015. He also led development, assembly and testing of a drifting hydrophone system for use in a NMFS sponsored pilot project focused toward assessing noise impacts on gray whales off the Oregon coast. Assistant Professor Holger Klinck led planning and logistics for the recovery and re-deployment of 12 hydrophone moorings located within US EEZ waters that form the NOAA Ocean Noise Reference Station network. Associate Professor David Mellinger led efforts to further software development of marine mammal acoustic detection and density estimation algorithms with intent toward making them freely available to users through a variety of existing software platforms. Applied Mathematician T-K Lau developed software to utilize acoustic signals recorded from the OOI cabled network for a submarine volcanic eruption at Axial Seamount in April 2015. Lau and Haxel also developed an algorithm to remove ocean glider system noise contamination for passive acoustic studies. Faculty Research Assistant Alex Turpin assisted H. Matsumoto in engineering development and assembly of hydrophone instruments for both fixed and mobile platforms. Faculty Research Assistant Carrie Miller assisted in the organization and logistical operations of the NRS hydrophone network. She also performed data analysis on an acoustic data set from the equatorial Atlantic. She continues training for shipping and logistics as well as completed a sea safety survival course.

CRUISES:
S. Nieukirk**,** November 22, 2015 – January 4, 2016, *R/V* Araon, expedition to the Ross Sea supporting deployment of Acoustics Program moorings.

J. Haxel, September 28 – October 2, 2015, *R/V* Bell Shimada, expedition to recover and re-deploy the NOAA noise reference station #3 off the Washington coast.

MEETINGS:
Dziak, R.P., **J.H, Haxel, H. Matsumoto**, C. Meinig, N. Delich, J. Osse, and M. Wetzler (2015): Deployment and recovery of a full-ocean depth mooring at Challenger Deep, Mariana Trench. In *Oceans 2015 MTS/IEEE, Marine Technology Society and Institute of Electrical and Electronics Engineers*, Washington, DC, 19–22 October 2015.

Haxel, J., A. Turpin, H. Matsumoto, H. Klinck, D. Hellin, and S. Henkel (2016): A portable, real-time passive acoustic system and autonomous hydrophone array for noise monitoring of offshore wave energy projects. In *Proceedings of the 4th Annual Marine Energy Technology Symposium 2016, National Hydropower Association Water Week*, National Hydropower Association, Washington, DC, 25–27 April 2016.

Matsumoto, H., J. Haxel, A. Turpin, S. Fregosi, **H. Klinck**, K. Klinck, S. Bauman-Pickering, A. Erofeev, J.A. Barth, R.P. Dziak, and C. Jones (2015): Simultaneous operation of mobile acoustic recording systems off the Washington Coast for cetacean studies: System noise level evaluations. In *Oceans 2015 MTS/IEEE, Marine Technology Society and Institute of Electrical and Electronics Engineers*, Washington, DC, 19–22 October 2015.

PUBLICATIONS:

Balcazar, N.E., J.S. Tripovich, **H. Klinck, S.L. Nieukirk, D.K. Mellinger**, R.P. Dziak, and T.L. Rogers (2015): Calls reveal population structure of blue whales across the southeast Indian Ocean and southwest Pacific Ocean. *J. Mammal.*, 96(6), 1184–1193, doi: 10.1093/jmammal/gyv126.

Klinck, H., S. Fregosi**, H. Matsumoto, A. Turpin, D.K. Mellinger**, A. Erofeev, J.A. Barth, R.K. Shearman, K. Jafarmadar, and R. Stelzer (2015): Mobile autonomous platforms for passive-acoustic monitoring of high-frequency cetaceans. In *Robotic Sailing 2015: Proceedings of the 8th International Robotic Sailing Conference*, A. Friebe and F. Haug (eds.), Springer International Publishing, 29–37.

Fregosi, S.**, H. Klinck**, M. Horning, D.P. Costa, D. Mann, K. Sexton, L.A. Hückstädt, **D.K. Mellinger**, and B.L. Southall (2016): An animal-borne active acoustic tag for minimally invasive behavioral response studies on marine mammals. *Animal Biotelemetry*, 4, 9, doi: 10.1186/s40317-016-0101-z.

Research on the Near- and Far-field Physical and Chemical Impacts and Consequences to Ocean Ecosystems Caused by Submarine Volcanoes and Hydrothermal Venting

and

Interpreting Digital Seafloor Bathymetry and Imagery, From Ship-based sonar, Deep-Towed Sidescan, Optical Sensors, Submersible and Remotely Controlled Vehicles

PROJECT BACKGROUND: CIMRS researchers study and document interactions between submarine volcanic events, hydrothermal systems, and chemosynthetic ecosystems. Time-series studies are focused at Axial Seamount, the most active submarine volcano in the NE Pacific. Axial is an excellent long-term study site because it has a continuous and high magma supply, volcanic eruptions are relatively frequent (every 4-13 years), and it is the only site in the world where a repeatable (and apparently predictable) cycle of inflation and deflation has been documented at a submarine volcano. The seamount is now a node on the Cabled Array component of the National Science Foundation's Ocean Observatories Initiative (OOI), which transmits real-time data from instruments on the seafloor to shore, and this is opening up new research opportunities. For example, CIMRS researchers collaborated with NOAA/PMEL Engineers to design and build bottom-pressure/tilt instruments that were installed on the OOI cabled observatory. In April 2015, those instruments detected the start of an eruption at Axial Seamount that had been previously forecast, based on the long-term inflation/deflation time-series.

Another focus of CIMRS research is exploration of submarine volcanoes and hydrothermal vent ecosystems in the subduction zones of the western Pacific, in both arc and back-arc settings. Part of this research is the use of repeated sonar mapping for detecting depth changes on the seafloor due to volcanic eruptions. These depth changes can be either positive (due to the addition of erupted material) or negative (due to collapses or landslides on unstable slopes). Documenting and quantifying these changes enables the calculation of eruption volumes and rates, yields

opportunities to explore the interaction between constructive and destructive events at submarine volcanoes, and gives insight into the processes of how volcanoes grow underwater.

Another avenue of research is investigating the fate and consequences of hydrothermal emissions into the global ocean. A powerful tool in this research is the Helium Isotope Lab located in Newport, Oregon. Helium-3 is an isotope that is produced in the earth's mantle and because it is inert and conservative, it is an unambiguous tracer of hydrothermal discharge. Thus, helium-3 can help identify vent sites in unexplored areas as well as track hydrothermal emissions across entire ocean basins.

These projects contribute to the NOAA mission of science, service, and stewardship through the Healthy Ocean Goal of sustaining marine habitats and biodiversity within healthy and productive ecosystems. CIMRS research also supports OAR's main science goal of gaining a holistic understanding and making useful predictions of future states of the Earth-Ocean system. Likewise, CIMRS research falls under 3 of the 5 PMEL research themes: Marine Ecosystem Research, Ocean and Coastal Processes Research, and Research Innovation.

PROJECT PROGRESS: Work under these projects continued in CIMRS FY16 with a focus on Axial Seamount in the NE Pacific, the Colville Ridge north of New Zealand, and the Mariana back-arc spreading center in the western Pacific on three research expeditions.

Professor William Chadwick, Senior Faculty Research Assistant Andra Bobbitt, and Senior Faculty Research Assistant Susan Merle participated in a research expedition to the Axial Seamount on R/V Thompson with ROV Jason and AUV Sentry from August 14-29, 2015. Chadwick served as Chief Scientist on the cruise and led geologic studies, and Bobbitt and Merle shared data processing and data management duties. Bobbitt also produced a comprehensive cruise report after the expedition and submitted data to the Marine Geoscience Data System for archiving. Research on the cruise included making seafloor pressure measurements at an array of seafloor benchmarks with the Jason ROV to document volcanic inflation and deflation. ROV dives also collected vent fluid and microbial samples from hydrothermal vents to better understand the microbial ecosystems that form the base of the food chain at seafloor hot springs and how they are affected by volcanic events. Considerable time was spent mapping and sampling the new lava flows that were erupted in April 2015, as well as sampling new hydrothermal vents on the 2015 lava flows. Senior Faculty Research Assistant Leigh Evans prepared gas-tight vent fluid samplers from the cruise and conducted laboratory geochemical analyses of the samples after the cruise. The following web site followed the cruise: http://axial2015.blogspot.com

Senior Faculty Research Assistant Susan Merle participated in another research cruise to the Colville Ridge, north of New Zealand from September 5-25, 2015. This expedition was a collaboration between OSU-CIMRS and collaborators at GNS-Science in New Zealand, and consisted primarily of collecting multibeam bathymetry of a large unmapped area of the seafloor.

