

**Final Progress Report**  
**to**  
**National Oceanic & Atmospheric Administration**

NOAA Award# NA110AR4320091A

No-Cost Extension

Reporting period: 7/1/17 – 9/30/18

Oregon State University

**Cooperative Institute for Marine Resources Studies**



This final progress report covers the projects that were still active during the second no-cost extension reporting period. They are identified by Amendment Number and Title. All other projects are considered complete with progress reported on July 30, 2016 as final reports.

**TASK 2**  
**(PROJECTS SUPPORT NOAA STRATEGIC PLAN GOAL OF HEALTHY OCEANS AND CLIMATE ADAPTATION AND MITIGATION)**

**Theme: Marine Ecosystem and Habitat**

**Amendment 30: The Effects of the PDO, ENSO, and Climate Change on the Northern California Current Ecosystem**

OSU RESEARCH STAFF: *Michael Malick*, Research Associate, Post-doc; *Xiuning Du*, Research Associate; *Jennifer Fisher*, Research Assistant  
NOAA TECHNICAL LEAD: *Mary Hunsicker*, Fish Ecology, NWFSC

**PROJECT BACKGROUND:** The California Current Large Marine Ecosystem (CCLME) includes a diverse suite of living marine resources (LMRs) with over 30 separate fisheries each netting over \$1M annually and totaling nearly \$500M annually. Global and regional climate-ocean models suggest anthropogenic climate change will bring profound changes to the CCLME. Some of the physical climate related changes that are of concern include: 1) increased variability in climate forcing (basin-scale winds and wind-driven transport) associated with the Pacific Decadal Oscillation (PDO), the North Pacific Gyre Oscillation (NPGO) and the El Niño-Southern Oscillation (ENSO), 2) and the potential for increased stratification in the water column due to global ocean warming that could lead to increased nutrient content of upwelled water. Future climate change will alter the production, structure, and function of the ecosystems in a manner not observed in the past, and resource scientists must develop new tools to address both short term and long term management needs. For example, climate models will need to be down-scaled to assist in regional and local decision-making that occurs at the scale of the NCCLME. The suite of potential climate change impacts poses a challenging suite of additional drivers that need to be incorporated into a diverse suite of NOAA Fisheries related management actions including Integrated Ecosystem Assessments (IEA), management of species under the Endangered Species Act, and stock assessments. For example, as part of the IEA for the CCLME, NOAA will need to develop the means to forecast ecosystem changes and changes in fish productivity and incorporate this understanding of the climate system into the IEA management framework. Physical climate variability impacts the structure of the pelagic ecosystem and the production and distribution of coastal fish. This variability influences the availability of resources to commercial and recreational fisheries and affects the local economies dependent on these industries. There are three distinct time scales of climate phenomena which have influenced coastal fisheries during the past several decades: coastal upwelling events (weekly to interannual variability), El Niño events (ENSO; interannual variability), and the Pacific Decadal Oscillation (PDO; interannual to multidecadal variability). More recently, another mode of Pacific variability has been identified (the North Pacific Gyre Oscillation, Di Lorenzo *et al.*, 2008) which also operates at decadal time scales. Each of these phenomena is linked to large-scale atmospheric pressure patterns which are likely to change in the coming

decades in response to long-term global warming. However, the relative importance of these processes and the mechanisms through which they affect fisheries remain unclear.

The spatial distribution of marine fish populations provides critical information about the availability of a population to monitoring, fisheries, and management actions. Yet, large uncertainties about the drivers of marine fish distributions combined with the lack of advanced warnings about seasonal shifts in spatial distributions limit decision-makers ability to respond to rapidly changing ecosystem conditions. This is particularly true for migratory marine species, whose seasonal distribution can vary greatly across space and time. In this project, the goal is to provide seasonal forecasts of Pacific hake distribution within the California Current Ecosystem to improve monitoring survey design and management planning. Specifically, this project pursues two main objectives: (1) test mechanistic hypotheses regarding the drivers of hake spatial distribution using statistical models and recently available *in situ* observations of ocean conditions and hake distribution, and (2) develop 1–6 month lead-time forecasts of Pacific hake distribution using models developed under objective one and seasonal projections of ocean conditions.

**PROJECT PROGRESS:** With the hire of Dr. Malick as Research Associate considerable progress has been made toward achieving development of seasonal forecasts of Pacific hake distribution. In particular, advancements were made in testing mechanistic hypotheses regarding the drivers of hake distribution, which is a necessary first step in constructing quantitative forecasting models. Project progress has occurred in four main areas: (1) processing and analysis of Pacific hake data collected during the NOAA summer hake acoustic survey, (2) processing and analysis of *in situ* oceanographic data, (3) preliminary fitting of statistical distribution models using the processed hake and oceanographic data, and (4) extracting and processing outputs from the J-SCOPE ocean forecasting model.

**1. Hake data processing and analysis.** Spatially referenced Pacific hake biomass estimates derived from acoustic backscatter data were available for 11 survey years ranging from 1995 to 2015 (Fig. 1). Processing of the hake biomass data required, (1) parsing the raw data, (2) re-formatting the data in a form suitable for analysis, (3) locating and matching date and times to each biomass observation from other hake survey data sources, (4) assigning bottom depth values to each biomass estimate using data from the ETOPO1 global relief model, (5) quality control of the data to make sure there are no obvious errors, and (6) writing the processed data to a platform agnostic format for use in later analyses. In addition to the hake biomass data sets, Dr. Malick also processed hake vertical distribution data, which provided data on the location of Pacific hake in the water column. These vertical distribution data were available for eight of the survey years.

