



University of Washington

2014–2016

Washington Sea Grant Program Directory

Research, Outreach, Education, and Communications

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Washington Sea Grant

College of the Environment

University of Washington

3716 Brooklyn Avenue N.E.

Seattle, WA 98105-6716

206.543.6600

seagrant@u.washington.edu

wsg.washington.edu



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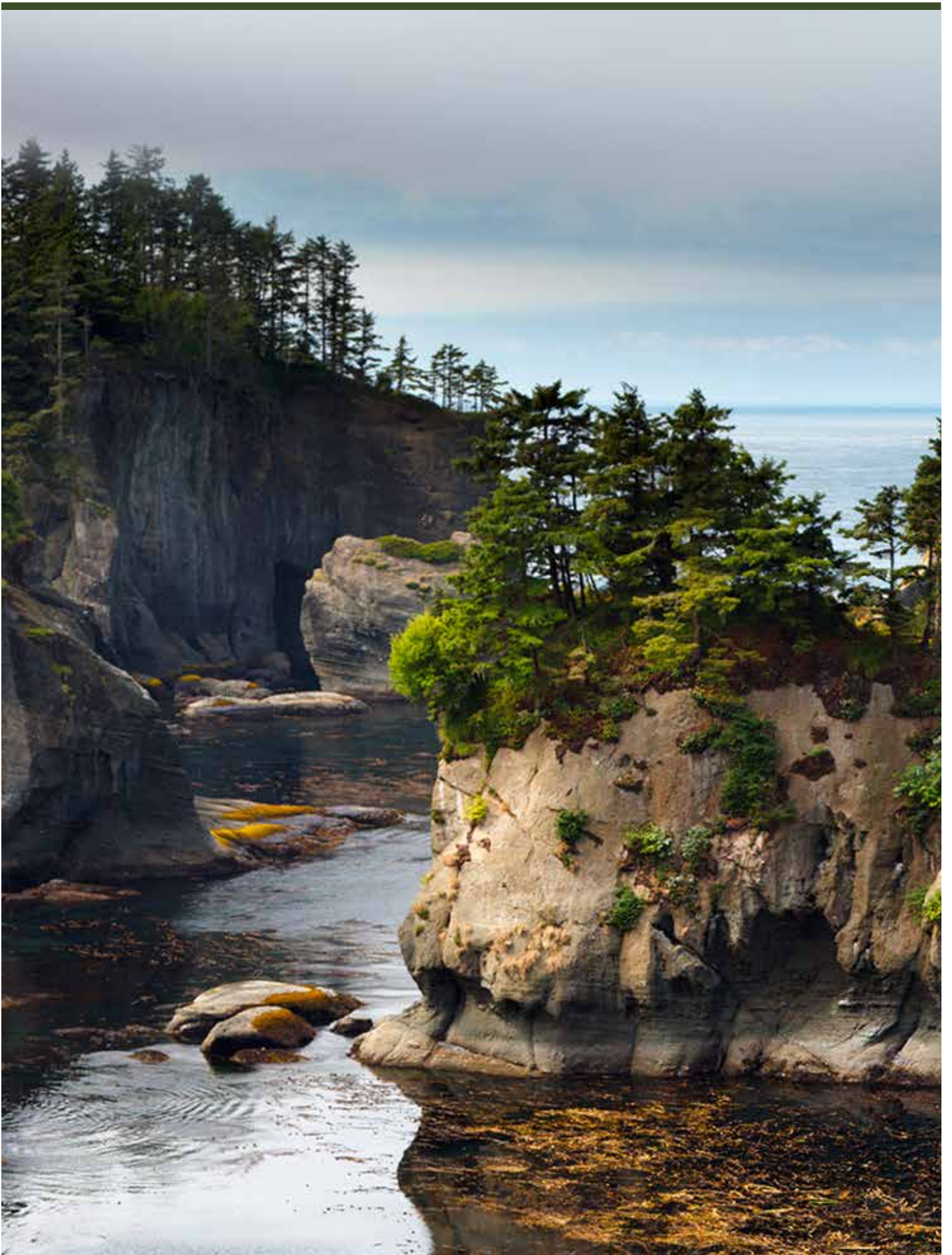


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INTRODUCTION

About this Directory

This publication describes research, outreach, education and communications activities for Washington Sea Grant (WSG) from 2014 through 2016. Project descriptions are organized under four topic areas that broadly align with the critical missions identified in the WSG 2014-2018 strategic plan:

- **Sustainable Fisheries and Aquaculture:** facilitate sustainable use of living marine resources through science-based management and environmentally and economically responsible approaches.
- **Healthy Coastal Ecosystems:** understand ocean and coastal environments and advance ecosystem-based approaches to manage, protect and restore natural resources.
- **Resilient Communities and Economies:** build capacity for coastal communities that are economically vibrant, environmentally healthy and resilient to hazards and climate change.
- **Ocean Literacy and Workforce Development:** educate learners of all ages and strengthen workforce capacity.

More information is available on the WSG website (wsg.washington.edu) and from project leaders and researchers, whose contact information is listed at the end of this directory.

What is Washington Sea Grant?

The National Sea Grant College Program was launched in 1966 as a federal investment in our oceans and coasts, building upon university strengths in the ocean sciences, engineering, and policy. In 1971 the University of Washington (UW) became one of the first four institutions nationwide to be designated as a Sea Grant College.

Today WSG identifies, addresses, and funds important marine issues, shares its expertise with coastal businesses and communities, provides tools for the management of ocean and coastal resources, and engages the public in protecting and sustainably using those resources. Based at the UW College of the Environment, WSG is part of a national network of 33 Sea Grant programs that is administered by the National Oceanic and Atmospheric Administration (NOAA) and funded through federal–university partnerships. Regionally, it has developed strategic partnerships with many local, state, tribal, and regional entities, including the Puget Sound Partnership, state resource agencies, NOAA's Western Region offices and research laboratories, and the five other Pacific Sea Grant programs.

WSG organizes its activities around four closely integrated core functions: research, advisory services, education, and communications.

Research

WSG-sponsored research seeks to build the knowledge and tools needed to strengthen the sustainable use of marine resources while preserving and, when necessary, restoring a healthy marine environment. It combines scientific excellence, rigorous review, and close attention to the challenges facing those who live along Washington's coasts and work and play on its waters. To ensure that research findings reach this wider audience, each project includes a plan for engaging potential users in its outcomes.

Advisory Services

WSG's mission is to provide scientific and technical information for use by coastal and marine communities. WSG helps Washington's marine workforce grow and develop the skills it needs to compete through training, special workshops, and the development of new tools and technologies. WSG specialists based at UW and in field offices throughout western Washington provide technical assistance and connect governments, tribes, marine businesses, and coastal residents to the best scientific information available. WSG staff share university resources and their own expertise in a wide range of fields, including water quality, ocean acidification, aquaculture, fisheries management and bycatch prevention, citizen science, habitat restoration, invasive species control, algal bloom monitoring, oil spill and other pollution prevention, maritime safety, coastal development, community sustainability, and hazard resilience.

Education

WSG helps learners of all ages understand how the ocean affects them and how they affect the ocean. Intensive summer science camps for middle and high school students and a popular statewide ocean sciences bowl whet youthful curiosity and commitment, encouraging students to pursue marine-related careers. A wide range of fellowship, internship, and research programs provide undergraduate, graduate, and postdoctoral students with real-world experience in marine science, policy, and resource management. Many work on issues of regional and national importance in state and federal resource agencies and on congressional staffs.

Communications

WSG disseminates its research findings, shares technological and operational innovations, and engages the public, press, government, industry, educators, and community organizations in the sustainable use of marine resources through a wide range of communications media. These include: books, reports, pamphlets, newsletters and other print publications; news releases and targeted media outreach; a comprehensive website and extensive publications database; Facebook, Twitter and other social media; public exhibits; and direct engagement, on both land and water, at festivals, trade fairs, boating gatherings, and other events. WSG constantly seeks to broaden output via new forms and forums, working to gain national scope through regular reports to NOAA administration and postings to the national network of Sea Grant programs. Throughout, three principles prevail: reliable and authoritative information, unbiased analysis, and clear, concise expression.

I FISHERIES, AQUACULTURE, AND SEAFOOD

Fisheries

Modeling the migration decisions of fish harvesters in rural Alaska

Chris Anderson, UW School of Aquatic and Fishery Sciences; Jennifer Meredith, UW School of Economics; Amber Himes-Cornell, NOAA Alaska Fisheries Science Center (Sea Grant/NOAA Fisheries Fellow in Marine Resource Economics)

Movement of Alaska residents out of commercial fishing has created concerns about the threat that this may pose to traditional communities and the need to better understand how fishing regulations influence migration decisions. This project develops a predictive economic model of how shifts in Alaska fisheries management affect rural fish harvesters' ability to make a living. The model builds on qualitative interviews, historical data, and newly collected survey data to identify the impact of policies designed to reduce the amount of migration out of rural fishing communities, such as training programs and permit and credit subsidies. It will help identify ways for fishery managers to enhance the sustainability of rural harvesting and traditional communities.

Use of survey data and ecological observations to improve rockfish stock assessments

Trevor Branch and Peter Kuriyama, UW School of Aquatic and Fishery Sciences; Allan Hicks, NOAA Northwest Fisheries Science Center (Sea Grant/NOAA Fisheries Fellow in Population Dynamics)

Trawl surveys are the primary independent source of information used by fishery managers in most West Coast stock assessments. However, they do not sample rocky habitats very well. Many of the 60-plus rockfish species managed under the Pacific Fishery Management Council's Groundfish Fishery Management Plan are most numerous in untrawlable habitats, including many species that are overfished and that are commercially and recreationally valuable. This project examines the feasibility of using indices of abundance and other data from trawl, hook-and-line, and other surveys to develop more accurate stock assessments of rockfish in the Southern California Bight to inform management.



Optimizing Bayesian analysis in data-rich stock assessments and management of data-limited fisheries

Trevor Branch and Cole Monnahan, UW School of Aquatic and Fishery Sciences (Sea Grant/NOAA Fisheries Fellow in Population Dynamics)

While complex data-rich models are the preferred tool for managing large, valuable fisheries, they require long computer runtimes and there are not enough data, time, or qualified analysts to conduct full assessments. Alternative data-poor methods require only catch data and some explicit assumptions, and data-moderate methods require less data and time than data-rich methods but are more accurate than data-poor methods. This project pursues four objectives: identify methods to decrease runtime for data-rich stock assessments; apply new analysis guidelines to past stock assessments in order to speed up future evaluations and compare management approaches; identify strategies for the optimal resources allocation for new stock assessments; and evaluate the long-term implications of data-limited methods for managing stock harvests.

Social and economic effects of individual fishing quotas for West Coast groundfish

Christopher Costello (regional lead), Steven Gaines, and Robert Deacon, University of California Santa Barbara; Trevor Branch (Washington lead) and Ray Hilborn, UW School of Aquatic and Fishery Sciences

Catch-share allocation is an increasingly popular approach to fisheries management in the United States. Quota allocations have demonstrated economic and ecological benefits, but there is widespread concern that they may have socially undesirable impacts or fail to solve other management goals, such as reducing the unintended bycatch of nontarget fishes. The West Coast groundfish fishery is transitioning to individual fishing quotas and faces a number of bycatch challenges. This project documents the changes in the fishery attributable to implementation of the new system and examines the status of fish stocks and discard practices.

Evaluation of growth rate variation in fish population dynamics and stock assessments

Timothy Essington and Christine Stawitz, UW School of Aquatic and Fishery Sciences; Melissa Haltuch, NOAA Northwest Fisheries Science Center (Sea Grant/NOAA Fisheries Fellow in Population Dynamics)

Recent research suggests that variation in growth rate may play a key role in fish-population regulation and dynamics. Density-dependent growth is well documented in fish populations and growth is also affected by changes in ocean conditions such as upwelling, surface temperature, and climate regimes. In addition, heavily exploited stocks often show decreased size-at-age. If population fluctuations are sensitive to growth variation, stock

assessments that assume fixed growth rates may be biased. This project quantifies growth and recruitment in various fish stocks at multiple life stages and assesses their importance to population fluctuations. It also studies the effects of growth variation on management reference points and growth-parameter estimates under alternative life histories and fishing pressures.

Marine safety training for tribal and other commercial fishermen

Sarah Fisksen and Steve Harbell, Washington Sea Grant

West Coast and Alaska fisheries have historically been the most dangerous in the country. The region's severe weather, cold water and rough seas require fishermen to work under adverse conditions and increase risks for crews and vessels. WSG helps Washington fishermen reduce these risks with port-based, Coast Guard-certified training in emergency evacuation, fire response, cold-water rescue, first aid, and other safety measures, using the latest equipment and procedures. It also trains recreational boaters in first aid and at-sea safety and survival. Nearly 20 years of WSG safety training on Puget Sound, Washington's outer coast, and the Columbia River have significantly reduced mortality in several fisheries.