Professor Chadwick and Senior Faculty Research Assistant Merle also participated in a cruise on R/V Falkor (operated by the Schmidt Ocean Institute) from November 21 to December 17, 2015. The cruise staged out of Guam and focused on a 600-km long section of the Mariana back-arc

spreading center that was virtually unexplored. CTD casts and tows were used to search for new hydrothermal vent sites, and AUV Sentry made dives to map the seafloor in high-resolution and to collect additional data to pinpoint the locations of vents. The cruise discovered 4 new hydrothermal vent sites, which will be returned to with an ROV in FY17. The following web site followed the cruise: http://schmidtocean.org/cruise/hydrothermal-hunt-at-mariana/

Research results were presented at 2015 Fall Meeting of the American Geophysical Union (AGU) in San Francisco, the 2015 Annual Meeting of the Geological Society of America in Baltimore, and the 2016 Ocean Sciences Meeting in New Orleans. The meeting presentations included CIMRS co-authorship on six posters and one oral presentation (note: Chadwick and Merle were at sea and could not attend the AGU meeting). Publications this year are less than usual due to the increased time at sea during the last year. However, two major data sets of long-term pressure measurements at Axial Seamount were compiled, published, and archived at the Marine Geoscience Data System and assigned DOI designations (see below). In addition, two papers are written and almost ready to submit (see below).

MEETING PRESENTATIONS:

Hanson, M., S. Beaulieu, V. Tunnicliffe, **W. W. Chadwick, Jr.**, and E. Breuer (2015), Looking for larvae above an erupting submarine volcano, NW Rota-1, Mariana arc. Abstract OS43A-2029 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Kelley, D. S., J. R. Delaney, **W. W. Chadwick, Jr.**, B. Philip, and **S. G. Merle** (2015), Axial Seamount 2015 eruption: A 127-m thick, microbially-covered lava flow. Abstract OS41B-08 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Nooner, S. L., **W. W. Chadwick, Jr**., D. W. Caress, D. A. Clague, J. B. Paduan, D. R. Yoerger, and G. S. Sasagawa (2015), Deformation associated with the 2015 eruption of Axial Seamount. Abstract OS43A-2015 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Paduan, J., D. A. Clague, D. W. Caress, B. M. Dreyer, R. A. Portner, J. F. Martin, and **W. W. Chadwick, Jr.** (2015), High-resolution Mapping and Sampling of Historic Flows on the Juan de Fuca and Gorda Ridges. Abstract presented at 2015 Annual GSA Meeting, Baltimore, MD, 1-4 Nov., GSA Abstracts with Programs, 47(7)

Caress, D. W., D. A. Clague, J. B. Paduan, H. Thomas, **W. W. Chadwick, Jr.**, S. L. Nooner, and D. R. Yoerger (2015), Vertical deformation of the Axial Seamount summit from repeated 1-m scale bathymetry surveys with AUVs. Abstract presented at 2015 Annual GSA Meeting, Baltimore, MD, 1-4 Nov., GSA Abstracts with Programs, 47(7)

Hanson, M., S. Beaulieu, V. Tunnicliffe, **W. W. Chadwick, Jr.**, and E. Breuer (2016), Looking for larvae above an erupting submarine volcano, NW Rota-1, Mariana arc. Abstract ME34B-0804 presented at 2015 Ocean Sciences Meeting, AGU, New Orleans, Louisiana, 22-26 Feb.

Resing, J. A., **W. W. Chadwick, Jr.**, E. T. Baker, S. G. Merle, S. L. Walker, N. Buck, D. A. Butterfield, P. M. Barrett, S. Michael, W. Hu, T. Baumberger, and C. L. Kaiser (2016),

Hydrothermal exploration of the Mariana Back Arc Basin and transport of trace Fe from the Mariana Arc. Abstract CT24A-0158 presented at 2015 Ocean Sciences Meeting, AGU, New Orleans, Louisiana, 22-26 Feb.

PUBLICATIONS:

Dziak, R. P., and **S. G. Merle** (2016) Growth, demise, and recent eruption history of the eastern Cobb-Eickelberg Seamounts at the intersection with the Juan de Fuca Ridge. In: **Plate Boundaries and Natural Hazards**, J. Duarte and W. Schellart (Eds), AGUMonograph, American Geophysical Union, ISBN: 978-1-119-05397-2.

DATA SETS PUBLISHED:

Chadwick, W. W., Jr., and S. L. Nooner (2015) Processed Bottom Pressure Recorder (BPR) data from uncabled instruments deployed at Axial Seamount on the Juan de Fuca Ridge (investigators William Chadwick and Scott Nooner). Integrated Earth Data Applications (IEDA). http://doi.org/10.1594/IEDA/322282.

Fox, C. G. (2016) Processed Bottom Pressure Recorder (BPR) data from uncabled instruments deployed at Axial Seamount on the Juan de Fuca Ridge (investigator Chris Fox). Integrated Earth Data Applications (IEDA). http://dx.doi.org/10.1594/IEDA/322344. (compiled and submitted by **Chadwick**)

Amendment 68, 77: Higher Resolution Deep Ocean Assessment and Reporting of Tsunamis

Funded: $45,964/$62,738

OSU RESEARCH STAFF: *Bruce Mate*, Professor, Marine Mammal Institute

NOAA TECHNICAL LEAD: *CMD Thomas Peltzer*, PMEL

PROJECT BACKGROUND: Recent advancements in sensors, software and power management hold promise that detection and measurement of near-field tsunamis with unprecedented resolution is now possible. This improved nano-resolution pressure sensor and algorithm will allow the separation of the tsunami signal from the earthquake "noise." The NOAA DART (Deep Ocean Assessment and Reporting of Tsunamis) 4G design builds on the DART-ETD (Easy-to-Deploy), which consists of a surface buoy connected to a subsurface tsunameter via an acoustic link. Real-time communications latencies from seafloor-to-shore have been reduced, while high-resolution tsunami height measurements have been increased. Successful laboratory testing of the sensor and algorithm has progressed and ocean testing is in the planning stages to demonstrate and validate the DART Near Field design.

PROJECT PROGRESS: The DART 4G System is an enhanced version of DART-ETD technology developed at NOAA-PMEL (Bernard and Meinig, 2011) that has been transitioned to industry (Lawson et al., 2011). An early prototype was deployed for 18 months on the Monterey Accelerated Research System (MARS) cabled observatory at a depth of ~900 m. Numerous

earthquakes and far-field tsunamis were captured and compared to a co-located standard DART tsunameter as well as nearby seismometers (Paros et al., 2011).

The enhancements include a new pressure sensor and software that run a detection and filter algorithm to transmit tsunami height data while the earthquake is rupturing. The new algorithms have been developed by studying near-field tsunami data and applying the most effective techniques. Advancements in power management allow for a system endurance of three years for the tsunameter and two years for the surface buoy. Shore-side software has also been upgraded to receive the higher-frequency observations during events. Additionally, component obsolescence issues have been addressed in the entire system and will be field tested in 2015.

Two prototypes DART 4G buoys systems were deployed in August/September 2015 from the RV Pacific Storm. The location for all deployments is a site approximately 80 nautical miles West of Newport, OR.

Amendment 72: Curation of ROV-collected rock samples in the OSU Marine Geology Repository for the 2015 CAPSTONE Expeditions using R/V Okeanos Explorer

Funded Amount: $40,866

OSU RESEARCH STAFF: *Anthony Koppers* Professor, Geophysics, CEOAS
NOAA TECHNICAL LEAD: *Alan Leonardi*, OER

PROJECT BACKGROUND: The NOAA office of Ocean Exploration and Research (OER) started to carry out a systematic exploration Campaign to Address Pacific monument Science, Technology, and Ocean NEeds (CAPSTONE) with NOAA's Ship the R/V Okeanos Explorer during the 2015-2017 field seasons. CAPSTONE included a major effort focused on addressing priority NOAA science and management needs in and along the Hawaiian Archipelago and Johnston Atoll from July to September 2015. In total four legs were carried out, three of which included collection of biological and rock samples using NOAA's two-body 6000 m Remotely Operated Vehicle (ROV) from the ocean floor and seamounts in these regions. The ROV-collected rock samples will be curated in the OSU Marine Geology Repository (OSU-MGR; see http://osu-mgr.org for more details). In total 70 rock samples were collected during the 2015 CAPSTONE legs. These rock samples will be sent to the OSU-MGR for curation, sample description and will be made available for sampling to the wider national and international research community for carrying out further science projects.