Following hake biomass and vertical data processing, two analyses were performed to help inform a choice of methods in subsequent analyses. First was a spatial covariation analysis of the hake biomass data at the survey transect level to help determine the appropriate spatial scale for aggregating the biomass estimates. This analysis indicated that hake biomass estimates tended to be spatially correlated on the scale of 4-7 km within a survey transect. This spatial covariation analysis was subsequently used to inform our methods of binning and matching the biomass estimates to oceanographic observations. Second, data analysis of hake vertical distribution helped inform the construction of oceanographic covariates that accurately capture the ocean

habitat used by hake. This vertical analysis indicated that the majority (90%) of acoustic hake observations occurred at depths between 100 and 400 m.

**2. Ocean data processing and analysis.** Oceanographic data collected from eight sensors deployed during the hake acoustic surveys were processed from raw data formats to formats suitable for use in statistical distribution models. The eight oceanographic sensors included three sensors attached to the trawl head ropes, three sensors deployed from the ship's deck, and two shipboard sensors. Oceanographic data processing was focused on creating two spatially explicit ocean datasets: (1) water column temperature and, (2) water column current velocity. Processing of the temperature data is largely complete and the current velocity data processing is ongoing. Using the processed temperature data, a temperature index was further developed to capture ocean conditions that represent Pacific hake habitat. Because there was generally less temperature data available at deeper depths, a temperature index was created that represents ocean temperature at 100 m depth across our spatial domain (Fig. 2).

Although oceanographic data were available for all hake survey years, the spatial coverage and sample sizes for temperature and current velocity data varied considerably across years (Fig. 2). To investigate options for “filling in” missing spatial coverage in the oceanographic variables in some years, investigators on the project located, acquired, and processed temperature data from three external sources (i.e., from cruises or surveys other than the hake survey) including World Ocean Database, ERRDAP, and CalCOFI. Data from these three sources were analyzed for 1998 and 2015 to determine the extent of spatial and temporal overlap with the hake biomass estimates. This analysis indicated that for 1998, adding oceanographic data from external sources could result in considerable gains in oceanographic data sample sizes and spatial coverage. In contrast, for 2015, little to no gains in sample size were observed, likely due to more extensive coverage of co-located oceanographic data from the hake survey in later survey years.

**3. Spatial distribution models.** Testing alternative hypotheses regarding the drivers of hake distribution via spatial distribution models first required that investigators “match” hake biomass estimates with ocean data in space and time. For the temperature at 100 m depth index, they matched temperature index points to hake biomass estimates that occurred within 2 km (half the minimum distance of spatial covariation in hake biomass data at the transect level) and 3 days of each other. These spatially and temporally matched biomass–ocean data were then used to explore preliminary spatial distribution models, in particular, the strength and relative importance of temperature at 100 m depth and bottom depth on hake distribution using generalized additive models (GAM). These initial models included hake presence-absence as the response variable and co-located temperature and bottom depth as covariates.

**4. J-SCOPE ocean forecasts.** J-SCOPE forecasts are derived from a Regional Ocean Modeling System (ROMS) model that has been specifically developed for forecasting ocean conditions. These outputs represent forecasts of physical ocean conditions in the Northern California Current (e.g., water column temperature). With assistance from investigators at the University of Washington to procure relevant outputs from the J-SCOPE ocean forecasting model, project investigators have acquired and processed monthly J-SCOPE forecast outputs of temperature for four years (2009, 2013, 2015, 2017).

CONFERENCES:

An overview of the project was presented to the Pacific hake Scientific Review Group in early March 2018 as part of the annual Pacific hake international management meeting. An abstract was submitted and accepted to present preliminary project results at the PICES 4th Annual International Symposium on the Effects of Climate Change on the World's Oceans in June 2018

Malick, Michael et al. 2018. Seasonal forecasting of Pacific hake distribution in the California Current Ecosystem. 4<sup>th</sup> Annual PICES International Symposium, Washington, D.C. June 4-8, 2018.

## Figures

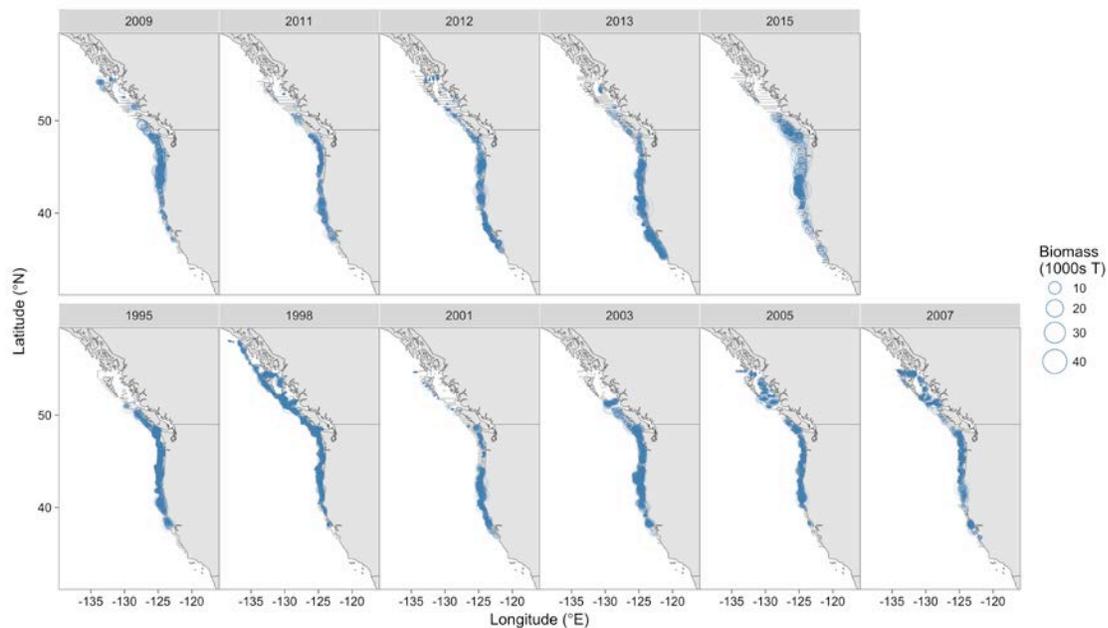


Figure 1. Spatial distribution of Pacific hake biomass estimates derived from acoustic backscatter. The area of the bubbles is proportional to the estimated biomass at a specific location. Dark grey lines indicate hake survey transects.