Marine technology training for fishermen and boaters

Sarah Fisksen, Washington Sea Grant

Vessel operational systems and technology change constantly. Many commercial and recreational boaters rely on education programs to keep up. WSG offers classes and workshops on vessel safety, maintenance and operations, covering marine refrigeration, corrosion, diesel engine troubleshooting, computers, navigation, and other topics of concern to Washington vessel owners and operators. Workshops are geared to commercial fishermen, but recreational boaters and others with close ties to the marine environment often participate.

Evaluation of past herring abundance and Native American use for current resource management

Lorenz Hauser, UW School of Aquatic and Fishery Sciences; Dana Lepofsky and Dongya Yang, Simon Fraser University; Robert Kopperl, Northwest Archaeological Associates

Herring are a foundation of the Puget Sound food web. In addition to feeding marine life from hungry sea lions to spawning Chinook salmon, Pacific herring have for centuries been a cultural touchstone for local tribes. But herring populations in Puget Sound are declining, imposing significant economic and cultural losses on the tribes. This project combines social and natural science approaches to examine the ways herring diversity and tribal uses have changed over time, through a synthesis of traditional knowledge, archaeology, and genetic research. The results will assist in evaluating management goals in Puget Sound and could lead to closer integration of tribal and state resource management.

Seabird bycatch prevention in fisheries

Edward F. Melvin, Washington Sea Grant

Hundreds of thousands of seabirds, including protected albatrosses and petrels, are trapped and drowned in longline and trawl fisheries worldwide each year. Seabird avoidance measures developed and promoted by WSG have dramatically reduced this avian bycatch in longline fisheries off Alaska and elsewhere, at the same time reducing bait loss and improving fishing efficiency. These measures, which use strategically deployed bird-repelling streamer lines, have been adopted by the North Pacific Fisheries Management Council and by tuna fisheries worldwide. WSG and its Oregon and California partners are testing and refining prevention measures in the West Coast sablefish fishery, the regional fishery with the greatest potential for protecting endangered albatrosses.

Aquaculture

South Puget Sound social and ecological carrying capacity for shellfish aquaculture

Dan Cheney, Pacific Shellfish Institute; João Ferreira, Longline Environment Ltd.; David Priekshot, Fisheries and Oceans Canada; Jonathan Davis, Baywater Inc.; Teri King, Washington Sea Grant; Mindy Roberts, Washington Department of Ecology; Danna Moore, Washington State University (WSU) Social and Economic Research Center (NOAA Sea Grant Aquaculture Research Program)

West Coast shellfish aquaculture has increased steadily over the last 30 years, serving growing domestic and export markets. This project is providing tools and information for assessing the ecological and social capacity of South Puget Sound to support shellfish aquaculture. It is assessing carrying capacity and developing methodologies and guidance documents that can inform marine spatial planning efforts. The research is using an ecosystem-based approach to support sustainable shellfish aquaculture and provide a framework for addressing issues that can lead to regulatory and permitting conflicts.

Determining how and where rock scallops can be grown without threatening wild populations

Lorenz Hauser, UW School of Aquatic and Fishery Sciences; Blake Brady, Washington Department of Fish and Wildlife; Jonathan Davis, Pacific Shellfish Institute and Taylor Shellfish Company, Inc.; Brent Vadopalas, UW School of Aquatic and Fishery Sciences (NOAA Sea Grant Aquaculture Research Program)

Prized flavor and the ability to thrive in widely diverse conditions make the native purple-hinged rock scallop a prime candidate for aquaculture. But state rules restrict transferring broodstock for fear of the impacts on wild populations. This project will quantify genetic differentiation among populations from

California to Alaska, compare resilience of different populations exposed to more acidic ocean conditions, test for the adaptation of local populations through reciprocal transplant experiments, and integrate the results into a population model of local adaptation. The results will inform pending regulatory decisions and may contribute to the development of a new, sustainable, and highly desirable native shellfish crop.

Use of geospatial data, community outreach, and public perspectives to inform shellfish aquaculture planning

Bobbi Hudson, Pacific Shellfish Institute; Teri King, Washington Sea Grant; Paul Olin, California Sea Grant (NOAA Sea Grant Aquaculture Research Program)

Shellfish aquaculture operations can create tensions between growers and coastal homeowners and other stakeholders. This project combines geospatial data on West Coast commercial shellfish aquaculture with findings from community outreach and research into public perceptions. It facilitates visualizations of the status of shellfish aquaculture for marine and coastal planning efforts. Researchers aim to illuminate the full range of public perspectives on shellfish aquaculture and the interrelationships among various social, economic, and ecological values. The project provides information relevant to planning for multiple uses of ocean and coastal areas.

Shellfish aquaculture technical assistance program

Teri King, Kevin Decker, and Jennifer Runyan, Washington Sea Grant (NOAA Sea Grant Aquaculture Extension Program)

Washington leads the nation in production of farmed clams, oysters and mussels with an annual value of over \$107 million. Despite their successes, shellfish growers face multiple challenges, including environmental threats such as ocean acidification and harmful algal blooms; shoreline development and habitat loss; market restrictions; and seafood safety concerns. Working with NOAA, shellfish producers, tribes, and state agencies, WSG offers advisory services to support sustainable aquaculture. The program sponsors and participates in conferences and training opportunities; shares research findings with decision makers, producers and resource managers; enlists the public in shellfish enhancement; and supports research on emerging issues. WSG contributes to the Washington State Shellfish Initiative and hosts Operation Clam Bake, the annual Shellfish Growers Conference, and symposia on aquaculture and the environment. Staff experts conduct research with growers to reduce the incidence and severity of *Vibrio* infestations and address other farm-specific and regional concerns. Aquaculture-related education activities include distribution of updated publications on best practices for safe shellfish harvests and farming operations and screenings of the documentary *Willapa Bay Oysters*.

Geospatial simulation model for siting and managing net-pen aquaculture to avoid fish-waste pollution

Jack Rensel and Frank O'Brien, System Science Applications Inc.; Dale Kiefer, University of Southern California (USC) Department of Biology; James Morris, NOAA National Ocean Service (NOAA Sea Grant Aquaculture Research Program)

Waters of the United States are well suited to fish aquaculture, but to date no commercial-scale operations have been permitted from three to 200 miles off the coast in the U.S. exclusive economic zone. Federal permitting and management authorities are fragmented, and agencies do not have the quantitative tools they need to develop clear requirements and safeguards for offshore operations. This project uses AquaModel, a geospatial software system that simulates the environmental effects, in both the benthos and the water column, of siting and operating net-pen fish farms in coastal and ocean waters. The project focuses especially on siting and feeding practices to avoid waste-induced eutrophication, while refining the accuracy of the AquaModel program.

Ecology and economics of shellfish aquaculture in Washington

Jonathan Reum, Kevin Decker, and Bridget Ferriss, Washington Sea Grant; P. Sean McDonald, UW School of Aquatic and Fishery Sciences; Wei Cheng and Neil Banas, Joint Institute for the Study of the Atmosphere and Ocean; Chris Harvey, NOAA Northwest Fisheries Science Center

In 2013, the Washington State Legislature directed and funded WSG to initiate a shellfish aquaculture research program. The purpose of the program is to assess possible negative and positive effects, including cumulative and economic impacts, of evolving Washington shellfish aquaculture practices. WSG engaged a group of scientific experts to develop recommendations for program research components and to select a team of investigators to carry out the research. Five program components are now underway: spatial analysis, qualitative food web analyses, Puget Sound ecosystem and circulation models, and an economic synthesis. WSG must report annually to the legislature on progress, and plans are underway for project completion by the end of 2015.

Alleviation of regulatory impediments to native shellfish aquaculture

Steven Roberts, Brent Vadopalas, and Carolyn Friedman, UW School of Aquatic and Fishery Sciences; Brady Blake, Washington Department of Fish and Wildlife; Jonathan Davis, Taylor Resources Inc.; Frederick Goetz, NOAA Fisheries Northwest Region (NOAA Sea Grant Aquaculture Research Program)

The cultivation of native shellfish can have both positive and adverse effects on the genetic makeup of nearby wild populations of the same species. Through inbreeding, aquaculture stock may threaten wild populations by weakening their potential for adaptation to changing environmental conditions. Conversely, the

addition of diverse cultured organisms may enrich wild genetic capacities. This project examines local adaptation in Olympia oysters and the safety of current breeding protocols by cross-breeding various wild and cultured stocks, then comparing the survival, fertility, and genetics of their offspring.

Assessment of policy and social dimensions of geoduck aquaculture to help resolve stakeholder conflicts

Clare Ryan and P. Sean McDonald, UW Program on Environment

Geoduck clam aquaculture in Puget Sound is economically promising but socially and politically challenging. As geoduck production has expanded, concerns have arisen about the potential impacts of farming practices on nearshore ecosystems. This project analyzes geoduck aquaculture's policy and social dimensions to help develop tools for resolving conflicts among stakeholders. Researchers also integrate their findings with ecological studies to provide a more holistic understanding of Washington management issues related to geoduck aquaculture.

An ecosystem-modeling approach to investigating the effects of geoduck aquaculture expansion

Glenn VanBlaricom and P. Sean McDonald, UW School of Aquatic and Fishery Sciences; Chris Harvey, NOAA Northwest Fisheries Science Center

In December 2013, Washington Sea Grant submitted a report to the Washington Legislature summarizing the results of a six-year study of the effects of geoduck aquaculture on the Puget Sound environment. While the study addressed major scientific questions, uncertainty remains about wider ecosystem effects. This project is integrating data collected from aquaculture sites and reference beaches during the study into a published food-web model for Central Puget Sound. With guidance from a multi-stakeholder advisory panel, it tests a spectrum of aquaculture scenarios and their potential impacts on habitat, fisheries, mortality, and predator-prey interactions. The eventual findings will guide recommendations for future aquaculture operations.

Enhancing sablefish aquaculture by developing technologies for producing more high-quality fingerlings

Graham Young, UW School of Aquatic and Fishery Sciences; Walton Dickhoff, Northwest Fisheries Science Center; Adam Luckenbach, Northwest Fisheries Science Center; John Dentler, Troutlodge Sablefish LLC; Jim Parsons, Troutlodge Sablefish LLC; Mary Arkoosh, Northwest Fisheries Science Center; Joseph Dietrich, Northwest Fisheries Science Center; Kurt Grinnell, Jamestown S'Klallam Tribe; William Fairgrieve, Northwest Fisheries Science Center; Laura Hoberecht, NOAA National Marine Fisheries Service (NOAA Sea Grant Aquaculture Research Program)

Pacific sablefish, with their firm flesh and buttery flavor, are an exceptionally valuable food fish. But wild harvests are limited,

and bottlenecks in larval production have discouraged sablefish aquaculture. This project removes these barriers by using newly developed technologies to produce all-female (hence faster-growing) larvae on a commercial scale, to wean them faster from costly live food to industrial feed, and to rear them at optimal temperatures for growth. It also explores new techniques for inducing ovulation, improving fertilization success, and vaccinating larvae by immersion rather than giving expensive injections at the fry stage.

Safe, Sustainable Seafood

Partnerships to sustain vibrant seafood and fishing businesses

Sarah Fisksen and Pete Granger, Washington Sea Grant

With lower prices paid at landing, declining catches, fewer fish buyers, and shrinking profit margins, commercial fishermen seek ways to increase the value of their catches through better handling, processing, storing, quality control, and marketing. Since 2006, WSG and Philips Publishing Group have presented the Wild Seafood Exchange, an annual forum for Northwest and Alaska fishermen to discuss ways to start or improve direct marketing operations. The Exchange brings together fishermen, seafood buyers, restaurant operators, retail food dealers, and financial, business, and marketing experts. A new partnership with Philips Publishing will assist in recruiting new commercial fishermen through a Young Fishermen's Summit modeled after Alaska Sea Grant's successful program. Participation in Seattle's annual Pacific Marine Expo also offers opportunities to share information and discuss industry needs. In addition, WSG is creating a financial and business planning toolkit to help fishermen boost their profitability, which will be delivered through the national Sea Grant network.

Use of zebrafish to assess health effects of persistent pollutants in Pacific salmon

Evan Gallagher, UW Department of Environmental and Occupational Health Services

Polybrominated diphenyl ether (PBDE) flame retardants are found in many products, including building materials, textiles, plastics, and electronics. PBDE levels have increased in fish, wildlife, and human tissues during the past decade, and PBDE residues in resident Puget Sound Chinook salmon are high relative to many other species. Increasing levels in marine mammals such as harbor seals that are at the top of the Puget Sound food chain give rise to questions about possible health effects in residents who consume local salmon. This project is using zebrafish as surrogates to understand human exposure to PBDEs, to develop new biomarkers for PBDEs and other emerging contaminants in fish models, and to develop novel, cost-effective models for studying human risk.