PROJECT PROGRESS: There was significant delay in funding this proposal which was to start February 1, 2016; progress has been slow as funding to OSU did not arrive until May. Rock samples arrived on or about May 17th. Dr. Anthony Koppers with assistance from his graduate research assistant Kevin Konrad to verify that all samples were received in accordance with the documentation and database. Samples were boxed, labeled with QR codes and IGSN numbers, and bagged. Samples are being cut, putting 1/3 away as ARCHIVE and the rest as WORKING halves using thin section billets. The camera system has been inspected by Dr. Koppers in College Station, Texas, and delivery is expected by the end of August (or September).

Theme: Marine Bioacoustics

Amendment 54: Advanced Methods for Passive Acoustic Detection, Classification, and Localization of Marine Mammals

Funded: $109,163

OSU RESEARCH STAFF: *David Mellinger*, Professor, Senior Research, CIMRS; *Sara Heimlich, Curtis Lending*, Faculty Research Assistants CIMRS

NOAA TECHNICAL LEAD: *Jonathan Klay*, Computing and Network Services, PMEL

PROJECT BACKGROUND: For effective long-term passive acoustic monitoring of today's large data sets, automated algorithms must provide the ability to detect and classify marine mammal vocalizations and ultimately, in some cases, provide data for estimating the population density of the species present. In recent years, researchers have developed a number of algorithms for detecting calls and classifying them to species or species group (such as beaked whales). Algorithms must be robust in real ocean environments where non-Gaussian and non-stationary noise sources, especially vocalizations from similar species, pose significant challenges. In this project, improved methods for detection, classification, and localization of many types of marine mammal sounds are being developed by CIMRS researchers using a two-pronged approach: developing improved DCL algorithms, and developing standardized interfaces and software.

PROJECT PROGRESS:

Detection/classification algorithms: tonal sounds. A whistle clustering manuscript was revised with a new classification section showing that shape-related whistle features carry species-specific information useful for species identification. The revised paper on this subject is currently in review.

Improvements were made to the *Silbido* whistle detector that improved the precision rate from 76.0% to 89.7% with a corresponding penalty in recall of only 0.1%, representing a 57% decrease in false positives generated by the detector with trivial impact on correct detections. A manuscript detailing these results is underway. Also, as part of the *Silbido* effort to reduce false positives, we constructed a visualization and debugging utility that lets one examine how the algorithm is working and provided a level of abstraction to better understand where the algorithm was making mistakes and let us examine how proposed changes would affect performance. Having this type of abstraction was a critical component to recognizing that there were problems due to noise regime changes and that the whistle graphs associated with false positive detections had certain characteristics that we could exploit.

Detection/classification algorithms: odontocete clicks. An article (Roch et al., 2015) was published describing current work with subaward collaborators from San Diego State University on the impact of equipment and site differences on odontocete species identification through features derived from echolocation clicks. The article demonstrates that there are significant performance impacts on species classification when training data are recorded with instruments of a specific type or at a specific location and tested under non-matching conditions. This has

significant impact on any Naval monitoring scheme that uses features from broadband echolocation clicks. We were also able to demonstrate that simple noise estimates can be used to reduce this penalty significantly. Further research in this area has the potential to further mitigate for train/test mismatch.

One of the most important things learned over the last year is that when one moves to working with very large datasets that have not been hand-curated to extract sections with data from relevant target species, performance degrades quickly. Analysis of the 2015 DCLDE development data led us to recognize that sporadic false positives from echolocation click detectors can wreak havoc on performance and we subsequently developed filtering rules that remove low frequency sporadic clicks as well as methods of identifying and removing instrument self-noise. Work with Kullback-Leibler distances between encounters enabled us to inspect characteristics of specific encounters to better determine what problems exist, and we are continuing work on this productive path.

Software: The architecture for writing detection, classification, and localization modules has been completed and communication between Ishmael and PAMGUARD and a test module has been established. The architecture provides a translation library for each DCL platform supported that marshals data into a format that can be shared with other processes. Modules run as separate programs that share a limited region of memory with the DCL platform. This allows modules written on platforms that require separate processes (e.g., Matlab, R) to be gracefully handled. Users designing classification modules will configure the DCL platform to send data to their module and make calls to a standard interface library. Results are sent back to the DCL platform in a similar manner. The plug-in architecture has been successfully demonstrated in Ishmael with a detector in MATLAB. The architecture now supports multiple languages, and work continues to refine the interface to make it as easy to use as possible.

PUBLICATIONS:

Frasier, K.E., E.E. Henderson, H.R. Bassett, and M.A. Roch. (2016) Automated identification and clustering of subunits within delphinid vocalizations. *Mar. Mamm. Sci.*; pre-print at doi:10.1111/mms.12303 . In press.

Mellinger, D.K., M.A. Roch, E.-M. Nosal, and **H. Klinck.** 2016. Signal processing, In: **Listening in the Ocean,** W. Au and M. Lammers (Eds.), Springer-Verlag, New York, pp. 359-409.

TASK 3

Theme: Seafloor Processes

Amendment 58: Seafloor Reflectance Mapping from EAARL-B Topographic Lidar Data in the U.S. Virgin Islands

Funded: $27,765

OSU RESEARCH STAFF: *Chris Parrish*, Assoc. Professor, Civil/Constr. Engineering
NOAA TECHNICAL LEAD: *Tim Batista*, NCCOS/NOS

PROJECT BACKGROUND: NOAA's CCMA Biogeography Branch generates and disseminates benthic habitat maps, which support ecosystem-based management of coastal and marine resources and simultaneously serve a range of data needs within the government and the broad coastal science community. In 2014, the Biogeography Branch partnered with USGS to acquire topobathymetric lidar data for high-priority coral reef habitat areas in the U.S. Virgin Islands (USVI). The airborne lidar system used to acquire the data was USGS's new Experimental Advanced Airborne Research Lidar (EAARL-B). Bathymetric digital elevation models (DEMs) generated from the lidar data are currently serving as input to the Biogeography Branch's benthic habitat mapping programs, which support several priorities identified in the NOAA NOS Priorities Roadmap (http://oceanservice.noaa.gov/about/NOSRoadmap.pdf) and NCCOS Strategic Plan (https://coastalscience.noaa.gov/about/docs/strategicplan2011-15.pdf).
The availability of return waveforms (digitized samples of the backscattered laser pulse) from EAARL-B seafloor returns provides the potential to further extend the value of the lidar data by enabling new seafloor data products to be generated. The goal of this project is to develop and test procedures and software for creating these new seafloor data products from EAARL-B waveforms in the USVI dataset to enhance seafloor characterization and better inform ecosystem-based management. In the current project year (July, 2015 – September, 2016), the OSU team is focusing on creating seafloor relative reflectance mosaics for project sites offshore of St. Croix, as well as St. Thomas and St. John. In loose terms, the output consists of seamless image mosaics, in which pixel values represent the "brightness" of the seafloor (and/or cover type, such as seagrass, algae, or coral) at the green (532 nm) wavelength of the topobathymetric lidar system. Previous research has demonstrated that these relative reflectance mosaics can facilitate benthic habitat classification, and they can also be used as stand-alone products for other types of seafloor analysis, including change detection.

PROJECT PROGRESS: In the current year of the project, the OSU team successfully developed and tested procedures for generating seafloor relative reflectance mosaics from EAARL-B data. The input to the process consists of bottom return peak amplitude and other waveform metrics generated using algorithms developed by the PI and implemented in the Airborne Lidar Processing Software (ALPS) by David Nagle of USGS. Bottom return peak amplitude is the key variable used in generating relative reflectance. However, to obtain estimates of seafloor reflectance from the bottom return peak amplitude values, several corrections are needed to reduce or remove the influence of environmental and system parameters, including water depth and turbidity, and incidence angle of the laser beam. Some of these corrections are particularly important when using data acquired with the EAARL-B system, which differs from other bathymetric lidar systems, in that it uses a cross-track scanning pattern, with the laser beam passing nearly through nadir on each scan line. The workflow for applying corrections to EAARL-B bottom return peak amplitude to generate relative reflectance is illustrated in Fig. 1.