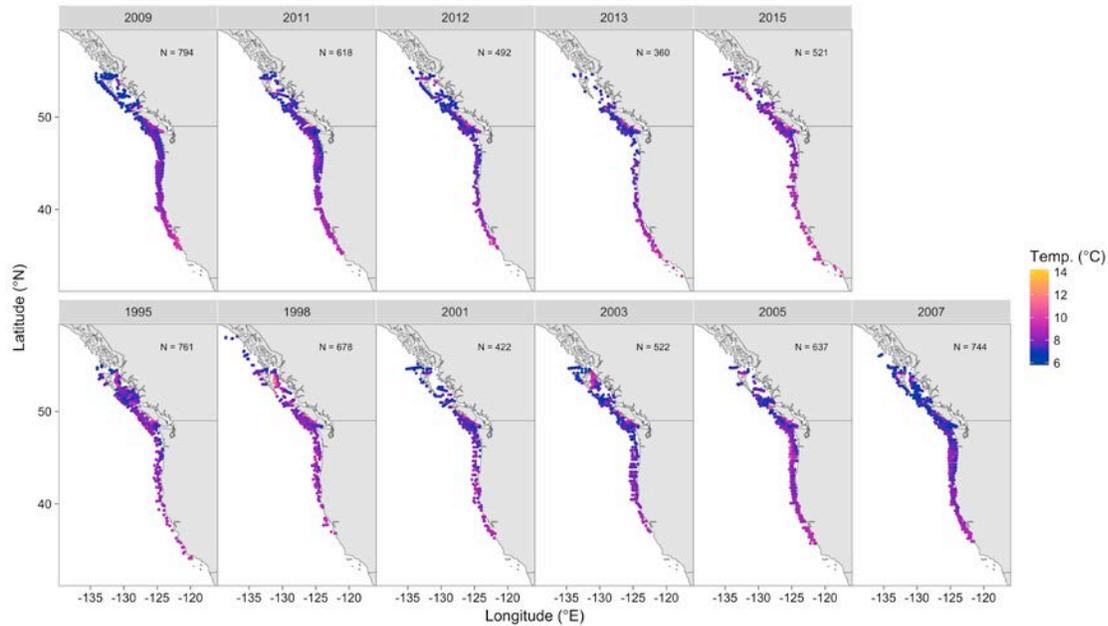


Figure 2. Spatial distribution of ocean temperature at 100 m depth. Numbers in top right corner of each panel indicate the number of temperature observations for that year.

#### **Amendment 48: Ocean Indicator Surveys**

OSU RESEARCH STAFF: *Jennifer Fisher*, Faculty Research Assistant, CIMRS

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

**PROJECT BACKGROUND:** The northern California Current (NCC) is an ecologically important region supporting numerous fish, bird and marine mammal populations. Based on developing 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. The 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., hake, sardine) and top predators such as sea-birds. Data collected was primarily over the continental shelf, with a few transects extending out to the edge of the Exclusive Economic Zone (EEZ; 200 nautical miles). The sampling design consisted of stations spaced every 5 nautical miles over the shelf and every 10 – 25 nautical miles further offshore. Data on hydrography (temperature, salinity, dissolved oxygen, fluorescence, transmissivity) were collected using a conductivity-temperature-depth sensor (CTD) equipped with auxiliary sensors. Nutrient and chlorophyll data were sampled from surface and depth using a bucket and Niskin bottle. Samples for zooplankton and krill were collected using a vertical net (0.5 m diameter, 200  $\mu$ m mesh) and obliquely-towed bongo net (0.6 m diameter, 330  $\mu$ m mesh).

Observers for seabirds and marine mammals were invited (and encouraged) to participate in the cruise, collecting visual data between stations along each transect.

**PROJECT PROGRESS:** Eleven research cruises were conducted aboard the R/V Elakha, and two aboard the R/V Pacific Storm. 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. 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 are undergoing analysis with environmental variables for a peer reviewed manuscript. Presently, all of the hydrographic, chlorophyll and nutrient samples have been processed and uploaded into a database, and the zooplankton have been enumerated for all dates from the vertical net for one shelf station along the NH line and zooplankton sample processing for the slope station and euphausiid abundance is ongoing.

### Outreach

HMSC Marine Science Day, April 2018. A booth was occupied with live plankton stations and scientists were available to talk about sampling along the Newport Hydrographic Line and to answer questions about ocean conditions and zooplankton.

Two research cruises in April and June 2018 aboard the R/V Pacific Storm were with local high school students. These cruises allow an opportunity for high school students to interact with scientists, to learn what sampling from a boat it all about, and they provide an opportunity to participate in science at sea.

### Data products

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>

The data have contributed to the Newportal Blog:

[https://www.nwfsc.noaa.gov/news/blogs/display\\_blogentry.cfm?blogid=1](https://www.nwfsc.noaa.gov/news/blogs/display_blogentry.cfm?blogid=1).