Enhanced product quality and value for tribal seafood producers

Pete Granger and Sarah Fisksen, Washington Sea Grant

Fish and shellfish are traditionally central to the economies and cultures of Western Washington's tribal communities. But today's tribal harvesters face limited markets and stiff competition. These can be overcome with improved catch handling and storage techniques, and by marketing unique local products such as the Olympic coast's marbled king salmon. Working with the Nisqually, Quinalt, Swinomish, and other tribes, WSG continues to provide training in seafood quality improvement and marketing, increasing the profitability of their fisheries. WSG also helps the Lummi Nation expand its retail seafood market, which serves Bellingham and Whatcom County and provides an outlet for both fresh catches and more profitable value-added products. And WSG continues to work with the Washington Trollers Association and Makah Tribe to introduce chefs, food writers, and restaurateurs to the distinctive marbled salmon through its annual lunch event at a premier Seattle restaurant.

Training in seafood handling for meatcutters

Pete Granger and Steve Harbell, Washington Sea Grant

Many customers wonder whether the fish they eat are clean, healthy, high-quality, and sustainably caught. Often they direct these questions to workers behind supermarket seafood counters who wish they could help customers find the answers. On the basis of a survey of meatcutters and seafood department managers in several local grocery chains, WSG designed a 12-hour seafood-retail training program for apprentice meatcutters. This program is offered in conjunction with the meatcutter apprenticeship programs of South Seattle Community College and the United Food and Commercial Workers International Union. After the trainings, apprentices are evaluated on their retention of seafood information and surveyed about customer knowledge and training impacts. WSG is also working to expand the program to the Tacoma Community College Meatcutters Apprenticeship Program.

State of the Oyster Study: testing shellfish for health and safety

Teri King and Jennifer Runyan, Washington Sea Grant

Shellfish need clean water to thrive. Pollutants can destroy their beds, and bacteria taken up by shellfish can sicken people who eat them. WSG's State of the Oyster Study is a citizen science monitoring program that trains waterfront property owners to test the safety of their shellfish before consumption. Four times a year, residents gather clams and oysters at low tide and bring them to WSG to be tested for *Vibrio parahaemolyticus* and bacterial indicators of fecal contamination. WSG then assists participants in interpreting the test results and, if necessary, works closely with them to identify and remedy sources of contamination.

II MARINE ECOSYSTEM HEALTH

Ocean Acidification

Impacts of ocean acidification on wild and farmed mussels in Puget Sound, Washington

Emily Carrington, UW Friday Harbor Laboratories; Carolyn Friedman, UW School of Aquatic and Fishery Sciences

The onset of ocean acidification presents an important new environmental stressor for commercially and ecologically important mussels in Puget Sound. Through laboratory studies and field observations of local mussel species, this project is assessing the interactions of ocean acidification, temperature change, food rationing, and seasonal spawning cycles on byssal (attachment) strength and dislodgment, a major cause of mussel mortality. Researchers will quantify the environmental conditions that wild and farmed mussels encounter and develop a high school curriculum on ocean acidification.

Washington State response to ocean acidification

Meg Chadsey, Washington Sea Grant and NOAA Pacific Marine Environmental Laboratory Liaison

In 2012, the Washington State Blue Ribbon Panel on Ocean Acidification (OA) released a report detailing the state's strategic response to growing concerns about shifting ocean chemistry. Recommended actions included monitoring acidification trends and effects, investigating its causes, building capacity for adaptation and remediation, and enlisting diverse constituencies in addressing

it. In collaboration with state, federal, and academic partners, WSG is responding by developing print and online outreach materials on acidification, conducting frequent public presentations, and working with NOAA to produce monthly webinars. An online acidification curriculum for K-12 classrooms and OA Literacy Framework for educators and students have been developed with the Suquamish Tribe. With the assistance of the Puget Sound Restoration Fund, the curriculum is being incorporated into high school environmental science classes in the Bainbridge Island School District.

Crossbreeding and selection for resistance to ocean acidification in Pacific oysters

Jonathan Davis, Pacific Shellfish Institute; Carolyn Friedman and Steven Roberts, UW School of Aquatic and Fishery Sciences; Brett Dumbauld, USDA Agricultural Research Center

Ocean acidification threatens valuable Pacific oyster hatchery seed production with increased larval mortality in high- CO_2 , low-pH waters. This project breeds oysters for resistance to acidification using a large number of genetically distinct lines maintained by a commercial grower. These lines are conditioned in ambient and elevated dissolved- CO_2 levels at two critical larval stages to determine whether, and in which lines, exposure leads to changes in gene expression. High-, medium-, and low-performing lines are then field-tested at four farms. The trials expand ongoing investigations of the intergenerational effects of exposing breeding adult oysters to acidified waters.



Effects of early exposure to ocean acidification on subsequent performance of Pacific oysters

Carolyn Friedman, UW School of Aquatic and Fishery Sciences; Mark Camara, USDA Research Service Shellfish Genetics Program; Jonathan Davis and Benoit Eudeline, Taylor Resources Inc.

An increasing number of studies document the negative effects of ocean acidification on the larval performance of marine shellfish. One direct result may be poor hatchery survival and low natural recruitment in Pacific oysters. However, experiments also are needed to evaluate effects at later life-history stages in order to more reliably predict ocean acidification effects over time. This project investigates how exposing broodstock and larvae to more corrosive waters impacts later life stages. It also estimates the genetic parameters needed to implement an effective breeding program that can improve oysters' tolerance of acidic conditions.

Effects of ocean acidification on trophically important crustacean zooplankton

Julie Keister, UW School of Oceanography; Paul McElhane, NOAA Northwest Fisheries Science Center

Crustacean zooplankton are the prey base for most fish, but little is known about how they will be affected by ocean acidification. Research to date has revealed mixed, highly species-specific responses; nothing has been published on effects in the acidification-impacted waters of Puget Sound. This project combines laboratory experiments and local field observations to investigate acidification's effects on the early growth, survival, and vertical distribution of two important zooplankton species, the copepod *Calanus pacificus* and krill *Euphausia pacifica*. Species response information from experiments is being used to inform existing regional food web models.

Other Environmental Threats

Public engagement to detect and control green crab and other aquatic invasive species

Jeff Adams, Washington Sea Grant

Nonnative plants and animals are continually introduced into aquatic systems. A few thrive, threatening personal property, livelihoods, coastal habitats, and native aquatic life. By understanding the pathways taken by aquatic invasive species (AIS), managers can prevent their spread, develop rapid response plans, and minimize the impacts of those already established. WSG provides AIS training to certified master gardeners, watershed stewards, and other volunteer groups upon request. Building on its collaboration with West Coast Sea Grant programs to stop the release of non-native crayfish from schools and classrooms, WSG will continue to work with teachers and assist efforts to control invasive crayfish in Pine Lake. In addition, WSG is working with

the Washington Department of Fish and Wildlife to develop and implement a volunteer-based early detection and monitoring program for European green crab in inland marine waters.

Tracking cyst formation and reactivation to anticipate *Heterosigma* blooms

Rose Ann Cattolico, UW Biology Department

The formation of toxic blooms by *Heterosigma akashiwo*, one of the world's most harmful algal species, can substantially damage salmon aquaculture operations; reduce the survival of oysters, sea urchins and other aquatic organisms; and compromise the health of coastal ecosystems. This project addresses the longstanding question of how and why *Heterosigma* switches from a dormant state, able to rest for months in bottom sediments, to a vigorous vegetative state during which it swims to the surface and forms toxic blooms. The project develops new tools to help aquaculture operations monitor *Heterosigma* cysts and anticipate blooms.

Beyond cyst mapping: a new tool for predicting toxic *Alexandrium* blooms

Cheryl Greengrove and Julie Masura, UW Tacoma Environmental Science; Stephanie Moore and Brian Bill, NOAA Northwest Fisheries Science Center

The alga *Alexandrium catenella* produces toxins that can accumulate in shellfish, causing severe illness in humans who eat them and costly product recalls. Resource managers have tried with limited success to predict *A. catenella* blooms by mapping winter levels of dormant cysts. This project tests the effectiveness of that approach, investigates the possibility of a secondary dormancy affecting germination cycles, and evaluates a potentially more effective predictor, cyst viability. It seeks to determine whether viability can be gauged by cyst appearance. By developing an alternate model for predicting blooms, it may make shellfish growing safer and more efficient.

Deploying a low-cost sensor network for early detection of harmful algal blooms

Daniel Grünbaum, UW School of Oceanography; Christopher MacGregor, Wallingford Imaging Systems

In 2003, harmful algal blooms (HABs) cost fisheries in the Pacific Northwest an estimated \$10-12 million. Today researchers are using new imaging technologies to develop inexpensive, field-tested remote sensors that monitor and measure two major HAB species while gathering potentially important data on other marine species. This project deploys a HAB sensor network across Puget Sound, streaming real-time data via Washington's ocean observing system (NANOOS) and the SoundToxin portal and providing early warnings about blooms to shellfish growers, tribal harvesters, and other HAB-affected stakeholders.

SoundToxins monitoring for harmful algal blooms

Teri King and Jennifer Runyan, Washington Sea Grant

Shellfish are critical to the economy and culture of Puget Sound and are a regular part of many residents' diets. The shellfish industry employs more than 3,200 people and contributes an estimated \$270 million to the economy. Growers and managers share a major challenge: ensuring that shellfish are safe for human consumption and free from toxins produced by harmful algal blooms (HABs) such as *Dinophysis*, which can cause diarrhetic shellfish poisoning. To bolster limited monitoring resources and provide early warning of HAB events, NOAA developed the SoundToxins program, which enlists volunteers and fish and shellfish producers as monitors. WSG provides volunteer coordination, training, and communication services for SoundToxins.

Potential impacts of seasonal hypoxia along the Quinault Reservation coast

Ervin Joe Schumacker, Quinault Indian Nation

When hypoxia events take place, low levels of dissolved oxygen in water cause the death of fish and other aquatic life. In recent years, the Quinault Reservation has observed fish kills that appear to be connected to hypoxia. At the same time, razor clams on historically robust clam beaches show poor reproduction and juvenile survival. This project creates a low-cost pilot monitoring network in which tribal fishermen and youth participate in gathering coastal water quality information related to ocean conditions. Measurements are used to quantify impacts of seasonal hypoxia on Pacific razor clams, develop adaptive management plans for this and other species, and contribute to ongoing efforts to understand marine environmental changes on the West Coast.

Marine Species at Risk

Use of seawater chemistry to trace larval exchanges between Olympia oyster populations

Bonnie Becker, UW Tacoma Interdisciplinary Arts and Sciences; Henry Carson, Washington Department of Fish and Wildlife; Marco Hatch, Northwest Indian College; Brian Allen and Betsy Peabody, Puget Sound Restoration Fund; Brent Vadopalas, UW School of Aquatic and Fishery Sciences

The native Olympia oyster played a key role in Puget Sound's ecology and economy. But despite cleaner water and an end to commercial harvests, it has failed to reestablish itself. An important question remains unanswered: to what extent does a restored oyster population self-seed, seed other sites, and exchange larvae with other populations? Genetic analysis assesses these connections across multiple generations, but restoration occurs on much shorter time scales. This project uses the distinctive chemical signatures of seawater at different locations to more speedily and precisely decipher the connections between various Olympia oyster populations.

Sound propagation models for Puget Sound to mitigate construction-noise impacts on marine life

Peter Dahl, UW Applied Physics Laboratory

Underwater noise from marine construction can threaten marine mammals such as killer whales and other sensitive species. Developers must establish monitoring plans to prevent animals' exposure to harmful noise levels. Currently, monitoring plans are based on a simple model for underwater sound transmission that may fail to accurately estimate levels across tens of square kilometers, potentially increasing plan size and inflating construction costs. This project is undertaking a detailed study of sound propagation in Puget Sound waters to develop a new and more accurate model. The goal is to provide a more cost-effective means to address marine construction noise and more reliable protection for sensitive marine animals.

Local adaptation of Pacific cod in Puget Sound

Lorenz Hauser, UW School of Aquatic and Fishery Sciences; Michael Canino, NOAA Alaska Fisheries Science Center; Tien-Shuin Tsou, Washington Department of Fish and Wildlife

Puget Sound is the southern edge of Pacific cod's natural range, and the species appears to be affected by warming water temperatures. The Sound's population has declined for several decades, especially compared with abundant North Pacific stocks, which support one of the world's most valuable fisheries. Partly because of its genetic isolation from ocean populations, Puget Sound Pacific cod was recently listed as a federal species of concern. This project examines the population's genetic makeup and level of local adaptation, in order to better understand the species' ability to adapt to a warming climate and help state and tribal managers plan its protection and recovery.

Prevalence and virulence of sea star wasting syndrome along the Washington coast

Benjamin Miner, Western Washington University (WWU) Department of Biology; Melissa Miner, University of California, Santa Cruz, Long Marine Lab

Sea star wasting syndrome is a general description of a set of symptoms that are found in many species of sea stars. Lesions appear, rapidly expand, and eventually cause the body to fragment and the individuals to die. Wasting disease can progress rapidly, leading to death after just a few days following the first appearance of symptoms. This project focuses on assessing disease prevalence in the Salish Sea and enlists the help of established citizen science programs, including those coordinated by WSG, to sample more easily-accessible areas.