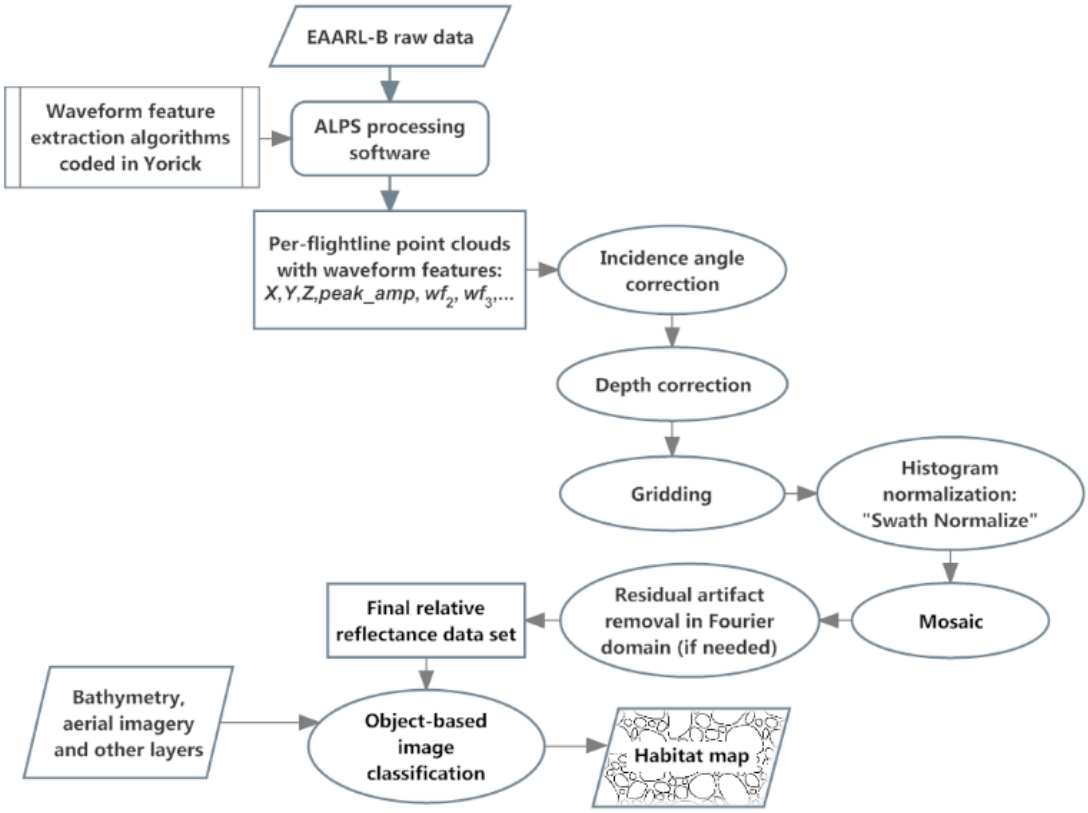


Figure 1: Workflow for EAARL-B relative reflectance mapping (Parrish and Wilson, 2015).

To date, the procedures illustrated in Fig. 1 have been applied to EAARL-B waveforms for the St. Croix project site. An example of the output of the depth and incidence angle correction algorithms is shown in Fig. 2 for a sub-site just southeast of Buck Island.

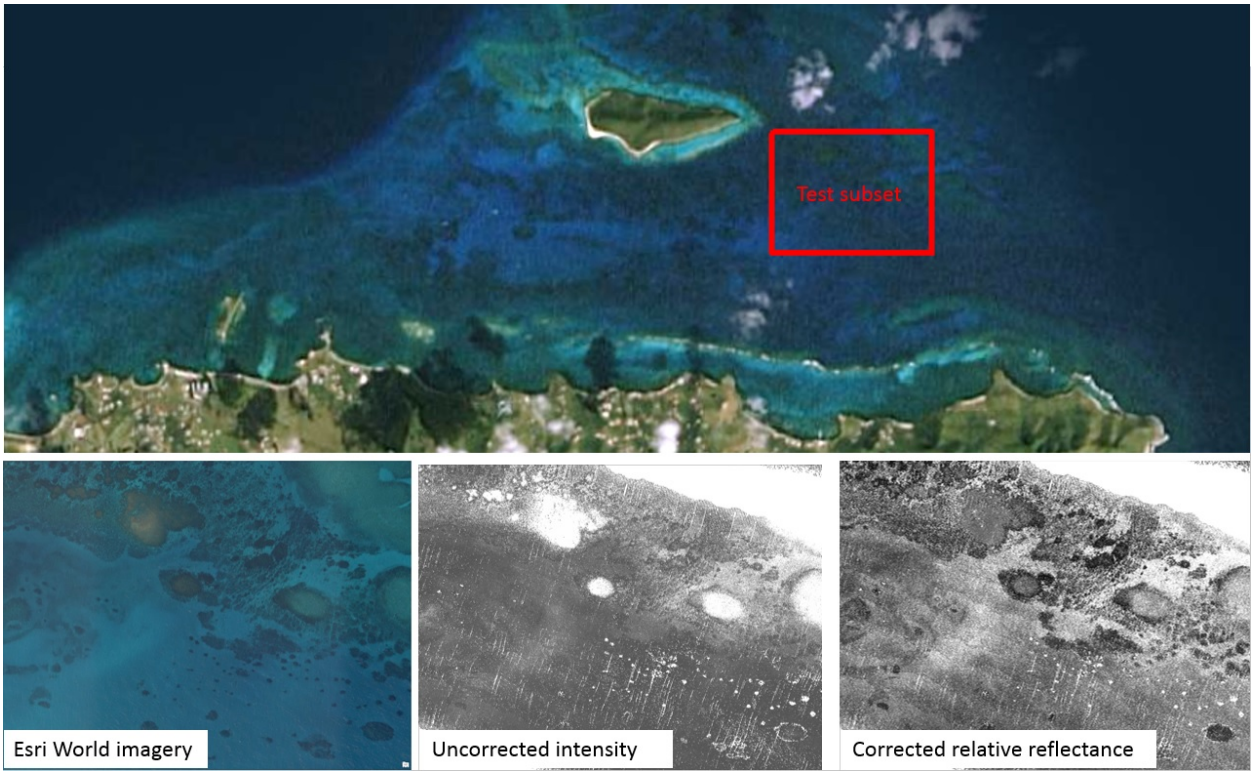


Figure 2: Example of the uncorrected (bottom middle) and corrected (bottom right) relative reflectance images developed from the USGS EAARL-B data.

Using these procedures, the OSU project team has generated a relative reflectance mosaic for the full St. Croix site (Fig. 3). This mosaic, along with accompanying metadata, was delivered to NOAA's Biogeography Branch in February, 2016. The procedures used to generate this relative reflectance mosaic are currently being extended to the larger (~550 km^2) St. Thomas - St. John project site.