Biological and physical data were uploaded to the California Current IEA ERRDAPP server:

<<https://www.integratedecosystemassessment.noaa.gov/regions/california-current-region/indicators/climate-and-ocean-drivers.html>>

### PRESENTATIONS/WORKSHOPS:

Invited plenary talk at the 13<sup>th</sup> International Conference on Copepoda, San Pedro, CA, July, 2017. Jennifer Fisher, Bill Peterson. *Relative influence of the Pacific Decadal Oscillation and coastal upwelling on copepod communities in the Oregon upwelling zone.*

Presentation at the Fish Ecology Program Meeting Newport OR January, 2018. Jennifer Fisher, Kym Jacobson, Bill Peterson, Cheryl Morgan, Samantha Zeman, Xiuning Du. *The Newport Hydrographic Line and Beyond*.

Invited lecture to Portland State University Marine Conservation Science & Management class, February 2018. Jennifer Fisher. *Environmental forcing and how that affects ecosystems*.

Presentation at the 4<sup>th</sup> International Symposium on the Effects of Climate Change on the World's Oceans, Washington DC, June 2018. Jennifer Fisher, Bill Peterson, Louise Copeman, Jessica Miller, Jay Peterson (Jay Peterson presented); *The 'skinny' about how the Blob changed the hydrography, zooplankton, lipid, and fatty acid structure off Oregon*.

Presentation at the 4<sup>th</sup> International Symposium on the Effects of Climate Change on the World's Oceans, Washington DC, June 2018. Kym Jacobson, Jennifer Fisher, Bill Peterson (Jacobson presented). *Increased variability in the copepod community structure, diversity, and biomass in the northeast Pacific (Newport, Oregon, USA) over the last 21 years*.

Invited talk at the Ocean Carbon and Biogeochemistry workshop, Woods Hole, MA, June 27, 2018. Jennifer Fisher, Bill Peterson, Kym Jacobson, Xiuning Du, Sam Zeman. *Two decades of monthly biophysical sampling of the coastal ocean off Newport, Oregon and how this informs fisheries*.

#### PUBLICATIONS:

Auth T.D., E.A. Daly, R.D. Brodeur, J.L. Fisher. 2018. Phenological and distributional shifts in ichthyoplankton associated with recent warming in the northeast Pacific Ocean. *Global Change Biology*. **24(1)**:259-72.

Chao, Y., J.D. Farrara, E. Bjorkstedt, F. Chai, F. Chavez, D. Rudnick, W. Enright, J.L. Fisher, W.T. Peterson, G.F. Welch, C.O. Davis, R.C. Dugdale, F.P. Wilkerson, H. Zhang, Y. Zhang, E. Ateljevich. 2017. The origins of the anomalous warming in the California coastal ocean and San Francisco Bay during 2014-2016 *J. Geophys. Res. Oceans* **122(9)**: 7537-7557.

Peterson, W.T., J.L. Fisher, P. Ted Strub, X. Du, C. Risien, J. Peterson, and C. Tracy Shaw. 2017. The pelagic ecosystem in the Northern California Current off Oregon during the 2014-2016 warm anomalies within the context of the past 20 years, *J. Geophys. Res. Oceans*, **122**, doi:10.1002/2017JC012952.

Wells B.K., I.D. Schroeder, S.J. Bograd, E.L. Hazen, M.G. Jacox, A. Leising, N. Mantua, J.A. Santora, J. Fisher, W.T. Peterson, E. Bjorkstedt. State of the California Current 2016-17: Still anything but normal in the north. (2017) *Calif. Coop. Oceanic Fish. Invest. Rep.*, **1;58**: 1-55.

Harvey, C., et al. 2017. Ecosystem Status Report of the California Current for 2017: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment

Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-139. <https://doi.org/10.7289/V5/TM-NWFSC-139ii>

## **Theme: Protection & Restoration of Marine Resources**

### **Amendment 14: Developing a Pilot Marine Debris Monitoring Program in Oregon**

OSU RESEARCH STAFF: *Jamie Doyle*, Extension Marine Community Development Educator, Oregon Sea Grant

NOAA TECHNICAL LEAD: *Sherry Lippiat*, Marine Debris Program, NOS

**PROJECT BACKGROUND:** In partnership with Surfrider Foundation, SOLV, and Oregon Shores Conservation Coalition CoastWatch Program, Oregon Sea Grant, the Marine Debris monitoring grants developed and implemented a pilot marine debris monitoring program in Oregon using the NOAA protocol. CoastWatch was the designated partner organization to implement these pilot projects. The majority of the project was completed between 2013-2015, and a small portion of the budget was retained to address some of the issues with recruiting volunteers, collecting and reporting monitoring.

Since this project began, several things have happened in Oregon. The Marine Debris Action Plan was finalized. The Marine Debris Research Priorities were identified. The citizen science efforts have increased, especially around Oregon's Marine Reserves. The last of the grant funding was used to lay the groundwork for a 2019 monitoring summit by supporting CoastWatch in early 2018 to continue the current monitoring efforts and to begin planning for a monitoring summit.

The 2018 updates from CoastWatch include:

- As the lead, CoastWatch has been conducting marine debris monitoring according to the NOAA protocol for nearly six years total, including for the past year.
- CoastWatch has directed marine debris monitoring surveys, using the NOAA protocol, at 10 sites during the 2018. Of these, five at present are consistent, five have had less than complete (monthly) results and they are working on improving capacity and number of people up those monitoring teams. Their goal is always to have a team, not just an individual or couple, at each site.
- CoastWatch during 2018 has conducted at least 20 training sessions devoted all or in part to marine debris monitoring.
- CoastWatch was designated as the lead group for monitoring activities as part of the Oregon Marine Debris Action Program, a consortium effort by state and federal agencies and NGOs, coordinated by NOAA, adopted for the state last year.

- CoastWatch is partnering with Oregon Sea Grant (responsible for reviewing marine debris practices in Oregon and advising on best practices under the Oregon Marine Debris Action Program) on organizing a "monitoring summit" for organizations and agencies working on marine debris monitoring in Oregon.
- CoastWatch and Sea Grant have been planning in the summer of 2018, and will continue to do so beyond the scope of this grant.