Fine-scale monitoring of Puget Sound ecosystems using benthic foraminifera

Elizabeth Nesbitt, UW Department of Earth and Space Sciences and the Burke Museum

Benthic foraminifera (forams) are microscopic shelled protists that live at the bottom of marine food webs. Dozens of different foram species are common in marine sediments. The species' makeup, type, and condition of shells are sensitive to environmental conditions, making them a useful indicator of marine and coastal pollution. This project continues an ongoing WSG-funded project to refine the use of forams as a low-cost, reproducible tool for fine-scale assessments of ecological health and for monitoring benthic ecosystems. This tool is being tested in three of the most vulnerable areas of Puget Sound: heavily industrialized Superfund sites in Central Sound, Hood Canal, and South Sound.

Monitoring killer-whale miscarriages: Is there a salmon connection?

Sam Wasser, UW Center for Conservation Biology

Since the 1990s, southern resident killer whales, the Salish Sea's iconic apex predators, have suffered a dramatic unexplained decline. The U.S. recovery plan identifies three potential causes: disturbance from vessel noise; exposure to persistent organic pollutants; and diminished food supply, in particular Chinook salmon. Hormonal analysis of fecal samples gathered using scat-detection dogs from 2008 through 2013 revealed a high incidence of miscarriages. Half occurred late in the pregnancy and appeared to be tied to poor nutrition and the presence of toxicants. This project continues sampling through 2015 in order to determine the outcomes of 2013 conceptions and maintain data continuity for planned long-term monitoring. Strong Columbia River salmon returns in 2014 make this data particularly important for understanding the relationship between nutrition and pregnancy success.

Salmon

Marine carrying capacity and first-year mortality of Chinook salmon

James Anderson and Jeffery Rutter, UW School of Aquatic and Fishery Sciences; Richard Zabel, NOAA Northwest Fisheries Science Center (Sea Grant/NOAA Fisheries Fellow in Population Dynamics)

A central element of many strategies for the recovery of wild salmon populations has been increasing the production of outmigrating smolts and larger juveniles in hatcheries. However, these increases appear to have had little effect on the number of adults returning. This suggests that density-dependent processes limit the production of adults. This project develops a theoretical framework for identifying the mechanisms influencing marine car-

rying capacity for juvenile salmon. It analyzes tagging and run-size databases and develops and tests new models to determine whether adult returns are related to smolt production in Chinook populations in the Columbia River basin. The results will inform management strategies to improve the outlook for wild salmon. Though the study focuses on Columbia River Chinook, its theoretical framework will apply to all anadromous fish.

Critical growth periods and causes of marine mortality in Puget Sound's juvenile Chinook salmon

David Beauchamp, UW School of Aquatic and Fishery Sciences; Julie Keister, UW School of Oceanography

Young Chinook salmon spend many months in nearshore habitats such as estuaries while they transition from fresh to salt water. Over time, researchers have found persistent problems in the early marine survival of young Chinook salmon in Puget Sound. This project is investigating possible factors behind this juvenile mortality by conducting assessments of size-selective mortality patterns in juvenile Chinook salmon. Researchers are studying a range of habitats as the small fish grow and migrate through Puget Sound. Findings will help identify critical growth periods for young salmon and the factors that affect growth during those periods. The project could provide critical information to assist watershed-based Chinook restoration and management.

Assessing stakeholder partnerships and improving collaborative governance in West Coast salmon recovery

Nives Dolšak, UW School of Marine and Environmental Affairs; Sara Singleton, WWU Department of Political Science

Northwest salmon and steelhead continue to face severe conservation challenges, with half of Washington's 32 populations listed as threatened or endangered. This project examines governance in salmon recovery and assesses conservation efforts that involve stakeholder collaboration and local involvement. It seeks to better understand governance processes in complex coastal and marine issues and improve collaboration between resource management and stakeholder groups. The project compares salmon recovery in two regions, Puget Sound and the Lower Columbia River, and assesses stakeholder involvement in three types of issues: land use, water quality, and habitat preservation.

Use of ancient, historical and modern salmon DNA to parse effects of human-induced change

Brian Kemp, WSU Department of Anthropology; Gary Thorgaard and Bobbi Johnson, WSU School of Biological Sciences

Salmon genotypes are routinely compared across watersheds – but not across time – even though human activities such as industrial fishing, dam building, and translocation and mixing have profoundly affected salmon populations over the last two centuries. This project intends to correct that knowledge deficiency by mapping the genetic structures of upper Columbia basin Chinook salmon in the 19th century and the dam-building years (1930–1950). It compares these to current structures and ancient genotypes derived from DNA preserved in 7,600-year-old archeological vertebrae samples. By producing a high-resolution picture of genetic change in response to major human impacts, this effort intends to add a fifth *h*, history, to “harvest, hydro-power, hatcheries, and habitat,” the familiar tetrad of influences that currently guide salmon management. The informed baselines thus developed may lead to more effective evaluation, restoration, and reintroduction of salmon populations.

Assessment of fitness-related genetic change to evaluate breeding practices in conservation hatcheries

Kerry Naish, UW School of Aquatic and Fishery Sciences; Kenneth Warheit, Washington Department of Fish and Wildlife; Maureen Purcell and Diane Elliott, U.S. Geological Service; David Fast, Yakima Nation Fisheries

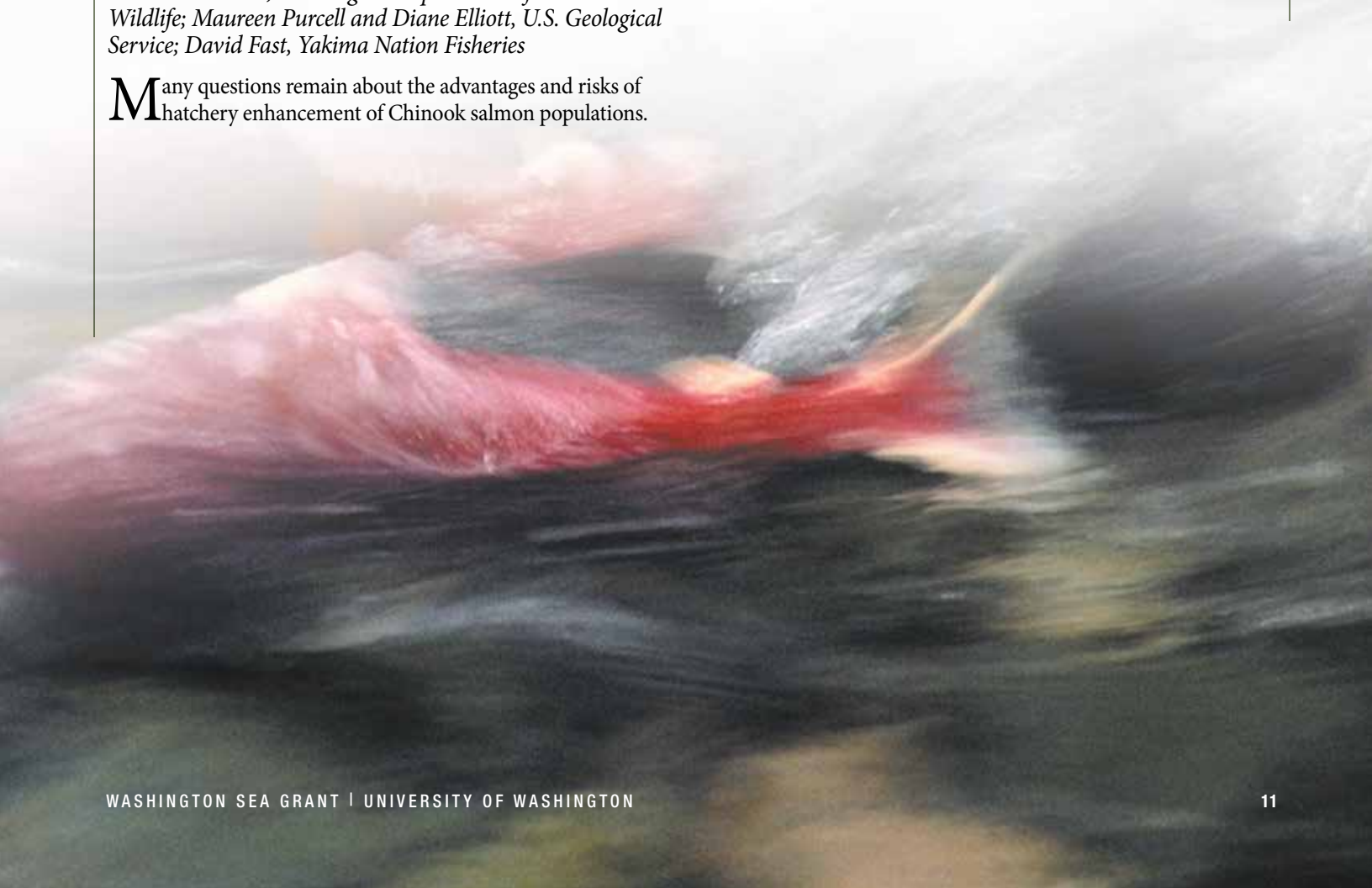
Many questions remain about the advantages and risks of hatchery enhancement of Chinook salmon populations.

This project is examining two approaches at the same hatchery: one that uses returning hatchery fish as broodstock, and another that uses only naturally spawned wild fish. Research assesses the rate of genetic change for offspring of each stock related to fitness traits and links to early development and disease resistance. Findings help managers develop best practices for enhancement programs, including insights into use of hatchery and wild fish broodstock to preserve population fitness. The project also develops genetic techniques for testing management approaches, assessing risk, and monitoring.

Salmon recovery and transformation following the Elwha River dam removals

Thomas Quinn, UW School of Aquatic and Fishery Sciences

Pacific salmon and trout are among the region’s most important fishes, keystone species in stream and riparian ecosystems. In 2014, the largest dam-removal project in U.S. history culminated in the full reopening of one of the region’s most productive streams, home to all five native salmon and two sea-run trout species. Scientists, resource managers, tribal residents, and the public are eager to see how the Elwha ecosystem will respond. This study is capturing critical baseline data on pre-removal habitats and the origin, genetics, behavior, and bioenergetics of their diverse salmon and trout populations. It chronicles their transformations as landlocked and ocean-going fish meet, mix, compete, and reestablish their life histories.



III RESILIENT COMMUNITIES

Hazard Resilience and Climate Adaptation

Facilitation of climate change adaptation in coastal communities

Sue Blake, Nicole Faghin, Ian Miller, Washington Sea Grant; Jamie Mooney, Washington Sea Grant and NOAA Pacific Marine Environmental Laboratory Liaison (PMEL)

State climate change projections suggest that Washington's coastal communities will bear the physical and ecological brunt of rising ocean temperatures and sea levels, more frequent storms, and other impacts. As a result, there is growing demand for vulnerability assessments and adaptation strategies at various community and governmental scales. WSG staff members are working with coastal communities to assess their vulnerabilities to climate change, develop adaptation plans, and implement priority actions identified in those plans. WSG develops and offers courses on planning for climate change; develops an enhanced Carbon Masters course; facilitates or conducts vulnerability assessments for communities and constituents; and promotes and conducts applied research to identify climate impacts in coastal Washington.