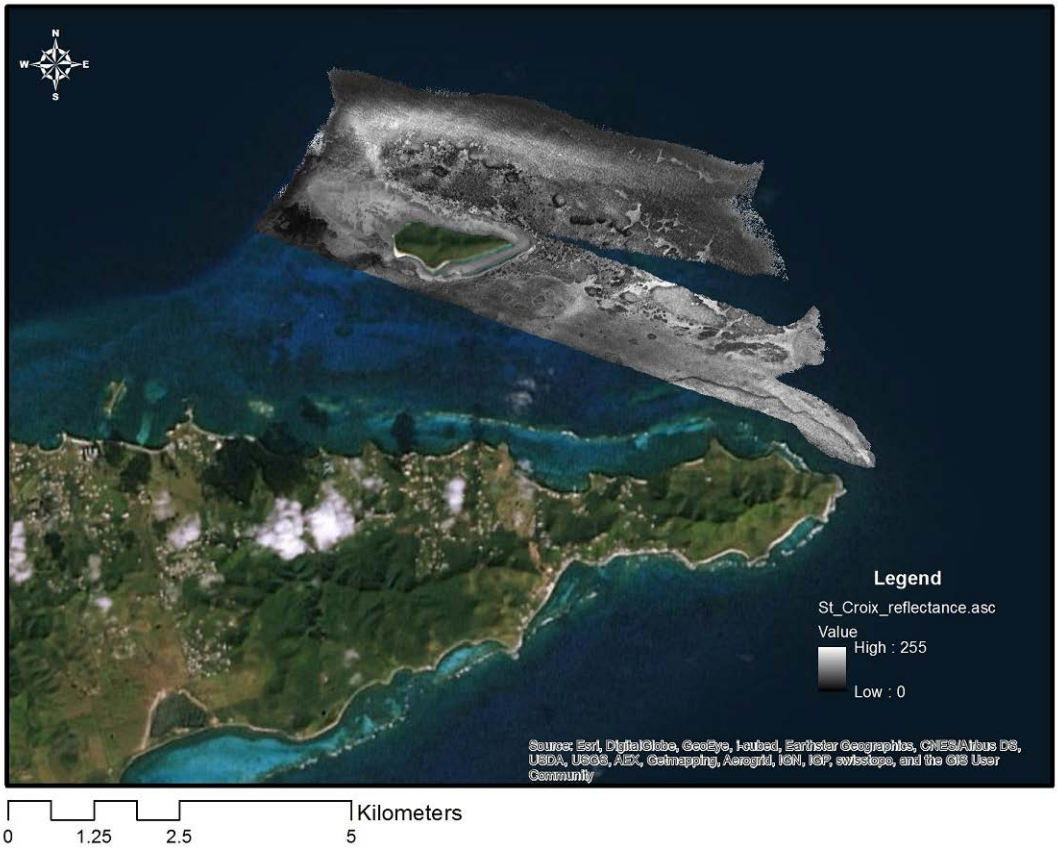


Figure 3: EAARL-B relative reflectance mosaic for St. Croix project site generated by OSU research team.

The OSU project team's current work (which is anticipated to extend into the next project year) is focused on two primary tasks: 1) completing the relative reflectance mapping for the larger St. Thomas - St. John site; and 2) developing corrections for additional waveform features (width, skewness, area under the curve) for a high-priority site in Flat Cays, ~3 km southwest of Charlotte Amalie West in St. Thomas. The output will be used by the full project team (including the NOAA leads within the Biogeography Branch and the UNH project team members) for conducting fieldwork in Flat Cays and improving the estimation and classification of coral reef morphology, biological cover and potentially other coral health-related indictors.

MEETINGS:
OSU project team members, Chris Parrish and Nick Wilson, participated in roughly quarterly teleconferences with the NOAA and UNH project team members, Tim Battista, Bryan Costa, and Jenn Dijkstra. The project team members also attended and presented at the 16th Annual Coastal Mapping & Charting Workshop of the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX). The OSU PI, Chris Parrish, is scheduled to give a seminar in the NOAA Science Seminar series on July 18, 2016. Additionally, the project team is scheduled to give three presentations at the upcoming JALBTCX Workshop in Silver Spring, Maryland, on July 19-21, 2016.

PUBLICATIONS:

Costa, B., T. Battista, C. Parrish, N. Wilson and J. Dijkstra, 2016. Evaluating the Utility of EAARL-B Lidar Waveforms for Mapping Coral Reef Habitats. The 17th Annual Coastal Mapping & Charting Workshop of the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), 19-21 July, Silver Spring, Maryland (accepted)

Parrish, C. and N. Wilson, 2015. Topobathymetric Lidar Waveform Features for Habitat Mapping and Hurricane Sandy Response. The 16th Annual Coastal Mapping & Charting Workshop of the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), 16-18 June, Corvallis, Oregon: http://shoals.sam.usace.army.mil/Workshop_Files/2015/Day_03_pdf/1330_Parrish_Wilson.pdf.

Parrish, C., N. Forfinski, and N. Wilson, 2016. Advances in Seafloor Mapping with New Spaceborne and Airborne Lidar Systems. The 17th Annual Coastal Mapping & Charting Workshop of the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX), 19-21 July, Silver Spring, Maryland (accepted).

Parrish, C.E., J.A. Dijkstra, J.P.M. O'Neil-Dunne, L. McKenna, and S. Pe'eri, 2016. Post-Sandy Benthic Habitat Mapping Using New Topobathymetric Lidar Technology and Object-Based Image Classification. *Journal of Coastal Research* (in press)

Wright, C.W., C. Kranenburg, T.A. Battista, and C. Parrish, 2016. Depth Calibration and Validation of the Experimental Advanced Airborne Research LiDAR, EAARL-B. *Journal of Coastal Research* (in press)

Amendment 67: Towards Optimizing the Determination of Accurate Heights Using GNS

Funded: $150,444

OSU RESEARCH STAFF: *Dan Gillins, Assoc. Professor, Civil/Constr. Eng.*
NOAA TECHNICAL LEAD: *Mark Armstrong, NGS/NOS*

Funded: $150,444

PROJECT BACKGROUND: In 1997, NOAA's National Geodetic Survey (NGS) published *NOAA Technical Memorandum NOS NGS-58*, "Guidelines for Establishing GPS-derived Ellipsoid Heights" (Zilkoski et al., 1997). These guidelines served a critical need in providing procedures that enable accurate ellipsoid heights on marks to be determined with GNSS. Accurate ellipsoid heights are an essential component of using GNSS (combined with a high-resolution hybrid geoid model) to determine accurate orthometric heights as an alternative to more expensive differential leveling surveys (NGS et al., 1998). However, recent research, as well as the experience of the broad community of surveyors, indicates that advances in GNSS technology, as well as the latest real-time GNSS techniques, may enable substantial efficiency gains in achieving accuracy requirements for GNSS-derived ellipsoid heights, as compared with what was achievable nearly 20 years ago. There is particular interest in the possibility of easing the requirements for multiple, long-duration static post-processed GPS observations, as required in NGS-58. For example, NGS-58 requires three 5-hr static GPS observations on several marks in order to determine ellipsoid heights with an accuracy less than 2 cm at 95% confidence.

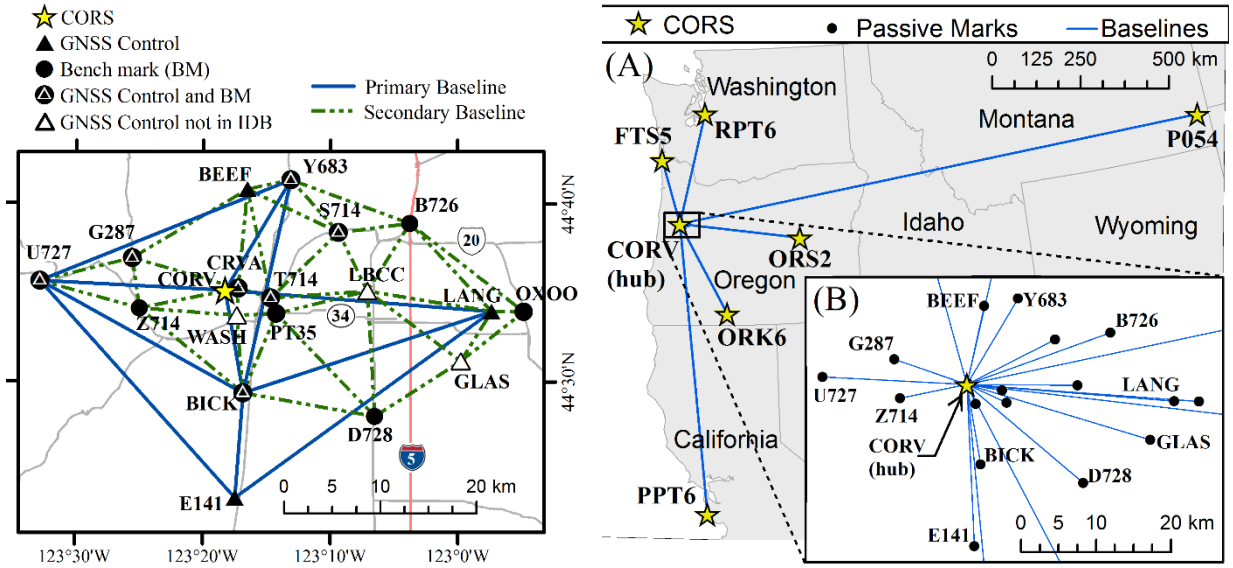
The purpose of this research is to investigate a variety of GNSS data acquisition and post-processing procedures that have been developed since 1997 which can be used to more quickly determine ellipsoid heights on marks. The data acquisition procedures and post-processing software under investigation in this study include: 1) static GPS observations post-processed in Trimble Business Center, commercial baseline processing software; 2) static GPS observations post-processed in OPUS-Projects, web-based software released by NGS in 2013; 3) real-time kinematic GPS and GPS+GLONASS observations using correctors from a single base station in a real-time network; 4) real-time GPS and GPS+GLONASS observations using full network correctors from a real-time network. Some of the GNSS data evaluated in this study were collected during an NGS survey study in South Carolina (Gustin, Cothern & Tucker, Inc. 2013; Dennis 2014). Additional GNSS data were collected on 18 passive marks in Oregon by the project team at Oregon State in the fall of 2014.