Given the Marine Debris Action Plan, and the ongoing interest of improving the marine debris monitoring data collected by volunteers, and increased efforts in citizen science, the efforts to improve marine debris monitoring will continue. This grant was a catalyst not only for Oregon to start contributing data using the NOAA protocol, but for understanding how to best structure, train, and provide ongoing support to community teams. That understanding is as valuable as the actual marine debris data collected, because with it, monitoring techniques and long-term data collection can improve, leading to long-term data sets and better understanding of the marine debris found on Oregon's beaches.

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

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 and worked through the 2016-17 academic year:
  - Deanna Caracciolo, Marine Resources Management student, began interviewing Spring 2016 quarter--completed 23 interviews.
  - Courtney Flathers, Masters of Public Policy student, began interviewing Spring 2016 quarter-- completed 16 interviews.

Both students completed their research projects and successfully defended in June 2017; papers available via OSU Scholars Archive.

- One additional student joined the project Fall Term 2017:
  - Brianna Haugen, MRM student, is using mostly existing interviews and her work is focusing on the intersection of perception of graying and climate change.

#### MEETING PRESENTATIONS:

Caracciolo and Flathers both presented oral presentations at the 2017 Annual Meeting of the Society for Applied Anthropology, Santa Fe, NM (Spring 2017).

Straw presented oral presentation at the 2018 Annual Meeting of the Society for Applied Anthropology, Philadelphia, PA (Spring 2018).

#### PUBLICATIONS:

Cramer et al. 2018. Graying of the fleet: Perceived impacts on coastal resilience and local policy. *Marine Policy*: 96:27-35.

#### **Amendment 76: A Pilot Project toward Measuring Physiological Effects of Noise Exposure on Pacific Gray Whales (*Eschrichtius robustus*)**

OSU RESEARCH STAFF: *Joe Haxel*, Asst. Professor, Sr. Research, CEOAS; *Leigh Torres*, Asst. Prof., Sr. Res., Marine Mammal Institute; *Sharon Nieu Kirk*, Sr. Research Assistant, CIMRS

NOAA TECHNICAL LEAD: *Robert Dziak*, OERD/PMEL

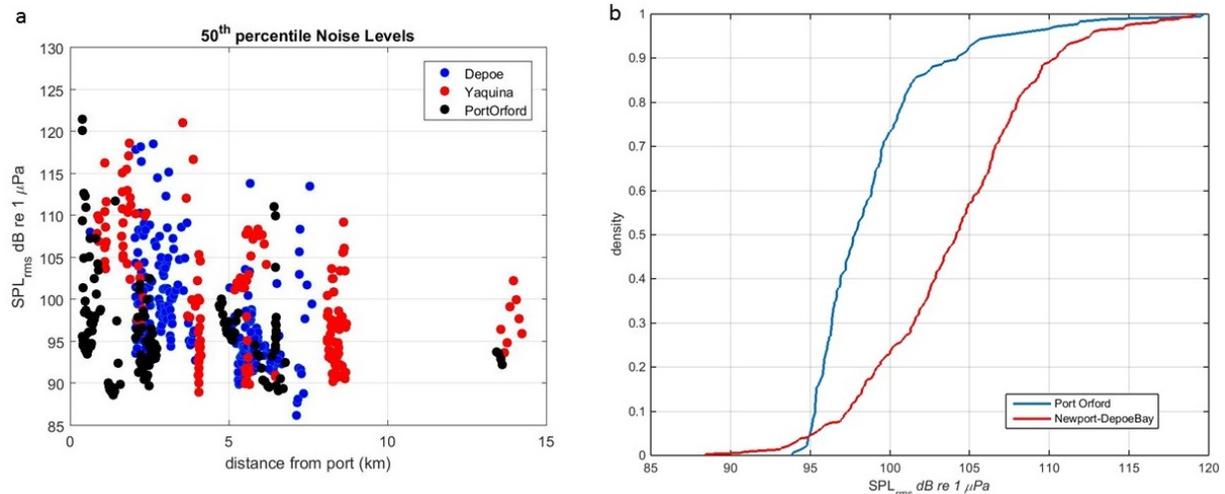
PROJECT BACKGROUND: Long-term, deep ocean acoustic measurements from fixed hydrophone stations have documented a steady increase in low frequency ambient noise levels (10-12 dB) in the Northeast Pacific since the 1960s, primarily associated with increased commercial shipping traffic throughout the basin. 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.

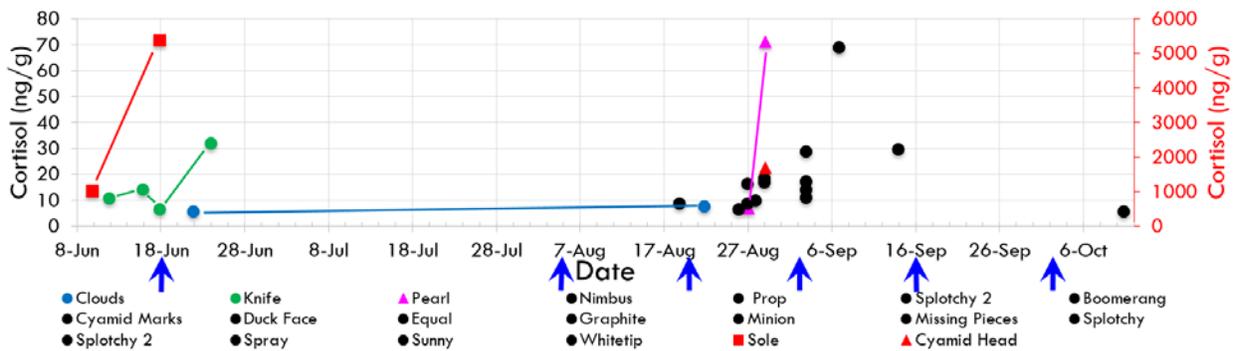
Using Pacific Coast Feeding Aggregation (PCFA) gray whales along the Oregon coast as our study species, CIMRS researchers developed methods and collected data aimed at addressing how chronic, elevated ambient noise levels may affect the physiology, behavior and ecology of individuals, and how these impacts may translate into biologically significant events with long-term consequences for individuals or populations (e.g., the Population Consequences of Acoustic Disturbance (PCAD) model).