Identification and measurement of successful climate change adaptation

Pamela Matson (regional lead) and Susan Moser, Stanford University School of Earth Sciences; Amy Snover (Washington lead), UW Climate Impacts Group; Hannah Gosnell, Oregon State University Department of Geosciences

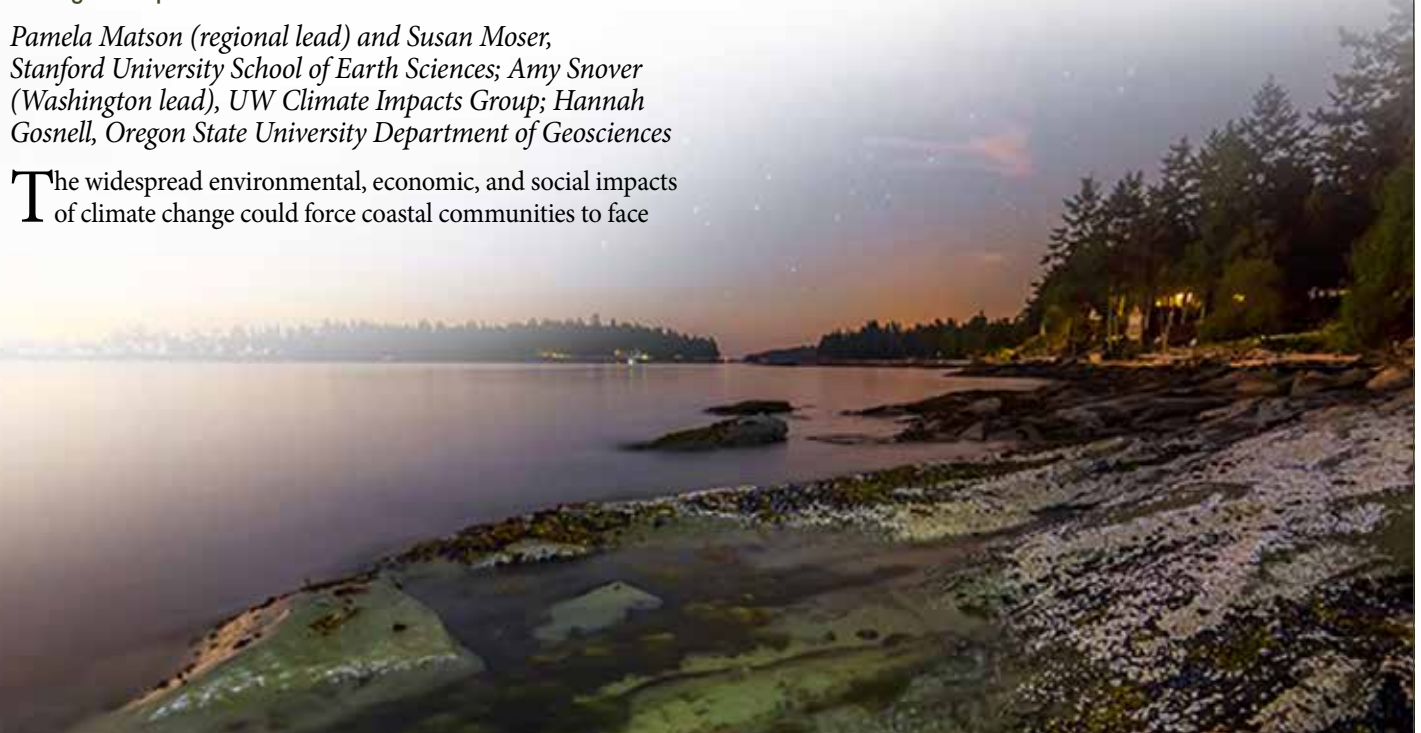
The widespread environmental, economic, and social impacts of climate change could force coastal communities to face

difficult choices and trade-offs in the decades ahead. Managing impacts of climate change and sea-level rise on coastal resources is a major concern in all three West Coast states. This regional project engages scientists and coastal practitioners in answering the question, "What would successful adaptation to climate change look like?" It explores adaptation outcomes, processes, and mechanisms as well as metrics that could measure the success of adaptation in California, Oregon, and Washington coastal communities.

Building tsunami resilience by modeling transportation disruption and disaster recovery

Scott Miles and Rebekah Green, WWU Environmental Studies; Anne Goodchild, UW Department of Civil and Environmental Engineering

Washington's outer coast faces serious seismic and tsunami hazards. Understanding and building community resilience to such crises requires examining recovery trajectories across multiple space and time scales, particularly for transportation disruption, restoration, and reconstruction. This project models such trajectories for Pacific County by synthesizing current estimates of prospective losses, community input, and computer simulations. The findings will inform recovery plans and policies and strengthen local and regional partnerships.



Shorelines as barriers to storms and sea-level rise

Ian Miller, Washington Sea Grant

Shorelines act as barriers against flooding, tsunamis, and other coastal hazards. But little is known about the behavior and evolution of common Washington shoreline types such as bluffs, sheltered low-energy beaches, and high-energy sand coasts with much more wave action. These knowledge gaps limit our ability to understand what drives coastal erosion, flooding, and inundation and how to safeguard communities from these and other coastal changes. WSG is investigating rates of shoreline change, patterns of bluff erosion, possible effects of sea-level rise, and the relative effectiveness of various natural shoreline barriers and human-made armoring and engineering approaches. Staff is helping wrap up a boat-based LiDAR survey of Elwha and Dungeness coastal bluffs and developing a methodology for measuring bluff erosion using aerial LiDAR and trials at Quinault. WSG is also leading an effort to improve estimates of vertical land movement, which modulates the effects of sea-level rise in this tectonically active region.

Training and tools to prepare for coastal hazards

Jamie Mooney, Washington Sea Grant and NOAA Pacific Marine Environmental Laboratory Liaison; Nicole Faghin and Ian Miller, Washington Sea Grant

WSG works with local entities to offer training and technical assistance to build community resilience and adaptive capacity. WSG offers National Disaster Preparedness Training Center courses on flood-risk reduction and conducts applied research on ways to improve coastal resilience. It reviews hazard and shoreline master plans for Olympic Peninsula communities, supports the incorporation of climate-change adaptation and stronger resilience in Snohomish County's Hazard Mitigation Plan, and works with UW researchers to embody seismic information in community planning mechanisms. Building on the model established by Sea Grant programs around the coast, WSG is working to complete a Homeowners Handbook for Natural Hazards for Puget Sound residents. Its Witness King Tides website and semiannual events inform coastal dwellers about these twice-yearly extreme tides. Through research and outreach such as mapping tsunami deposits and promoting a western Washington "Tsunami Trail," WSG builds public awareness and scientific understanding of this paramount coastal hazard.

Coastal hazard resilience network

Jamie Mooney, Washington Sea Grant and NOAA Pacific Marine Environmental Laboratory Liaison

Western Washington is susceptible to a diverse range of natural hazards ranging from common threats like coastal erosion and flooding to rare but potentially catastrophic events like earthquakes and tsunamis. Local, state, federal, and tribal governments have invested in hazard-related research and management, but planning and coordination remain limited. Partnering with

the Washington Department of Ecology, WSG has developed a statewide coastal hazard resilience network, with website and listserv, that connects researchers, planners, and communities. Such a network would transfer research findings to communities, encourage incorporation of lessons learned into community planning, and facilitate more effective mitigation, response planning, and community awareness.

Appraisal of sociocultural dimensions of climate change

Melissa Poe, Washington Sea Grant and NOAA Northwest Fisheries Science Center Liaison

The cumulative risks to the health and well-being of Pacific Northwest communities that face climate shifts and coastal hazards are largely unknown. Among the critical challenges these communities must address are needs to strengthen resilience, minimize vulnerability, and protect and restore marine ecosystems. This project is synthesizing the social science literature on the vulnerability of communities experiencing coastal hazards such as ocean acidification and climate change. It also leads the design of a community participation "rapid appraisal" in several Washington and Oregon communities facing such hazards. This appraisal assesses variables in culturally significant ecosystems, such as important food species and a communities' sense of place, and identifies anticipated and cumulative threats posed to them.

Marine and Coastal Planning, Management, and Restoration

Monitoring the physical and ecological outcomes of shoreline restoration efforts

Jeff Adams, Washington Sea Grant; Jason Toft, UW School of Aquatic and Fishery Sciences

Each year, state and federal governments spend millions of dollars funding competitively ranked projects for restoring salmon habitat. But they provide very little funding for monitoring, assessing the effectiveness of restoration approaches, or ensuring that ecological responses meet project goals. Using trained volunteers, WSG is conducting long-term monitoring — including topographic surveys and beach transect surveys of sediment, slope, and biological communities — of a large restoration project on a Bainbridge Island residential shoreline. WSG provides oversight, analyzes the data collected, supervises citizen volunteers, and shares results with others interested in shoreline restoration. WSG is also monitoring restorations at a Bremerton park and a private site near Silverdale and exploring the possibility of a network of long-term baseline monitoring sites around the Kitsap Peninsula. To support such restoration efforts, staff are completing a guide to shoreline plants, together with related web content, and a toolkit for volunteers and other shoreline monitors.

Evaluating marine protected areas' conservation role on Puget Sound

Patrick Christie and David Fluharty, UW School of Marine and Environmental Affairs; Richard Pollnac, University of Rhode Island; Brad Warren, Global Ocean Health

Set aside for species and habitat conservation, Puget Sound's marine protected areas (MPAs) offer potentially important management tools that could help restore overfished rockfish species. By supporting more robust populations, MPAs also may help increase the likelihood that marine species can adapt to ocean acidification. But little is known about how well MPAs are managed or how effective they are as conservation measures. This project is collaborating with state agencies, tribes, and stakeholders to fill knowledge gaps by using social science tools to compare 25 Puget Sound MPA sites. Findings are being used to create accessible public outreach materials as well as peer-reviewed publications.

Training and professional development for shoreline and coastal planners

Nicole Faghin, Washington Sea Grant

Communities, nongovernmental organizations, and coastal businesses in Western Washington need information to help them prepare for future coastal issues. WSG meets this need by providing training, outreach, network coordination, and technical assistance to support shoreline and coastal planning. Working with the Washington Department of Ecology, WSG established and continues to support the Shoreline and Coastal Planners Group (SCPG), which provides regular opportunities for coastal professionals to discuss policy concerns, new technologies, emerging issues, and other relevant topics. WSG maintains the SCPG email list and website, coordinates regular group meetings, develops training opportunities for shoreline planning professionals, facilitates new partnerships, provides a network for exchanging technical information, and coordinates training for planners with Ecology's Coastal Training Program.

Working waterfronts and waterways

Nicole Faghin, Washington Sea Grant

Working waterfronts contribute to local economies and are important to Washington's cultural and social heritage. But shoreline-dependent industries, government agencies, native tribes, and the public struggle over access to shorelines, waterways, and waterfronts. The past decade has brought significant, accelerating conversion of valuable waterfront real estate, with negative socioeconomic and environmental effects. WSG continues to work with stakeholders and other Sea Grant programs to promote the best uses of working waterfronts, hosting the 2013 National Working Waterfronts and Waterways Symposium in Tacoma and assisting with 2016 preparations. WSG is a member of the National Working Waterways Network and is working with the Washington Public Ports Association and other maritime entities to create a Washington network. It actively supports the efforts of a public and private

maritime education and training providers, and industry representatives, to strengthen maritime workforce capacity in the state.

Evaluating the sustainability of tidal energy development in Puget Sound

Brian Kirk, Washington Sea Grant

Clean, renewable energy from the ocean can reduce carbon dioxide emissions. Puget Sound is one of the few U.S. regions with good tidal energy potential, but underwater current-driven electrical generation faces technical, economic, environmental, and social challenges. WSG is part of a multidisciplinary team evaluating the sustainability of large-scale tidal energy, using Puget Sound as a case study. Project goals are to advance our understanding of tidal energy systems, quantify trade-offs between technological, environmental, and social costs, and create tools for developing a sustainable industry. WSG pulls together the outreach effort, meeting with potential stakeholders, staffing community meetings, and providing other support as needed.

Brokering lane agreements between crabbers and towboat operators

Steve Harbell, Kevin Decker, Sarah Fiskens, Washington Sea Grant

In the late 1970s, conflicts between ocean-going tugs and commercial crabbers in Washington, Oregon, and California were a major problem. Crab pots fouled tugs as they moved between coastal ports, and the loss of gear created severe hardship for towboat owners. Sea Grant programs on the West Coast helped broker an agreement that provided navigable towboat and barge lanes through the crabbing grounds between Cape Flattery, Washington, and San Francisco. Since the late 1990s, WSG has led the process, maintaining the industries' cooperation and saving them more than \$1 million annually. WSG continues to hold several negotiations each year, improve electronic towlane charts, and evaluate the project's economic impacts. In addition, WSG is facilitating discussions between industry and the National Weather Service and U.S. Coast Guard to improve marine weather forecasting and coastal bar closure policies, and highlighting discussion outcomes.

Coastal response and recovery following the Elwha dam removals

Ian Miller, Washington Sea Grant

The historic removal of two Elwha River dams has unleashed a massive flux of sediment — the largest beach nourishment experiment in Washington history. WSG is monitoring changes in beach morphology on the previously eroding Elwha delta and investigating potential habitat recovery along the adjacent Strait of Juan de Fuca. It assists estuary bathymetry and intertidal community surveys by the Lower Elwha Klallam Tribe and biannual topography and bathymetry surveys by the U.S. Geological Survey, and serves as lead partner in USGS-led surveys of subtidal biological communities.

Sociocultural indicators of human well-being for ecosystem management

Melissa Poe, Washington Sea Grant and NOAA Northwest Fisheries Science Center Liaison; Penny Dalton, Washington Sea Grant

Ecosystem-based management is gaining new importance in ocean and coastal policymaking, and integrated ecosystem assessments (IEAs) are an important tool in this work. To foster a better understanding of the social dimensions in policy-making, the NOAA Northwest Fisheries Science Center and WSG have established a social science liaison housed at WSG. The liaison serves as a bridge between NOAA, WSG, and various regional partners, helping both agencies address sociocultural well-being and community resilience, and participating in a national Sea Grant social science network. In this joint work with the Northwest Center and the UW School of Marine and Environmental Affairs, one initial focus is the development of noneconomic indicators of human wellbeing for use in Puget Sound and California Current IEAs.

Effects of sediment porewater sulfide on eelgrass health and distribution in Puget Sound

David Shull, Sylvia Yang, and Denise Crowe, WWU Shannon Point Marine Center; Jennifer Ruesink, UW Department of Biology; Sandy Wyllie-Echeverria, UW Friday Harbor Laboratories

Eelgrass is an ecologically, economically, and culturally important aquatic plant that also serves as an indicator of the health of Puget Sound estuaries. The Puget Sound Partnership action agenda seeks to expand regional eelgrass acreage by 20 percent by the year 2020, but porewater sulfide (a product of microbial activity in low-oxygen conditions) may work to limit eelgrass distribution. This study is surveying two sites to understand the relationship between eelgrass abundance and sediment porewater sulfide. The results will assist development of eelgrass restoration strategies.