After evaluating the various procedures and software, the ultimate goal for the project team is to write procedures for how to efficiently determine ellipsoid heights using the latest GNSS hardware and software. The written procedures will recommend techniques for collecting the data in the field, using real-time observations when and where appropriate, and post-processing static observations in OPUS-Projects. They will specify techniques (e.g., the number and duration of GNSS sessions) in order to achieve a particular accuracy in ellipsoid height.

PROJECT PROGRESS: In 2015, the project team analyzed the static GPS data collected during the 2014 field campaign. The data consisted of fifteen 10-hr GNSS sessions on 18 passive marks in the Willamette Valley, Oregon. Samples of this data were selected in order to construct two survey networks, the geometry of each following recommendations in NGS-58. Baseline observations for both networks were post-processed in Trimble Business Center, and the networks were adjusted using NGS software ADJUST (Milbert and Kass 1987). The first network, known as the "5H Loop Network" consisted entirely of 5-hr. duration static GPS observations between the marks. This network exceeded requirements in NGS58, and it was constructed to serve as a "ground-truth" model for comparing results. The "5H/1H Loop Network" was nearly identical to the 5H Loop Network, except that secondary baselines (typically shorter than 15 km in length) were made up of 1-hr. duration static GPS observations. The 5H/1H Loop Network generally followed the minimum recommendations in the NGS-58 survey guidelines.

Each of the 15 static GPS sessions were also post-processed in OPUS-Projects following a hub network design as recommended by NGS in Armstrong et al. (2015). The resulting 15 session solutions were compiled in order to form a survey network, and the network was then adjusted by least squares methods using both OPUS-Projects and ADJUST. The network adjusted in OPUS-Projects was named the "OP Hub Network", and the network adjusted in ADJUST was named the "OP+ADJUST Hub Network." For all adjustments, the networks were minimally constrained to the nearby continuously operating reference station (CORS) named CORV.

Figure 1a shows a diagram of the loop networks, and Figure 1b depicts the hub networks. The ellipsoid heights on the project marks from the network adjustment solutions were averaged. Figure 2 shows the difference from the average ellipsoid height for each mark, symbolized by network solution.



(a) (b)

Figure 1. (a) diagram of the 5H and 5H/1H Loop Networks; (b) diagram of the OP and OP+ADJUST Hub Networks

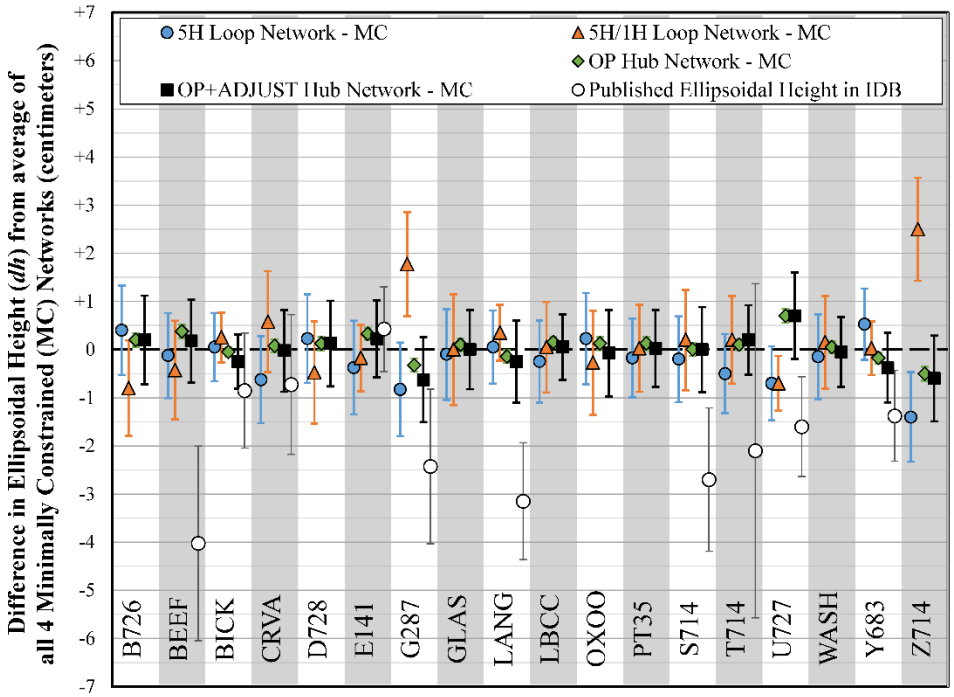


Figure 2. Comparison of ellipsoid height from four network solutions and published heights in the NGS Integrated Database (IDB).

Figure 2 presents a number of interesting findings. First, the error bars for the OP Hub Network are very short, and we believe that OPUS-Projects is over-estimating the accuracy of its adjusted heights. All four network solutions provided similar heights, but the 5H/1H Loop Network had the most variation and large difference from the average on two of the 18 marks (G287 and Z714). For the other three network solutions, the heights agreed within ± 1 cm of the average, and these precise results indicate that baselines processed in OPUS-Projects yielded heights quite similar to baselines processed in Trimble Business Center.

Details of this work were documented in a technical report submitted to NGS in December 2015 (Gillins and Eddy 2015). In addition, a peer-reviewed journal paper (Gillins and Eddy 2016) summarizing this work was accepted in the ASCE Journal of Surveying Engineering. These papers recommended the procedure followed for the OP+ADJUST Hub Network for post-processing and adjusting static GPS survey networks in OPUS-Projects.

Since the fall of 2015, the team has analyzed the results of real-time observations collected during the aforementioned South Carolina and Oregon surveys. To analyze the accuracy of these observations, the team first used processed > 30 h of static GPS observations on all of the project marks following the workflow for the OP+ADJUST Hub Network. Then, the coordinates on the marks as found in real-time were differenced with the adjusted coordinates from the network solutions, and vertical root-mean-square error (VRMS) of these differences were found according to each mark and observation duration. Figure 3 shows VRMS as a function of observation duration for single-base and full network correctors and for GPS-only and GPS+GLONASS observables using the South Carolina Real-Time Network.