**PROJECT PROGRESS:** During multiple field seasons from May – October (2016-2018), the team collected data from two different gray whale foraging locations along the Oregon coast. These sites vary in their environmental characteristics and anthropogenic activity: the naturally dominated soundscape of the Port Orford region in southern Oregon, and the high vessel traffic region near Newport and Depoe Bay along the central coast. The research field and analytical methods aimed to monitor coastal ambient ocean noise (hydrophones) and assess stress levels in gray whales (fecal sample collection and analysis) while controlling for body condition (UAS photogrammetry), reproductive state (fecal hormone analysis), demographic unit (long-term sighting histories), and prey availability (zooplankton collection and GoPro drops).

**Analysis and Results:** CIMRS researchers accomplished multiple methodological and scientific advances. (1) Initial characterization of the Oregon coastal soundscape; noise level variability increases with proximity to ports in both the Port Orford and Newport regions; Newport regional noise levels are generally elevated in comparison to Port Orford (Fig. 1). (2) Developed UAS whale photogrammetry methods and documented individual and population level changes in body condition throughout feedings season; through photo-id matching to long-term sighting histories, determined body condition variation by demographic unit. (3) Developed methods of gray whale fecal hormone analysis and described stress and reproductive hormone variation. (4) Collected zooplankton samples and conducted GoPro camera drops and determined spatial and temporal variation in gray whale prey availability along Oregon coast. Figure 2 presents the preliminary analysis of linking the data streams collected during the project.



**Figure 1. a)** Median Sound Pressure Levels (SPL<sub>rms</sub>) from drifting hydrophone records (color coded by Port) plotted against the distance to nearby ports showing the increasing range of noise levels with proximity. **b)** The empirical cumulative distribution of median noise levels from acoustic recordings where typical noise levels (50<sup>th</sup> percentile) are consistently higher in the Newport region.



**Figure 2.** Temporal patterns of cortisol (stress) levels in individual gray whales across field season. Halibut fishing openers that cause punctuated noise events are demarcated by blue arrows. Symbols in red have very high cortisol level and correspond to the right y-axis.

**PRESENTATIONS:**

- Lemos, L. and L. Torres. 2017. Combining traditional and novel techniques to link body condition and hormone variability in gray whales. *Society for Marine Mammalogy Conference*, Halifax, Canada, October 2017
- Torres, L., S. Nieu Kirk, L. Lemos. 2017. Drone up! Quantifying whale behavior and body condition from a new perspective. *Society for Marine Mammalogy Conference*, Halifax, Canada, October 2017
- Haxel, J., L. Torres, S. Nieu Kirk, L. Lemos, A. Lau. 2018. Snapping shrimp in Oregon? A potential acoustic cue for marine predators. *Ocean Sciences Conference*, Portland, Oregon, February 2018

PUBLICATIONS:

Burnett, J. D., L. Lemos, D. R. Barlow, M. G. Wing, T. E. Chandler and L. G. Torres. In press. Estimating morphometric attributes of baleen whales with photogrammetry from small UAS: A case study with blue and gray whales. *Marine Mammal Science*.

## Theme: Seafloor Processes

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

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:** In the beginning, there was significant delay in funding of this project, which was to start 1 February 2016. Initial progress has been slow as funding to OSU did not arrive until May 2016 and the rock samples didn't arrive until 17 May 2016 in the OSU Marine and Geology Repository (OSU-MGR).

Once the rocks arrived at the OSU-MGR, Dr. Anthony Koppers with assistance from his research assistant Dr. Kevin Konrad worked to verify that all samples were received in accordance with the documentation and database. Samples were boxed, labeled with QR codes and IGSN numbers, photographed, and bagged. Samples were then cut, putting 1/3 away as ARCHIVE and the rest as WORKING halves. Samples are stored in plastic boxes for long-term curation and archiving.

Thin section billets were cut from the working halves and sent out for the making of double-polished thin sections. Upon their return, the thin sections were photographed in plain polarized light and cross polarized light, and then described for their petrology (e.g., mineral contents, alteration, volcanic features, and vesicles). All samples have been curated, packaged and are now made available for 2015.

YEAR	EXPEDITION	SAMPLES	ONLINE ADDRESS
2015	EX1504L2	31	<a href="http://osu-mgr.org/noaa-ex1504I2/">http://osu-mgr.org/noaa-ex1504I2/</a>
2015	EX1504L3	9	<a href="http://osu-mgr.org/noaa-ex1504I3/">http://osu-mgr.org/noaa-ex1504I3/</a>
2015	EX1504L4	28	<a href="http://osu-mgr.org/noaa-ex1504I4/">http://osu-mgr.org/noaa-ex1504I4/</a>

All data, metadata and imagery were entered into the OSU-MGR database and presented online. Below is a list of representative URLs as examples of content made available.