Marine spatial planning for Washington's Pacific coast

Bridget Trosin, Penny Dalton, Kevin Decker, Washington Sea Grant and Melissa Poe, Washington Sea Grant and NOAA Northwest Fisheries Science Liaison

Growing demand for marine resources creates competition and conflict between uses, from shipping and fisheries to scientific exploration and energy development. Marine spatial plans (MSPs) grounded in strong public participation and science-based decision making can be important tools for balancing these interests, preserving existing sustainable uses, and maintaining ocean health. WSG is part of the state team charged by the legislature with developing an MSP for Washington's outer coast. Its role is to help coastal communities understand marine spatial planning and facilitate information sharing between state planners, federal partners, tribes, local marine resource committees, and other stakeholders. WSG conducts public outreach, facilitates planning meetings and workshops, and coordinates the

project's independent scientific review. It supports the MSP effort by evaluating state economic indicators as population, income, and employment trends; conducting an economic base analysis focusing on primary export industries; developing a conceptual model of the effort's human dimensions; reviewing and synthesizing approaches to mapping human values; and identifying spatial indicators of human uses and values.

Shoreline Living and Work

Technical assistance and homeowner support to improve local water quality

Jeff Adams, Sue Blake, Teri King, and Jennifer Runyan, Washington Sea Grant

Stormwater runoff and poor residential practices are major sources of toxins, chemicals, pathogens, nutrients, and sediment flowing into Puget Sound. WSG educates people and communities about how to become part of the solution by reducing stormwater pollution. The program continues to help citizens understand their impacts on the marine environment, enlisting them in activities and best practices that promote environmental stewardship, such as sustainable landscaping, natural yard care, septic system maintenance, natural cleaning products, and rain gardens.

Environmental and economic impacts of West Coast moorage marinas

Christine Bae, UW Department of Urban Design and Planning; Nathaniel Trumbull, University of Connecticut; James Elliott Moore, USC; Ji Young Park, State University of New York at Buffalo

Recreational marinas are growing rapidly on the West Coast but fall outside most research disciplines. This interdisciplinary study gauges the net economic impacts and investigates the environmental externalities of moorage marinas in Southern California and Western Washington. It uses GIS to correlate marina locations and NOAA Mussel Watch data on pollution and other impacts since 1986. Researchers compare economic and environmental impacts under baseline and alternative scenarios, helping regulators and coastal communities develop smart, well-informed marina policies.

Clean vessels, pumpouts, and prevention of pollution from boat sewage

Aaron Barnett and Brian Kirk, Washington Sea Grant

In partnership with the Washington State Parks Clean Vessel Act program, WSG educates boaters about the importance of proper sewage disposal and the location of pumpout stations, helps marina operators secure grants to install more stations, and consults on the deploying mobile pumpout services in heavily used waters. WSG conducts direct outreach to boaters, port districts, and marinas statewide through site visits, boat shows, and

other events, emphasizing underserved areas with high boater concentrations. It shows boaters how to use pumpout stations and distributes adapters that mechanically connect pumpout hoses to boat holding tanks, eliminating a common source of sewage spills and reducing boaters' reluctance to use pumpouts. To better understand boating impacts, WSG is designing a study to measure sewage discharges at a popular boating site.

Washington Clean Marina Program and prevention of small oil spills from fishing vessels and recreational boats

Aaron Barnett, Sarah Fiskén, and Brian Kirk, Washington Sea Grant

Small oil spills from commercial and recreational vessels are often the result of a lack of knowledge about proper techniques for vessel operation and maintenance. To address this problem, WSG works with state and regional partners to determine the most common causes of spills based on reported incidents. Using this data, WSG develops outreach approaches to educate vessel owners and help them improve their operations, reducing spills due to targeted causes. At the same time, WSG promotes spill reporting through the "Spills Aren't Slick" campaign. WSG, in an ongoing partnership with the Washington Clean Marina program, reviews and updates boating facility best management practices, and inspects and certifies Clean Marinas. WSG incorporates oil spill prevention into classes and workshops for commercial fishermen, and distributes spill cleanup kits at marinas, boat shows, and other boating venues.

Incentives for sustainable shoreline development

Nicole Faghin and Ian Miller, Washington Sea Grant

Each year Washington loses more of its natural shorelines to development and erosion-control structures such as bulkheads, seawalls, and riprap. WSG is working on several fronts to stem the loss and encourage environmentally friendly shoreline development. As a lead partner in Green Shores for Homes, WSG is developing voluntary incentives for sustainable coastal planning, design, and development. Patterned after the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED), Green Shores will promote alternatives to traditional development and work to minimize environmental impacts in a cost-effective manner. To encourage homeowners to adopt shoreline-friendly practices, Green Shores proposes a credit rating system that currently is under development by WSG, the City of Seattle, San Juan County, British Columbia's Island Trust, and the Green Shores technical team. With the Puget Sound Partnership and others, WSG encourages soft-shore alternatives to armoring and greater shoreline setbacks, and assists homeowners and others interested in shoreline restoration to find alternatives to conventional armoring.

Retail boat sale tracking

Robert Goodwin, Washington Sea Grant (retired)

Year after year, Washington's boating industry — from boat building to retail sales — is an important contributor to the state's economy. WSG continues to partner with the Washington Department of Licensing and Northwest Marine Trade Association to provide quarterly and yearly data on in-state boat sales. This information helps dealers monitor sales trends to make more informed business decisions, redirect strategies as needed, and boost overall sales. State officials also use the information to locate new pumpout stations for boat waste, target oil-spill prevention outreach, and verify demand for new in-water moorage and dry-stack storage.

Test of a prototype waterfront stormwater system to treat coastal runoff

Nancy Rottle, UW Department of Landscape Architecture; Richard Horner, UW Department of Civil and Environmental Engineering

This project is assessing the capacity of a multi-functional water treatment feature to simultaneously reduce contamination and environmental degradation caused by stormwater runoff and provide high-quality public space. Initial plans were to test the prototype in Coupeville, located on Whidbey Island's shellfish-rich Penn Cove. However, delays in construction have led to use of an alternative location in Manchester, Kitsap County. The project trains residents and student researchers and deepens public understanding of shoreline and aquatic issues. If successful, this innovative design approach will help other coastal communities find ways to capture the economic, aesthetic, and environmental benefits of green shoreline infrastructure.

Biological effectiveness of bioretention for stormwater control

John Stark and Jenifer McIntyre, WSU Puyallup Research and Extension Center; Nathaniel Scholz, NOAA Fisheries Northwest Region; Jay Davis, U.S. Fish and Wildlife Service

Bioretention systems such as rain gardens are a cornerstone of low-impact development: inexpensive, widely applicable techniques for reducing runoff and removing toxins from stormwater. Most evaluations of bioretention have focused on physical and chemical metrics rather than biological criteria. This project evaluates the effects of untreated and bioretention-treated stormwater on pre-spawn mortality in adult coho salmon, and on coho embryos and aquatic invertebrates in simulated urban streams. The results will provide local governments and other stakeholders a better understanding of bioretention.

IV OCEAN LITERACY

Citizen Science and Volunteers

Citizen science support and use in research and resource management

Kate Litle, Washington Sea Grant

Involvement in citizen science can deepen public knowledge, awareness, and sense of place, and inspire behavioral change. Citizen science can also provide rigorous, cost-effective data collection for research, monitoring, and management needs. WSG is working to foster connections between scientists, managers, volunteer groups, and others; provide consultation for citizen science programs; and develop resources to help link citizen science projects to scientific programs where these efforts can contribute. Among those resources is Citizen Science Washington, an online clearinghouse of information on programs in the state. WSG also offers small competitive citizen science grants to qualifying individuals and groups.

Bivalves for Clean Water: enlisting coastal residents in water quality and shellfish enhancement

Teri King and Jennifer Runyan, Washington Sea Grant

The Bivalves for Clean Water program uses shellfish to educate marine shoreline owners and recreational shellfish harvesters about coastal pollution and ecosystem health. The program introduces local property owners and harvesters to the water quality and shellfish resource management issues challenging Puget Sound and Hood Canal. This multifaceted approach lets participants choose activities that fit their individual learning styles and interests. Activities offered include workshops, fieldtrips, shellfish enhancement activities, citizen monitoring, beach walks and assessments, site visits, publications and one-on-one technical assistance. WSG recruits and trains volunteers to identify and eliminate pollution sources in their watersheds, enhance recreational shellfish populations, and conduct safe recreational harvest trips. Tribal, state, and industry partners contribute shellfish for planting in enhancement projects.



Support for volunteer stewardship programs along Puget Sound

Jeff Adams and Sue Blake, Washington Sea Grant

Shoreline homeowners and those living and working in coastal watersheds are more likely to protect natural features that they appreciate and use. Continuing education opportunities deepen volunteers' understanding of intertidal natural history and conservation, shoreline restoration, and other watershed issues, building their proficiency to inform the public and contribute to local monitoring programs. In collaboration with WSU's Kitsap County Extension, WSG is coordinating the Kitsap Watershed Stewardship Program, whose participants include Beach Naturalists, Salmon Stewards, Stream Stewards, and Native Plant Advisors. WSG also will continue its collaborative effort to develop a certified Master Naturalist program with a peer-reviewed curriculum that produces knowledgeable, dedicated citizens to promote the stewardship of Washington's marine and coastal resources.

The COASST model: determining what makes citizen science succeed

Julia Parrish, UW School of Aquatic and Fishery Sciences; Shawn Rowe, Oregon State University; Heidi Ballard, University of California-Davis

Citizen science offers unique opportunities to build public engagement and community capacity while addressing major environmental and resource issues in a timely, cost-efficient way. Effective programs enhance science learning, long-term public involvement, and the knowledge needed to collect accurate data. This project gauges the essential elements of a rigorous, successful coastal citizen science program quantitatively and qualitatively, using individual demographics; organizational, community, and regional predictors; and focus group evaluations. Its focus is on COASST, a coastal observation and seabird survey team that operates along the West Coast as far north as Alaska.

Ocean Learning

Marine education events for students and the public

Jeff Adams, Sue Blake, Kevin Decker, Steve Harbell, Teri King, and Jennifer Runyan, Washington Sea Grant

To improve coastal residents' understanding of the importance of the marine environment, WSG continues to organize, sponsor, and participate in theme-based education events throughout western Washington. These include Kids' Day at Mason County's OysterFest, the Kitsap Water Festival, Whatcom Water Weeks, tideflat tours at the Hama Hama Oyster Rama, a touch tank at the Allyn Geoduck Festival, public beach walks, and student beach explorations. WSG hosts a monthly talk show on marine issues on Aberdeen's KBKW-AM. WSG also partners with the WSU Extension in Whatcom County to produce public-education and applied-research programs focused on local waters and watersheds, and create an information network promoting stewardship, community awareness, access to partnerships, and project coordination.

Development of a digital library

Marcus Duke and Robyn Ricks, Washington Sea Grant

In more than 40 years of operation, WSG has developed hundreds of technical and scientific publications, some of which remain among the best-known references on the Puget Sound and Washington coast marine environments. To address continuing requests for these publications, many of which are out of print with very limited availability, WSG digitizes and archives them, making them available for download from the redesigned website. The current inventory of online publications is being updated with a feature to ease publication searches and include a request function allowing constituents to identify priorities for digitizing vintage documents.

Collaborative scholarships and mentoring programs

Nancy Reichley, Jeff Adams, Nicole Faghin, and Ian Miller, Washington Sea Grant

In addition to fellowships and internships, WSG provides opportunities for a wide range of university students interested in the sciences to enhance their learning experiences. WSG marine advisory specialists serve as mentors for undergraduate Capstone students from the UW Program on the Environment (PoE). In addition, WSG provides dedicated funding or teaching support for PoE's graduate-level Keystone program to address environmental management issues that align with WSG priorities. Student participants in Keystone projects can go on to earn an environmental management certificate. WSG partners with the Washington NASA Space Grant Consortium to support undergraduate scholarships and summer research opportunities for students pursuing degrees in the marine sciences. Field staff routinely explore opportunities for students from local colleges

and education institutions to participate in WSG projects and student research positions. One recent example is establishment of a pilot internship program for students attending the North Olympic Peninsula Skills Center.

Graduate and postgraduate fellowships in marine policy and science

Nancy Reichley, Washington Sea Grant

The future health of oceans and coastal areas depends on the next generation of leaders in marine policy and science. WSG coordinates state applications for the national Sea Grant fellowship programs including Knauss, Sea Grant–NOAA Fisheries Fellowships, and NOAA Coastal Management fellowships. It also offers the Marc Hershman Marine Policy Fellowship, which places graduate students in state agencies and marine organizations in Olympia, Tacoma, and Seattle for one year to work on ocean and coastal science and management issues. WSG actively promotes fellowship opportunities, recruiting top-tier students from across the state. Strong partnerships with host offices ensure high-quality experiences, productive contributions, and frequent post-fellowship employment opportunities.