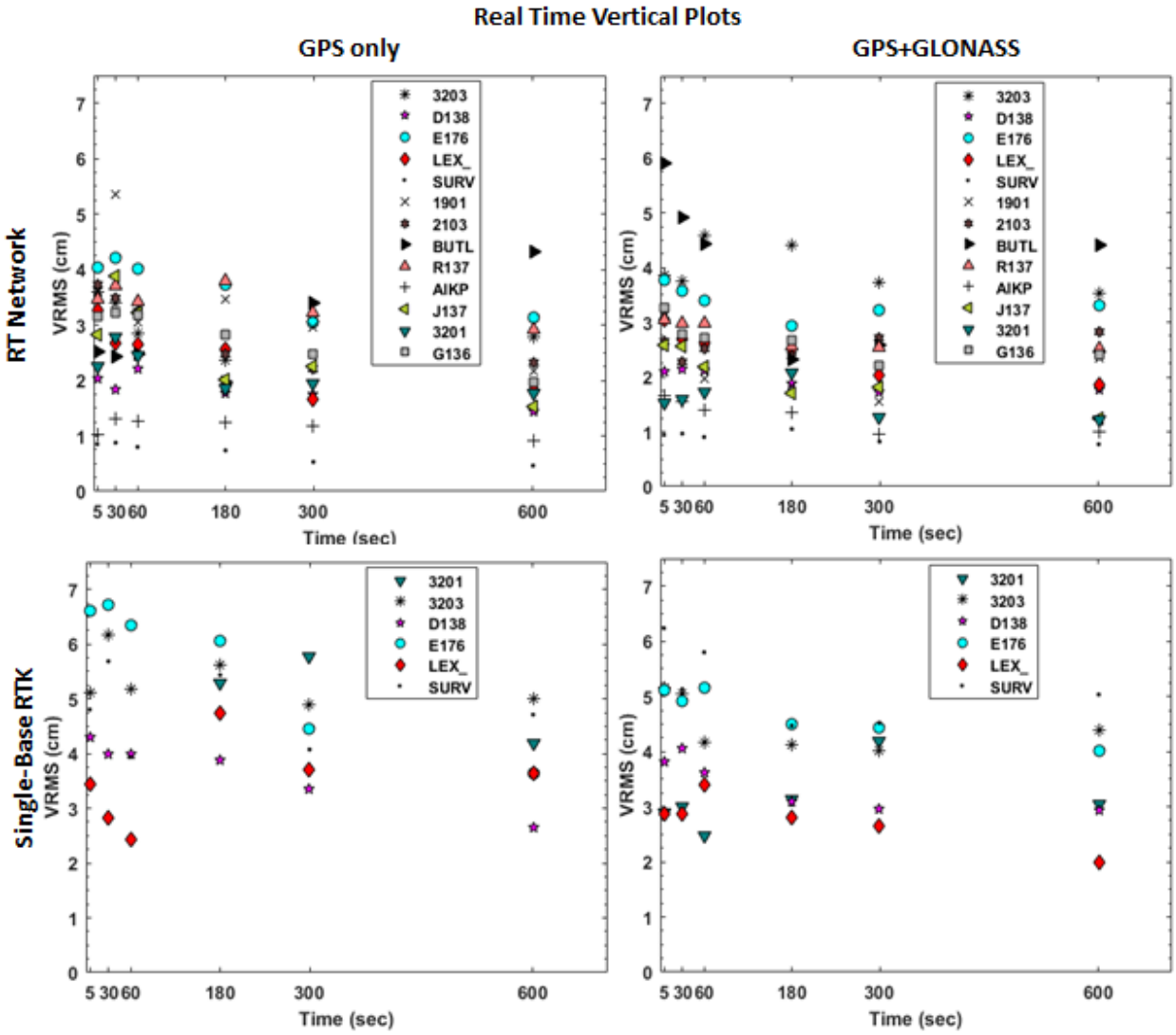


Figure 3. Variations in vertical RMS errors between real time networks and single base RTK GPS and GPS+GLONASS observations.

As expected, VRMS was typically smaller for those observations using the full network corrector rather than a single-base corrector. Interestingly, VRMS hardly improves as the duration of the observation increases, especially after approximately 180 sec. Plots similar to Figure 3 are under development for the Oregon real-time data. The team is also investigating the influence of baseline length and change in elevation on the accuracy of the real-time data. Final recommendations will be given in the technical report due December 2016.

The team is also currently developing a "hybrid network" approach for determining accurate ellipsoid heights with GNSS. In the hybrid network approach, static GPS sessions from CORS and base stations in the real-time networks in Oregon and South Carolina were first uploaded and post-processed in OPUS-Projects. Then, real-time observations (180 sec. duration using the full network corrector) from the base stations to the passive marks were added to build a "static+real-time" hybrid network. All real-time and static baseline observations were then adjusted by least

squares using ADJUST. The team has found that ADJUST estimates ellipsoid heights on the project marks less than 2 cm at 95% confidence when including at least six real-time 180-sec observations on each mark. This hybrid approach has potential to significantly reduced the amount of time spent in the field observing each mark (i.e., from 15 h to 18 min.) in order to determine ellipsoid heights < 2 cm at 95% confidence.

Lastly, the team is also currently investigating methods to combine terrestrial differential leveling observations and GNSS measurements into an integrated network for adjustment. This work has several challenges that must be addressed, including development of a mathematical model for such an integrated adjustment, and proper modeling of uncertainty on leveling control and observations.

PRESENTATIONS:

The team has presented this research at the following conferences and meetings to date:

Invited Talk, *California Land Surveyors Association 2016 Annual Meeting*, "Height Modernization with OPUS-Projects," March 2016.

Contributed Talk, *Professional Land Surveyors of Oregon (PLSO) 2016 Annual Conference, Eugene, OR*, "Height Modernization with OPUS-Projects," January 2016.

Invited Talk, *California Land Surveyors Association Web-Meeting*, "Towards Optimizing the Determination of Accurate Heights with GNSS, an Update," December 2015.

Invited Talk, *Fall 2015 Western Region Height Modernization Group Web-Meeting*, "Towards Optimizing the Determination of Accurate Heights with GNSS, an Update," November 2015.

PUBLICATIONS:

Gillins, D. and Eddy, M. 2016. Comparison of GPS height modernization surveys using OPUS-projects and following NGS-58 Guidelines. *J. Surv. Eng*. 10.1061/(ASCE)SU.1943-5428.0000196, 05016007.

Amendment 69: A Multidisciplinary, Integrative Approach to Valuing Ecosystem Services from Natural Infrastructure

Funded: $444,743

OSU RESEARCH STAFF: *Steven Dundas*, Assistant Professor, Applied Economics; *Daniel Cox*, Professor, Civil and Construction Engineering; *Sally Hacker*, Professor, Integrative Biology; *David Kling*, Assistant Professor, Applied Economics; *David Lewis*, Associate Professor, Applied Economics; *Christopher Parrish*, Associate Professor, Civil and Construction Engineering; *Peter Ruggiero*, Associate Professor, College of Earth, Ocean, and Atmospheric Sciences

NOAA TECHNICAL LEAD: *Felix Martinez*, NCCOS

PROJECT BACKGROUND: This research advances the multidisciplinary science of coastal ecosystem services. Our focus is on natural infrastructure, which we define broadly as a physical stock (i.e., durable physical quantities) that constitutes restoration of, or extension to natural ecosystem components. We aim to understand the nature and determinants of socially-optimal investment in natural infrastructure in coasts and estuaries from an economic perspective. The economic theory of investment provides the conceptual foundation for our planned research. Socially optimal investment maximizes *total economic value* (TEV): uncertain benefits of an investment net of costs over time. Focusing on a selection of natural infrastructure types, we will measure the expected benefits of an investment to society, expected direct costs, and expected co-benefits from provision of ancillary ecosystem services using a portfolio of empirical and mathematical modeling techniques. We will then develop optimal investment plans for each infrastructure type. Our study area encompasses the coast and estuaries of Oregon.
In order to analyze approaches that maximize the TEV of a natural infrastructure investment, required information includes how the investment is expected to impact the target ecosystem, how the modified ecosystem is expected to provide services, and how society values those changes (expected benefits and costs). As with ecosystem service research in other domains, two major methodological challenges we will encounter in the course of this research are: a) the problem of quantifying the benefit of an ecosystem service that lacks a market price; and b) understanding the "production" relationship between an investment and expected service provision (plus expected ancillary effects on other service flows). Our research will address these two challenges by joining state-of-the-art non-market valuation methods with empirical ecological and engineering-economic models of natural infrastructure investment. We anticipate that our resulting models will yield generalizable methodological insights that will extend the frontier of ecosystem service science.

We divide our economic research into three methodological tracks. Track I is focused on estimating willingness-to-pay (WTP) for protection services related to any type of coastal infrastructure (green or grey) improvement by analyzing coastal housing market data. In Track II we will develop and implement two choice experiment surveys for the purpose of estimating WTP for ecosystem service benefits that accrue to households. In Track III we will develop a suite of mathematical optimization models to analyze how investment in natural infrastructure may be planned to maximize the value of ecosystem services to the public.