<a href="http://osu-mgr.org/">http://osu-mgr.org/</a>	Home page for the OSU-MGR
<a href="http://osu-mgr.org/noaa-ex/">http://osu-mgr.org/noaa-ex/</a>	Home page for all of the NOAA Okeanos Explorer ROV rock collection (map interface)
<a href="http://osu-mgr.org/noaa-ex1603/">http://osu-mgr.org/noaa-ex1603/</a>	Expedition page for the collection of the EX1603 expedition to the Papahānaumokuākea Marine National Monument Hohonu Moana: Exploring the Deep Waters Off Hawai‘i (map interface)
<a href="http://osu-mgr.org/noaa-ex1605/">http://osu-mgr.org/noaa-ex1605/</a>	Expedition page for the collection of the EX1605 expedition to the Commonwealth of the Northern Mariana Islands and the Marianas Trench Marine National Monument (map interface)
<a href="http://osu-mgr.org/noaa-ex1606/">http://osu-mgr.org/noaa-ex1606/</a>	Expedition page for the collection of the EX1606 expedition to the Pacific Remote Islands Marine National Monument (map interface)
<a href="http://osu-mgr.org/noaa-ex1603-table/">http://osu-mgr.org/noaa-ex1603-table/</a>	Expedition page for the collection of the EX1603 expedition to the Papahānaumokuākea Marine National Monument Hohonu Moana: Exploring the Deep Waters Off Hawai‘i (table interface)
<a href="http://osu-mgr.org/request-samples/">http://osu-mgr.org/request-samples/</a>	Home page with instructions for making sample requests to the OSU-MGR

### TASK 3

#### Theme: Seafloor Processes

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

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. The focus is on natural infrastructure, which is defined broadly as a physical stock (i.e., durable physical quantities) that constitutes restoration of, or extension to natural ecosystem components. The aim is 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 the 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, the team measured 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. The team then develops optimal investment plans for each infrastructure type. The 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 encountered in the course of this research were: 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). The research addressed these two challenges by joining state-of-the-art non-market valuation methods with empirical ecological and engineering-economic models of natural infrastructure investment. It is anticipated that the team’s resulting models will yield generalizable methodological insights that will extend the frontier of ecosystem service science.

Economic research is divided into three methodological tracks. Track I 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 researchers develop and implement two choice experiment surveys for the purpose of estimating WTP for ecosystem service benefits that accrue to households. In Track III the team develops 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.

Four distinct systems on the Oregon coast are investigated that serve as applied pathways for the 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:**

The progress made since the beginning of this reporting period (October 2016) is highlighted below by detailing the contributions of each team member.

Environmental economist Steven Dundas (Assistant Professor, Department of Applied Economics and Coastal Oregon Marine Experiment Station) is the lead PI of this grant responsible for administration and management duties. Dundas has organized team meetings, planned the advisory board meeting, developed a project website, participated in outreach related to grant activities (e.g. 5<sup>th</sup> Oregon Coast Economic Summit and the Oregon Ocean Science Trust Summit) and contributed to a majority of the research meetings/discussions related to this project. Dundas is also the coordinating economist for both the Coastal Protection and Coastal Land Use Pathways where he has led housing market and spatial data collection efforts. Dundas and co-PI Lewis are currently finishing the first of multiple housing market analyses of the effects of coastal protection features on shoreline property values. These Track I modeling efforts are providing 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 and graduate student Jason Beasley have developed an empirical model of coastal landowners’ investment in grey infrastructure and preliminary results are currently being evaluated. Results from the efforts described above will be integrated into models of shoreline change from co-PI Ruggiero and his graduate students to test different coastal management policy options and optimize ecosystem service provision (Track III).

Dundas, co-PIs Kling and Cox, and Beasley have continued scoping the potential for urban natural infrastructure as a vertical evacuation option for tsunami inundation in Seaside, Oregon. Preliminary work at integrating evacuation, transportation, and economic models is currently ongoing with results expected in 2018. Dundas has contributed to the development of survey instruments and coordination of focus group testing in both Oregon Coast Coho salmon survey (Estuary Pathway) and the coastal dune and beach habitat survey (Dune Landscape pathway). Dundas is also beginning development of a third survey instrument designed to elicit preferences for different types of coastline management from both coastal and non-coastal households (Track II).

Environmental economist David Lewis (Professor, Department of Applied Economics) is the coordinating economist for the Estuary Pathway of research and has collaborated with other team members and NOAA economist and Board member Lew to develop a choice experiment survey on restoring Oregon Coast Coho salmon through estuarine conservation (Track II). The survey has been placed through multiple focus groups and has been widely vetted by economists, and environmental scientists and managers familiar with Oregon Coast coho. The survey was sent to 5,000 randomly selected households in the Pacific Northwest between September and November of 2017. The survey results form the foundation for placing non-market values on estuary conservation actions that generate public goods, and we received 941 usable survey responses. Lewis is leading the data analysis of the Coho survey and multiple co-PIs and Board member Lew have collaborated on a first draft manuscript that analyzes the survey results (Lewis et al. 2018). Results from this manuscript demonstrate estimated aggregate annual WTP for Pacific Northwest Residents for Coho restoration scenarios (see Fig. 1). This work is being presented in multiple professional settings in 2018 and we hope to submit the manuscript for publication in fall of 2018.

Lewis has also collaborated with PI Dundas on the Coastal Protection pathway and has been working with other team members to develop preliminary results for a hedonic analysis of the effects of alternative shoreline grey infrastructure on shoreline property markets, and an empirical model of coastal landowners' investment in grey infrastructure.

Natural resource economist David Kling (Assistant Professor, Department of Applied Economics) worked in collaboration with the PI Dundas and co-PI Lewis to implement the economic research component of the project. Kling is serving as the economist coordinator for the project's Dune Landscape pathway. Working with PI Dundas and co-PIs Hacker and Ruggiero, and graduate student Tu Nguyen, Kling was the primary author of a nonmarket valuation survey focusing on natural infrastructure and ecosystem services provided by Pacific Northwest coastal dunes and sandy beaches (Track II). Kling participated in focus-group testing of the draft survey instrument in November 2016 (in Sacramento), February 2017, and March (both in Portland, OR). Thirty-one (31) final illustrations for the survey were delivered by illustrator Katherine Roy in summer 2018 (see Fig. 2 for examples). He also began work on development of a dynamic ecological-economic model of coastal dune capital management (Track III). In addition, with PI Dundas and co-PI Cox, and graduate student Jason Beasley, he collaborated on preliminary work on a model for valuing expected tsunami risk benefits provided by green infrastructure. In the 2017-2018 project period, Kling will coordinate revision to the survey instrument, with the goal of deploying it to a random sample of the public in mid-to-late 2017. Kling will also coordinate development of modeling tools for support and planning of natural infrastructure management, with primary application to coastal dunes and sandy beaches.