Science communications fellowships

Nancy Reichley and MaryAnn Wagner, Washington Sea Grant

The impact of a marine research project may depend on how results are communicated to a broad audience. WSG staff mentor communications fellows, allowing them to earn credentials and gain entry-level experience in the field. The program draws potential fellows from academic institutions around the state. To build their portfolios, fellows are encouraged to write feature-length articles and shorter news pieces for *Sea Star*, contribute to social media and the website and become involved in other Sea Grant communication projects and campaigns.

WOW, a marine education resources database

Nancy Reichley, Washington Sea Grant

Washington on Water (WOW) is a unique web-based regional resource center that supports a regional marine education network of K–12 educators, academia, government, businesses, and nonprofit organizations. To support high-quality marine education, WOW provides comprehensive, readily accessible information on local marine science topics, classroom support resources, and professional development opportunities, with secondary emphasis on relevant national resources. The database currently lists 362 resources and is updated frequently. WSG is conducting an evaluation to guide continued improvements in WOW's user interface and available resources.

NOAA Science Camp and Junior Leadership Program

Maile Sullivan, Washington Sea Grant

Five-day summer-camp sessions at NOAA's Sand Point facility give sixth, seventh, and eighth graders the opportunity to explore marine sciences in an environment that encourages both personal growth and interest in NOAA-related professions. Participants are introduced to earth and ocean sciences and to science careers through hands-on activities emphasizing solutions to real-world problems. Each session, NOAA scientists and students come together to explore and solve an environmental mystery. To keep older teens in the "science pipeline," the junior leadership camp immerses high school students in youth leadership, inquiry-based science, and career development. WSG continues offering science camps that engage middle and high school students and introduce them to the interdisciplinary nature of NOAA research. One goal is design of a performance evaluation strategy to track former participants and assess the program's long-term impacts.

Orca Bowl, Washington's high school ocean sciences tournament

Maile Sullivan, Washington Sea Grant

This academic competition and ocean-literacy event challenges high school students' knowledge of science, math, and technology in the context of the world's oceans, recognizes their accomplishments, provides enhanced enrichment for participants and their schools, and fosters interest in ocean-related studies and careers. Students tackle rapid-fire short-answer questions that test problem-solving skills and embrace all areas of marine science. All receive prizes for participation, with top awards that include scholarships and shipboard science experiences. The winning Orca Bowl team competes in the National Ocean Sciences Bowl (NOSB) finals, with support from the Consortium for Ocean Leadership. The program encourages participation by new schools, targeting underserved communities that would especially benefit from marine-science resources.

Sea Star, WSG newsletter

Eric Scigliano, MaryAnn Wagner, and Robyn Ricks, Washington Sea Grant

Sea Star is published quarterly and distributed to more than 3,000 constituents. The newsletter features stories about current research projects, emerging issues, and notes from the field. *Sea Star* continues to be an important outreach tool for WSG; one survey indicated that nearly three-quarters of subscribers continue to read most of the articles in each issue, and more than 60 percent of readers still prefer the print edition to an electronic format. WSG communications staff continue efforts to expand *Sea Star* features and increase readership.

CONTACT INFORMATION

Jeff Adams

Marine Water Quality
Specialist
Washington Sea Grant
University of Washington
345 Sixth St., Suite 350
Bremerton, WA 98337
360.337.4619
jaws@uw.edu

Brian Allen

Puget Sound
Restoration Fund
590 Madison Ave. N
Bainbridge Island, WA 98110
360.280.7410
brian@restorationfund.org

Chris Anderson

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.1101
cmand@uw.edu

James Anderson

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.6396
jjand@uw.edu

Mary Arkoosh

NOAA Northwest Fisheries
Science Center
2032 SE OSU Drive
Oregon State University
Newport, OR 97365
541.867.0327
mary.arkoosh@noaa.gov

Christine Bae

Dept. of Urban Design
and Planning
University of Washington
Box 355740
Seattle, WA 98195
206.543.4190
cbae@uw.edu

Heidi Ballard

Environmental Science
Education
University of California
Davis
One Shields Ave.
Davis, CA 95616
530.754.6255
hballard@ucdavis.edu

Neil Banas

Joint Institute for the Study
of the Atmosphere and
Ocean
University of Washington
Box 355351
Seattle, WA 98195
206.221.4402
neil@ocean.washington.edu

Aaron Barnett

Boater Outreach Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.8929
aaronb5@uw.edu

David Beauchamp

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.221.5791
davebea@uw.edu

Bonnie Becker

School of Interdisciplinary
Arts and Sciences
University of Washington
Tacoma
1900 Commerce St.
Tacoma, WA 98402
253.692.4546
bjbecker@uw.edu

Brian Bill

NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112
206.860.3387
brian.d.bill@noaa.gov

Brady Blake

Washington Dept. of Fish
and Wildlife
Point Whitney Shellfish
Laboratory
1000 Point Whitney Rd.
Brinnon, WA 98320
360.586.1498 x 223
brady.blake@dfw.wa.gov

Sue Blake

Water Resource Educator
Washington Sea Grant
Whatcom County Extension
1000 N. Forest St., Suite 201
Bellingham, WA 98225-
360.676.6736
sgblake@uw.edu

Trevor Branch

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.221.0776
tbranch@uw.edu

Mark Camara

USDA-ARS Shellfish
Genetics Program
Hatfield Marine
Science Center
Oregon State University
2030 S.E. Marine Science Dr.
Newport, OR 97365
541.867.0296
Mark.Camara@oregonstate.edu

Michael Canino

NOAA Alaska Fisheries
Science Center
7600 Sand Point Way NE
Seattle, WA 98115
206.526.4108
mike.canino@noaa.gov

Emily Carrington

Friday Harbor Laboratories
University of Washington
620 University Road
Friday Harbor, WA 98250
206.221.4767
ecarrington@uw.edu

Henry Carson

Washington Dept. of Fish
and Wildlife
1111 Washington St. SE
Olympia, WA 98501
360.902.2846
henry.carson@dfw.wa.gov

Rose Ann Cattolico

Dept. of Biology
University of Washington
Box 355325
Seattle, WA 98195
206.543.9363
racat@uw.edu

Meg Chadsey

Ocean Acidification Specialist
and NOAA PMEL Liaison
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.669.1387
wsgoa@uw.edu

Dan Cheney

Pacific Shellfish Institute
120 State Ave NE #1056
Olympia, WA 98501
360.754.2741
psi@pacshell.org

Patrick Christie

School of Marine and
Environmental Affairs
University of Washington
3707 Brooklyn Ave NE
Seattle, WA 98105
206.685.6661
patrickc@uw.edu

Christopher Costello

Bren School of Environmental
Science and Management
University of California
Santa Barbara
4410 Bren Hall
Santa Barbara, CA 93106
805.893.5802
costello@bren.ucsb.edu

Denise Crowe

Shannon Point Marine Center
Western Washington
University
1900 Shannon Point Rd.
Anacortes, WA 98221
360.293.2188
denise.crowe@www.edu

Peter Dahl

Applied Physics Laboratory
University of Washington
Box 355640
Seattle, WA 98105-6698
206.543.2667
dahl@apl.washington.edu

Penny Dalton

Director
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.543.6600
pdalton@uw.edu

Jay Davis

U.S. Fish and Wildlife Service
510 Desmond Dr. SE
Lacey, WA 98503
360.753.9568
jay_davis@fws.gov

Jonathan Davis

Taylor Resources Inc.
701 Broad Spit Rd.
Quilcene, WA 98376
360.765.3566
jdavis@bainbridge.net

Robert Deacon

Dept. of Economics
University of California
Santa Barbara
2127 North Hall
Santa Barbara, CA 93106
805.893.3670
deacon@econ.ucsb.edu

Kevin Decker

Marine Outreach Specialist
Washington Sea Grant
Grays Harbor College
1620 Edward P. Smith Dr.
Aberdeen, WA 98520
360.538.2521
kadecker@uw.edu

John Dentler

Troutlodge Sablefish LLC
8920 Franklin Ave
Gig Harbor, WA 98322
253.279.9950
jdentler@troutlodge.com

Walton Dickhoff
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3234
walton.w.dickhoff@noaa.gov

Joseph Dietrich
NOAA Northwest Fisheries
Science Center
Oregon State University
2032 SE OSU Drive
Newport, OR 97365
541.867.0264
Joseph.dietrich@noaa.gov

Nives Dolsak
School of Marine and
Environmental Affairs
University of Washington
Box 355685
Seattle, WA 98195
206.543.7004
nives@uw.edu

Marcus Duke
Computer Systems Admini-
strator and Web Editor
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.538.2521
mduke@uw.edu

Brian Dumbauld
USDA Agricultural
Research Center
Hatfield Marine Science
Center
Oregon State University
2030 SE Marine Science Dr.
Newport, Oregon 97365
541.867.0191
brett.dumbauld@oregonstate.edu

Diane Elliott
Western Fisheries
Research Center
U.S. Geological Service
6505 65th St. NE
Seattle, WA 98115
206.526.6282
dgelliott@usgs.gov

Tim Essington
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.616.3698
essing@uw.edu

Benoit Eudeline
Taylor Shellfish Farms
701 Broad Spit Rd.
Quilcene, WA 98376
360.765.3566
benoite@taylorshellfish.com

Nicole Faghin
Coastal Management
Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.8286
faghin@uw.edu

William Fairgrieve
NOAA Northwest Fisheries
Science Center
7305 Beach Dr. E
Port Orchard, WA 98366
360.871.8305
William.fairgrieve@noaa.gov

David Fast
Yakima Nation Fisheries
771 Pence Rd.
Yakima, WA 98902
509.966.5291
fast@yakama.com

João Ferreira
Dept. of Environmental
Sciences and Engineering
New University of Lisbon
Quinta da Torre 2829-516
Monte de Caparica, Portugal
351.21.2948300, ext. 10117
joao@hoomi.com

Bridget Ferriss
Marine Research Scientist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.8286
ferriss@uw.edu

Sarah Fiskén
Continuing Education
Coordinator
Washington Sea Grant
University of Washington
West Wall Bldg., Room 124
Fishermen's Terminal
Seattle, WA 98199
206.543.1225
sfisken@uw.edu

David Fluharty
School of Marine and
Environmental Affairs
University of Washington
3707 Brooklyn Ave NE
Seattle, WA 98105
206.685.2518
fluharty@uw.edu

Carolyn Friedman
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.9519
carolynf@uw.edu

Steven Gaines
Bren School of Environmental
Science and Management
University of California
Santa Barbara
Bren Hall
Isla Vista, CA 93117
805.893.7363
gaines@bren.ucsb.edu

Evan Gallagher
Dept. of Environmental and
Occupational Health Sciences
University of Washington
Box 354695
Seattle, WA 98195
206.616.4739
evang3@uw.edu

Frederick Goetz
NOAA Fisheries Northwest
Region
7305 E Beach Dr.
Port Orchard, WA 98366
360.871.8322
rick.goetz@noaa.gov

Anne Goodchild
Dept. of Civil and
Environmental Engineering
University of Washington
Box 352700
Seattle, WA 98195
206.543.3747
annegood@uw.edu

Robert Goodwin
(retired)
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
509.422.1733
goodrf@uw.edu

Hannah Gosnell
Dept. of Geosciences
Oregon State University
104 CEOAs Administration
Building
Corvallis, OR 97331
541.737.1222
gosnellh@geo.oregonstate.edu

Pete Granger
Seafood Industry Specialist
Washington Sea Grant
Whatcom County Extension
1000 N. Forest St.
Bellingham, WA 98225
360.223.3995
pgranger@uw.edu

Rebekah Green
Huxley College of the
Environment
Western Washington
University
516 High St., MS 9085
Bellingham, WA 98225
360.650.2707
rebekah.green@wwu.edu

Cheryl Greengrove
University of Washington
Tacoma
1900 Commerce St.
Tacoma, WA 98402
253.692.5658
cgreen@uw.edu

Kurt Grinnell
Jamestown S' Klallam Tribe
1033 Old Blyn Highway
Sequim, WA 98382
360.461.1229
nativetrust@hotmail.com

Daniel Grünbaum
School of Oceanography
University of Washington
Box 354350
Seattle, WA 98195
206.221.6594
grunbaum@ocean.washington.edu

Melissa Haltuch
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3480
melissa.haltuch@noaa.gov

Steve Harbell
Marine Field Agent
Washington Sea Grant
University of Washington
324 S. Main Street
Montesano, WA 98563
360.249.2007
sharbell@uw.edu

Chris Harvey
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3228
chris.harvey@noaa.gov

Marco Hatch
National Indian Center
for Marine Environmental
Research and Education
Northwest Indian College
2522 Kwina Rd.
Bellingham, WA 98226
360.594.4082
marcoh@nwic.edu

Lorenz Hauser
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.685.3270
lhauser@uw.edu

Eileen Herman
Administrative Assistant
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.9117
emherman@uw.edu