We are investigating four distinct systems on the Oregon coast that serve as applied pathways for our work. The project pathways are: 1) quantifying protection from different land features and types of risk in the coastal system subject to wave action (Coastal Protection Pathway); 2) resilience, native species conservation, and the non-consumptive value of dune habitat (Dune Habitat Pathway); 3) restoring coastal wetlands and the resulting implications for anadromous fish, water quality, and blue carbon in estuarine systems (Estuary Pathway); and 4) how to allocate land use to facilitate tsunami evacuation (Coastal Land Use Pathway).

PROJECT PROGRESS: Our first annual Advisory Board meeting was held in Corvallis, Oregon on March 30th, 2016. Participants included: Felix Martinez (NOAA NCCOS), John Stein (NOAA Northwest Fisheries Science Center), Jarod Norton (U.S. Army Corps of Engineers), Brady Callahan (Oregon Parks and Recreation), Dan Lew (NOAA Alaska Fisheries Science

Center), Dan Elbert (U.S. Fish and Wildlife Service), Jonathan Allen (Oregon Department of Geology and Mineral Industries), William Jenkins (Oregon Department of Fish and Wildlife), Dave Hansen (Oregon Sea Grant), Steven Dundas (Oregon State University), Daniel Cox (Oregon State University), David Kling (Oregon State University), David Lewis (Oregon State University), Christopher Parrish (Oregon State University), and Peter Ruggiero (Oregon State University).

There were three primary objectives of this meeting: 1) Bring together experts on Oregon's coastal systems and present the project's research agenda; 2) Discuss and explore research connections to coastal resource managers; and 3) Develop a framework for stakeholder involvement and planning future Advisory Board meetings.

The progress made since the beginning of this project (October 2015) is highlighted below by detailing the contributions of each team member. At this stage of the project, the economic valuation components (Tracks I and II) are discussed as these are the necessary precursors (i.e. inputs) to the development dynamic models of natural infrastructure investment (Track III). Environmental economist and lead PI Steven Dundas conducted weekly meetings with the other environmental economists (David Lewis, David Kling) to refine the methodological tracks and develop the overall economics research strategy for the project, including the team's focus on four pathways. Dundas, Lewis, and Kling organized multiple larger meetings of all PIs to unify the experts involved given the transdisciplinary nature of the research agenda. Dundas, Lewis, and Kling have identified an undergraduate intern (Eric Didion) to assist in spatial data construction during summer 2016 and graduate students (Tu Nguyen, William Beasley, and Cassie Finer) to support all research pathways for academic year 2016-2017. The undergraduate intern will be funded through a USDA grant aimed at bringing under-represented minorities into active research programs.

Dundas has taken the coordination role for the Coastal Protection and Coastal Land Use Pathways and has led housing market and spatial data collection efforts on both fronts. Dundas is currently conducting a preliminary hedonic analysis of the effects of coastal protection features on shoreline property values with results anticipated by Fall 2016. This Track I modeling effort will provide baseline values of willingness to pay for coastal protection from both grey (i.e. rip-rap revetments) and natural (i.e. dunes) infrastructure while also differentiating values for "chronic" (i.e. sea-level rise) and "acute" (i.e. tsunami inundation) coastal risks. Dundas has also conducted preliminary research on urban natural infrastructure to support the Coastal Land Use pathway and has contributed to the development of the survey instrument in the Dune Habitat pathway.

Lewis has agreed to be the coordinating economist for the Estuary Pathway of research and has developed a preliminary draft of a choice experiment survey on estuarine ecosystem services (Track II) to be used in the broader project. The survey will form the foundation for placing non-market values on multiple estuarine ecosystem services that have public goods characteristics. Going forward, the draft survey will be vetted by multiple natural and social scientists in summer 2016, be put through focus groups in fall 2016, and placed into the field in winter/spring of 2017 to a random sample of Pacific Northwest residents. Lewis has also worked with lead PI Dundas to collect all housing transactions data to be used in the multiple pathways, and has jointly

planned the full spatial database construction with Dundas and Co-I Parrish. Lewis has also collaborated with Dundas on the Coastal Protection pathway and will work with other team members to develop hedonic analyses of the effects of alternative shoreline natural and grey infrastructure on estuarine property markets.

Kling is serving as the economist coordinator for the project's Dune Habitat pathway. Working with Dundas, Sally Hacker, and Peter Ruggiero, Kling conducted preliminary research for a nonmarket valuation survey focusing on natural infrastructure and ecosystem services in dune and sandy beach habitat on the Pacific Northwest coast (Track II). The survey instrument will be focus group-tested in fall 2016, and then deployed in winter/spring of 2017 to a random sample of Pacific Northwest residents. In 2016-2017 project period, Kling will contribute to hedonic analysis (Track I) and preliminary dynamic model development (Track III) in support of multiple project pathways. Beginning in July 2016, Kling will also serve as the primary advisor of a graduate student (Tu Nguyen), who will provide research assistance in support of the dune habitat pathway.

Coastal Geomorphologist Peter Ruggiero worked with the rest of the team to develop and refine the Dune Habitat pathway. Ruggiero has extensive experience in assessing the impacts of storms to beaches and dunes and is now working on two distinct approaches focused on modeling beach and dune recovery processes. Ruggiero is providing these modeling approaches and other basic coastal geomorphologic information relevant to incorporating the ecosystem services provided by coastal beaches and dune into climate change adaption planning. This knowledge is informing the choice experiment surveys that are currently being developed. Ruggiero has recruited a graduate student (Paige Hovenga) to help provide research and logistical support for the Dune Habitat pathway.

Coastal ecologist Sally Hacker has worked with the research team to provide information on the ecosystem function and services portion of the overall project. Up to this point in the project, she is focusing on the ecological aspects of the Estuary Pathway and Dune Habitat Pathway. With extensive experience working in Pacific Northwest estuaries and coastal dunes, Hacker is providing basic ecological information on the important services associated with these ecosystems and helping to develop drafts of the choice experiment surveys. She will continue this work over the summer, with the goal of vetting the surveys in late summer 2016 and testing them on focus groups in fall 2016. Hacker has also recruited a graduate student (Caitlin White) to help provide research and logistical support for the survey development over the summer. Coastal engineer Daniel Cox has worked with Dundas and Kling on the Coastal Land Use Pathway. This pathway focuses on land use and tsunami evacuation routes in coastal communities, with a focus on greenbelts and open space. Cox, Dundas and Kling have identified two potential study areas on the Oregon coast: south Newport area and the city of Seaside. The south Newport area was chosen because of the prominence of South Beach State Park and the possibility of understanding the role of a coastal green belt to increase life safety. The city of Seaside was chosen because of the possibility of making future land use changes to increase life safety for tsunami evacuation and to enhance economic activity through tourism. The team has reviewed an existing Agent-Based Tsunami evacuation model for both south Newport and Seaside and have deemed it useful to meet the objectives of this project. The team has identified an undergraduate research student (Amy Wyman) who will conduct the analysis for south

Newport in summer 2016. The undergraduate student will be funded through an existing NSF project. The research team will meet monthly over the summer to review the work.

Geomatics Engineer Chris Parrish and his students are currently working to assemble coastal geospatial data, including topographic and bathymetric LIDAR, multispectral imagery, tidally-referenced shoreline, existing habitat maps, and land cover maps. A particular emphasis is on obtaining multi-temporal data (e.g., coastal LIDAR data spanning nearly 18 years), including data collected before and after shoreline stabilization measures were enacted along various portions of the Oregon coast. These data will be intersected with parcel data obtained by the project team to assist in evaluating relationships between coastal geomorphology (including changes resulting from shoreline stabilization measures) and property value in support of multiple project pathways. Parrish is currently supervising a MS student (Richard Slocum) and co-mentoring an undergraduate intern (Didion) involved in generating the project database and performing geospatial data analysis.

MEETING PRESENTATIONS:

Dundas, S.J. The Value of Coastal Protection: Evidence from the Oregon Coast. Research design and preliminary results presented in a session on *Climate Change and the Economics of Shoreline Management and Adaptation* at the *5th National Forum on Socioeconomic Research in Coastal Systems*, New Orleans, LA March 21st, 2016.

APPENDIX B: OTHER AGENCY AWARDS

PI Name	Project Title	Lead NOAA Collaborator	Awarding Agency	Funding Amount
M. Banks	Ocean Survival of Salmonids	Kurt Fresh NWFSC	Dept of Energy/ BPA	$267,647