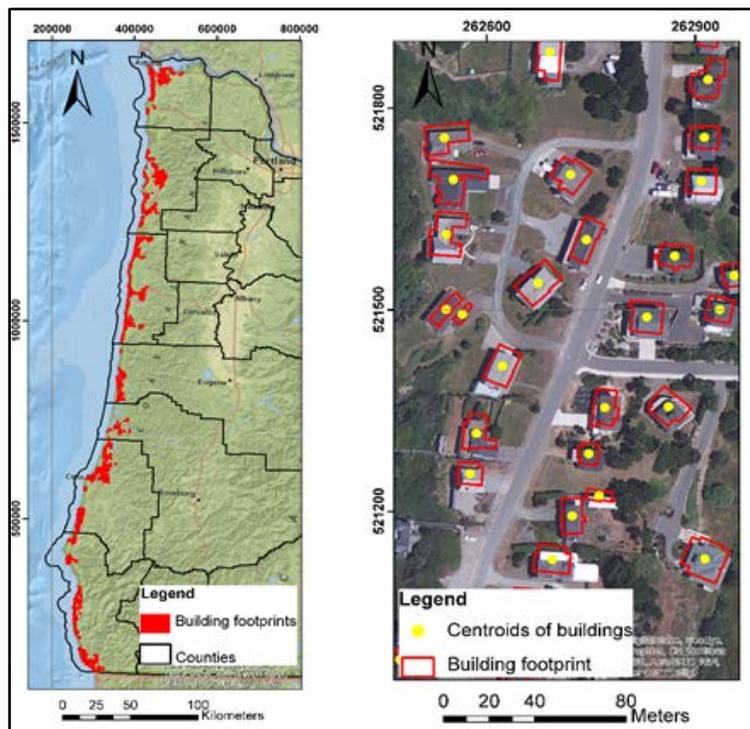


Figure 1. Automatic detection of the buildings: a) full extent, and b) detailed view.

riprap structures using LIDAR data. The input data consisted of features layers derived from elevation and intensity information provided by LIDAR sensor (e.g., slope, aspect, curvature, etc.). The study area was located in Gleneden Beach, in Lincoln City, where there are significant riprap structures backed by bluff. A supervised, object-based image analysis (OBIA) classification was performed, and results showed a 92% success rate in mapping riprap (Fig. 2).



*Fig 2. Mapping of riprap structures with LIDAR data. Light blue polygon shows the riprap classification.*

The method appears highly promising for obtaining physical characteristics of these structures (e.g., elevation, width, slope, length, etc.), information that is valuable to the Coastal Protection Pathway and to OPRD. This work will be extended in the thesis research of team member, Laura Barreiro Fernández. The overall focus of this ongoing work is monitoring Shoreline Protective Structures (SPS) on the Oregon coast using remote sensing. The types of structures being analyzed include riprap, seawalls and dynamic revetments, and the remote sensing technologies being utilized include LIDAR and aerial imagery collected with conventional airplanes and unmanned aircraft systems (UAS). The research will define a methodology to be used by OPRD, the responsible agency for SPS management in Oregon. To date, relatively little work has been done on monitoring these types of SPS via remote sensing, so the results of this work are anticipated to be a valuable outcome of this portion of the project.

Coastal engineer Daniel Cox has worked with PI Dundas, co-PI Kling and graduate student Jason Beasley 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 the city of Seaside an area to explore a model for valuing expected tsunami risk benefits provided by green infrastructure.

#### MEETING PRESENTATIONS:

**Dundas, S.J.** 2017. A transdisciplinary approach to valuing ecosystem services from coastal

natural infrastructure. Part of an Organized Symposium on *Linking Biodiversity, Material Cycling, and Ecosystem Services in Coastal Ecosystems* at the Ecological Society of America Annual Meeting, Portland, OR.

**Lewis, D.J., Dundas, S.J., Kling, D.M., Lew, D.K., and S.D. Hacker.** 2018. Public preferences for natural capital investments that help threatened species: The case of Oregon Coast Coho salmon. Agricultural and Applied Economics Association Annual Meeting, Washington, DC.

**Lewis, D.J., Dundas, S.J., Kling, D.M., Lew, D.K., and S.D. Hacker.** 2018. Public preferences for natural capital investments that help threatened species: The case of Oregon Coast Coho salmon. The International Institute of Fisheries Economics & Trade, Seattle, WA.

## PROJECT OUTCOMES

Although the primary research is still developing, we see clear potential for the anticipated results of our research program associated with this project to lead to changes in the knowledge or actions of stakeholders and policymakers. Some examples are described below.

- Results from a general population survey of residents of the PNW about estuarine habitat restoration/coho salmon are now being generated. We sent 5,000 surveys and achieved our target response rate of 20%. Co-PI Lewis interacted with numerous members of the general public who were survey respondents and had questions about the estuarine/coho survey. We are currently seeking guidance from Oregon Sea Grant and Board member Walker (Director, Oregon Sea Grant) to effectively target our outreach efforts. Results are anticipated to inform numerous agencies and organizations involved in conservation of Oregon Coast Coho, including NOAA, the Oregon Department of Forestry, and the U.S. Forest Service, among others.