Allan Hicks
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.302.2435
allan.hicks@noaa.gov

Ray Hilborn
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.3587
rayh@uw.edu

Amber Himes-Cornell
NOAA Alaska Fisheries
Science Center
7600 Sand Point Way NE
Seattle, WA 98115
206.526.4221
amber.hiimes@noaa.gov

Laura Hoberecht
NOAA National Marine
Fisheries Science Center
7600 Sand Point Way
Seattle, WA 98115
206.526.4453
laura.hoberecht@noaa.gov

Richard Horner
Dept. of Civil and
Environmental Engineering
University of Washington
230 NW 55th St.
Seattle, WA 98107
206.782.7400
rrhorner@uw.edu

Gwyn Hinton
Administrator
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.543.9966
ghinton@uw.edu

Anne Hollowed
NOAA National Marine
Fisheries Science Center
7600 Sand Point Way, NE
Seattle, WA 98115
206.526.1223
anne.hollowed@noaa.gov

Bobbi Hudson
Pacific Shellfish Institute
120 State Ave NE #1056
Olympia, WA 98501
360.754.2741
bobbi@pacshell.org

Bobbi Johnson
School of Biological Sciences
Washington State University
PO Box 6444910
Pullman, WA 99164
509.335.7403
bobbi.adams@wsu.edu

Chelsea Kahn
Research and Information
Analyst
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.5718
chekahn@uw.edu

Julie Keister
School of Oceanography
University of Washington
Box 357940
Seattle, WA 98195
206.543.7620
jkeister@uw.edu

Brian Kemp
Dept. of Anthropology
Washington State University
PO Box 6444910
Pullman, WA 99164
509.335.7403
bmkemp@wsu.edu

Dale Kiefer
Dept. of Biology
University of California
AHF 342
Los Angeles, CA 90089
213.740.5814
kiefer@physics.usc.edu

Teri King
Aquaculture/Marine Water
Quality Specialist
Washington Sea Grant
University of Washington
P.O. Box 488
Shelton, WA 98584
360.432.3045
guatemala@uw.edu

Brian Kirk
Associate Director
Washington Sea Grant
Box 355060
Seattle, WA 98195
206.685.9261
kirkbd@uw.edu

Robert Kopperl
SWCA Environmental
Consultants
5418 20th Ave NW Suite 200
Seattle, WA 98107
206.781.1909
rkopperl@swca.com

Peter Kuriyama
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
858.337.6463
ptrkrym@uw.edu

Dana Lepofsky
Dept. of Archaeology
Simon Fraser University
8888 University Dr.
Burnaby, B.C., Canada V5A
1S6
778.782.5403
dlepofsk@sfu.ca

Kate Little
Assistant Director for
Programs
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.0151
kalittle@uw.edu

Adam Luckenbach
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3463
adam.luckenbach@noaa.gov

Eric Lundquist
Washington Sea Grant
School of Oceanography
University of Washington
Box 355020
Seattle, WA 98195
206.543.0594
ericl@ocean.washington.edu

Christopher MacGregor
Wallingford Imaging
Systems
P.O. Box 31939
Seattle, WA 98103
206.650.0686
chris@cybermato.com

Julie Masura
Environmental Science
University of Washington
Tacoma
Box 358436
Tacoma, WA 98402
253.692.4317
jmasura@uw.edu

Pamela Matson
School of Earth Sciences
and Woods Institute for
the Environment
Stanford University
Stanford, CA 94305
650.723.2750
Pamela.matson@stanford.edu

P. Sean McDonald
Program of the Environment
University of Washington
Box 355679
Seattle, WA 98195
206.221.5456
psean@uw.edu

Paul McElhany
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98115
206.860.5608
paul.mcelhany@noaa.gov

Jenifer McIntyre
Puyallup Research and
Extension Center
Washington State University
2606 West Pioneer Avenue
Puyallup, WA 98371
206.369.1832
jen.mcintyre@wsu.edu

Edward F. Melvin
Marine Fisheries Senior
Scientist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.543.9968
emelvin@uw.edu

Jennifer Meredith
School of Economics
University of Washington
Box 353330
Seattle, WA 98195
206.685.7477
jenner8@uw.edu

Scott Miles
Huxley College of the
Environment
Western Washington
University
516 High St., MS 9085
Bellingham, WA 98225
206.406.9805
scott.miles@wwu.edu

Ian Miller
Coastal Hazards Specialist
Washington Sea Grant
University of Washington and
Peninsula College
1502 E. Lauridsen Blvd., #82
Port Angeles, WA 98362
360.417.6460
immiller@uw.edu

Benjamin Miner
Dept. of Biology
Western Washington
University
516 High St.
Bellingham, WA 98225
360.650.3640
Benjamin.miner@wwu.edu

Melissa Miner
Long Marine Lab
University of California,
Southern California
100 Shaffer Rd.
Santa Cruz, CA 95060
831.459.5149
emminer@usc.edu

Jamie Mooney
Coastal Resources Specialist
and NOAA PMEL Liaison
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.3368
monneyja@uw.edu

Danna L. Moore
Social & Economic Sciences
Research Center
Washington State University
Box 644014
Pullman, WA 99164-4014
509.335.1117
moored@wsu.edu

James Elliott Moore II

University of Southern
California
3715 McClintock Ave.,
Suite 240
Los Angeles, CA 90089
213.740.0595
jmoore@usc.edu

Stephanie Moore

NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3327
Stephanie.moore@noaa.gov

James Morris

NOAA National Ocean
Service
101 Pivers Island Rd.
Beaufort, NC 28519
252.728.8782
james.morris@noaa.gov

Susanne Moser

School of Earth Sciences
and Woods Institute for
the Environment
Stanford University
402 Arroyo Seco
Santa Cruz, CA 95060
promundi@susannemoser.com

Kerry-Ann Naish

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.221.6375
knaish@uw.edu

Elizabeth Nesbitt

Burke Museum
University of Washington
Box 353010
Seattle, WA 98195
206.543.5949
lnessbitt@uw.edu

Frank O'Brien

System Science
Applications Inc.
3 Trovita
Irvine, CA 92620
714.730.6858
fjobrien@cox.net

Paul Olin

California Sea Grant
133 Aviation Blvd., Suite 109
Santa Rosa, CA 95403
707.565.2621
pgolin@ucdavis.edu

Ji Young Park

Dept. of Urban and
Regional Planning
State University of
New York at Buffalo
05L Squire Hall
Buffalo, NY 14214
716.829.5331
jp292@buffalo.edu

Julia Parrish

College of the Environment
University of Washington
Box 355020
Seattle, WA 98195
206.221.5787
jparrish@uw.edu

Jim Parsons

Troutlodge Sablefish LLC
3518 6th Ave #201
Tacoma, WA 98406
253.261.8751
jparrisons@troutlodge.com

Betsy Peabody

Puget Sound
Restoration Fund
590 Madison Ave. N
Bainbridge Island, WA
98110
206.780.6947
betsy@restorationfund.org

Melissa Poe

Social Science Specialist and
NOAA NWFSC Liaison
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98105
206.685.8209
mpoe@uw.edu

Richard Pollnac

Marine Affairs and Coastal
Resources Center
University of Rhode Island
Coastal Institute
1 Greenhouse Road,
Suite 205
Kingston, RI, 02881
401.874.5107
pollnac3@gmail.com

David Priekshot

Dept. of Fisheries
and Oceans
3012 Kathleen Dr.
Duncan BC, Canada
V9LSR7
250.715.1771
d.priekshot@fisheries.ubc.ca

Andre Punt

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.221.6319
aepunt@uw.edu

Maureen Purcell

Western Fisheries
Research Center
U.S. Geological Service
6505 65th St. NE
Seattle, WA 98115
206.526.6282 x 252
mpurcell@usgs.gov

Thomas Quinn

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.9042
tquinn@uw.edu

Nancy Reichley

Education Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.8302
reichn@uw.edu

Jack Rensel

Rensel Associates
Aquatic Sciences
4209 234th St NE
Arlington, WA 98223
360.435.3285
jackrensel@att.net

Jonathan Reum

Marine Research Scientist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.5337
reumj@uw.edu

Robyn Ricks

Creative Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.685.2607
robyn@uw.edu

Mindy Roberts

Washington State Dept.
of Ecology
PO Box 47775
Olympia, WA 98504
360.407.6804
mindy.roberts@ecy.wa.gov

Steven Roberts

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.600.4495
sr320@uw.edu

Nancy Rottle

Landscape Architecture
University of Washington
Box 355734
Seattle, WA 98195
206.543.7897
nrottle@uw.edu

Shawn Rowe

Oregon Sea Grant
Hatfield Marine Science
Center
Oregon State University
2030 SE Marine Science
Newport, OR 97365
541.867.0190
Shawn.rowe@oregonstate.edu

Jennifer Ruesink

Dept. of Biology
University of Washington
Box 351800
Seattle, WA 98195
206.543.7095
ruesink@uw.edu

Jennifer Runyan

Aquaculture Outreach
Specialist
Washington Sea Grant
University of Washington
P.O. Box 488
Shelton, WA 98584
360.432.3054
jrunyan@uw.edu

Jeffrey Rutter

School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98105
206.755.2293
jdrutter@uw.edu

Clare Ryan

School of Environmental
and Forest Sciences
University of Washington
Box 352100
Seattle, WA 98195
206.616.3987
cmryan@uw.edu

Nathaniel Scholz

NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3454
nathaniel.scholz@noaa.gov

Ervin Joe Schumacker

Quinault Indian Nation
P.O. Box 189
Taholah, WA 98587
360.276.8215
jschumacker@quinault.org

Eric Scigliano

Science Writer
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.9568
escig@uw.edu

David Shull

Shannon Point
Marine Center
Western Washington
University
1900 Shannon Point Rd.
Anacortes, WA 98221
360.393.7925
david.shull@www.edu

Sara Singleton

Dept. of Political Science
Western Washington
University
516 High St. MS 9082
Bellingham, WA 98225
360.650.4880
sara.singleton@www.edu

Amy Snover
Joint Institute for the
Study of the Atmosphere
and Ocean,
Climate Impacts Group
University of Washington
Box 355672
Seattle, WA 98105
206.221.0222
aksnover@uw.edu

John Stark
Puyallup Research and
Extension Center
Washington State University
2606 West Pioneer Avenue
Puyallup, WA 98371
253.445.4568
starkj@wsu.edu

Christine Stawitz
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.617.2060
cstawitz@uw.edu

Maile Sullivan
Education Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.543.2822
mailesul@uw.edu

Cody Monnahan
Quantitative Ecology and
Resource Management
University of Washington
Box 352182
Seattle, WA 98195
206.616.9571
monnahan@uw.edu

Gary Thorgaard
School of Biological Sciences
Washington State University
Box 644236
Pullman, WA 99164
509.335.7438
gary.thorgaard@wsu.edu

Jason Toft
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.221.5460
toftj@uw.edu

Bridget Trosin
Coastal Policy Specialist
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.6129
bemmett@uw.edu

Nathaniel Trumbull
Department of Geography
University of Connecticut
1084 Shennecossett Rd.
Groton, CT 06340
860.405.9272
trumbull@uconn.edu

Tien-Shuin Tsou
Washington Dept. of Fish
and Wildlife
600 Capitol Way N
Olympia, WA 98501
360.902.2855
tien-shui.tsou@dfw.wa.gov

Brent Vadopalas
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.616.6341
brentv@uw.edu

Glenn VanBlaricom
School of Aquatic and
Fishery Sciences
University of Washington
Box 355020
Seattle, WA 98195
206.543.6475
glennvb@uw.edu

MaryAnn Wagner
Assistant Director for
Communications
Washington Sea Grant
University of Washington
Box 355060
Seattle, WA 98195
206.616.6353
maryannw@uw.edu

Kenneth Warheit
Washington Dept. of
Fish and Wildlife
600 Capitol Way N.
Olympia, WA 98501
360.902.2595
Kenneth.warheit@dfw.wa.gov

Brad Warren
Director
Global Ocean Health
Program
7714 14th Ave SW
Seattle, WA 98106
206.579.2407
brad.warren@sustainablefish.org

Sam Wasser
Center for
Conservation Biology
University of Washington
Box 351800
Seattle, WA 98195
206.543.1669
wassers@uw.edu

Sandy Wyllie-Echeverria
Friday Harbor Laboratories
University of Washington
620 University Road
Friday Harbor, WA 98250
360.298.0751
zmseed@uw.edu

Dongya Yang
Dept. of Archaeology
Simon Fraser University
8888 University Dr.
Burnaby, B.C., Canada
V5A 1S6
778.782.4651
donyang@sfu.ca

Sylvia Yang
Shannon Point
Marine Center
Western Washington
University
1900 Shannon Point Road
Anacortes, WA 98221
360.293.2188
sylvia.yang@wwwu.edu

Richard Zabel
NOAA Northwest Fisheries
Science Center
2725 Montlake Blvd. E
Seattle, WA 98112
206.860.3290
rich.zabel@noaa.gov

