

SPECIAL ISSUE: MARINE STUDIES



terra

DISCOVERY | CREATIVITY | INNOVATION • Spring 2016

Ocean Blues

The urgent quest to safeguard
our beleaguered seas

Oregon State
UNIVERSITY

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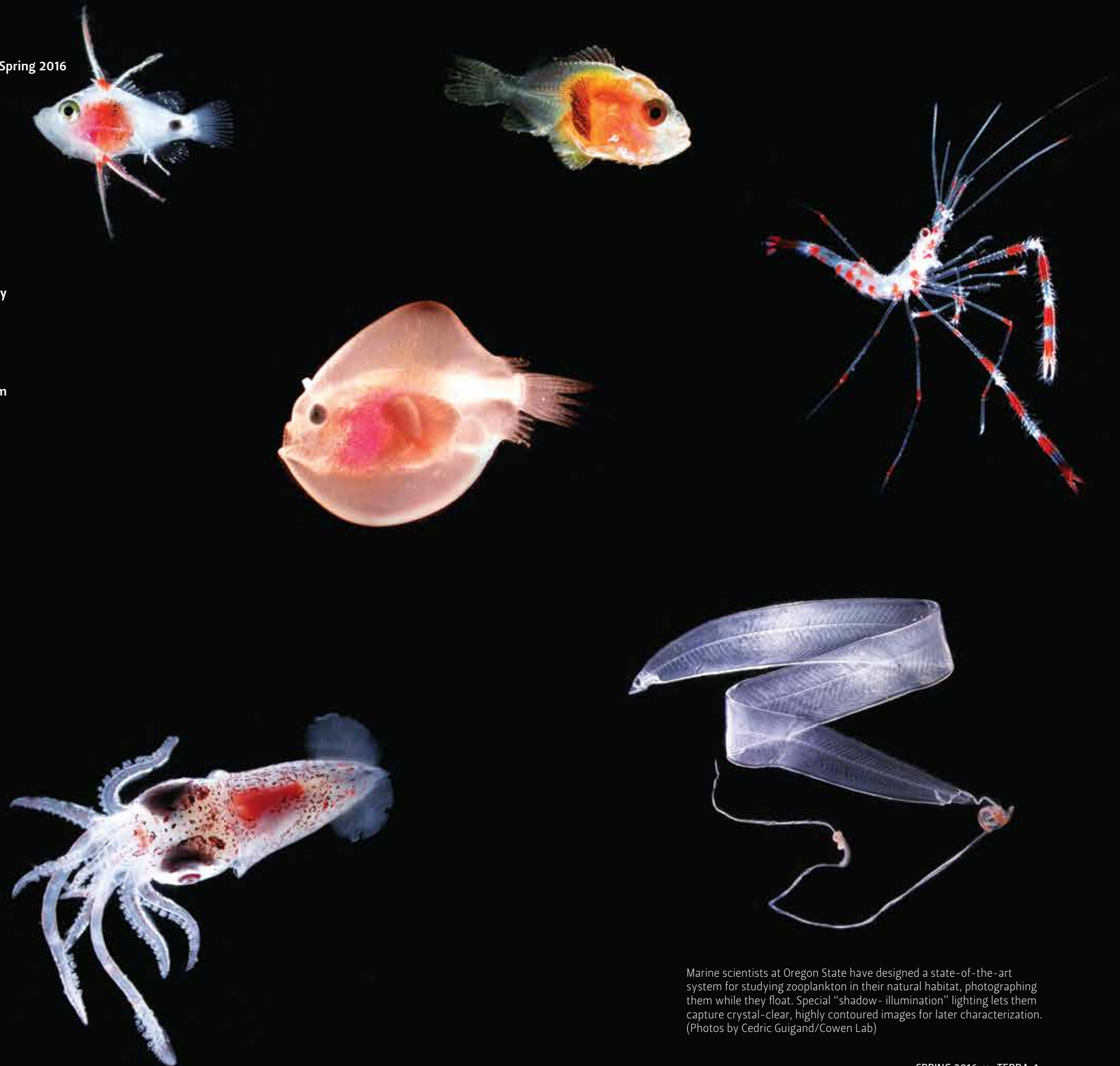
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Marine scientists at Oregon State have designed a state-of-the-art system for studying zooplankton in their natural habitat, photographing them while they float. Special "shadow-illumination" lighting lets them capture crystal-clear, highly contoured images for later characterization. (Photos by Cedric Guigand/Cowen Lab)



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Vice President for Research

Cynthia Sagers

Vice President for University Relations and Marketing

Steven Clark

Associate Vice President for University Relations and Marketing

Annie Athon Heck

Editor

Nicolas Houtman

Associate Editor

Lee Sherman

Contributing Writers

Mark Floyd, Nathan Gilles

Art Director

Amy Charron

Designers

Amy Charron, Teresa Hall, Long Lam, Heather Miller

Photography

David Baker, Chris Becerra, Ari Friedlaender, Cedric Guigand

Production Manager

Laura Shields

Oregon State is Oregon's leading public research university with more than \$309 million in research funding in FY2015. Classified by the Carnegie Foundation for the Advancement of Teaching in its top category (very high research activity), OSU is one of only two American universities to hold the Land-, Sea-, Sun- and Space-Grant designations. OSU comprises 11 academic colleges with strengths in Earth systems, health, entrepreneurship and the arts and sciences.

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Send address corrections to:

Emily Smith
102 Adams Hall Building
Oregon State University
Corvallis, OR 97331
emily.smith2@oregonstate.edu
541.737.3871

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The All-Encircling Sea

Within the lifespan of most people alive today, our relationship to the ocean has fundamentally changed. In 1951, in her classic, *The Sea Around Us*, Rachel Carson wrote, mankind “cannot control or change the ocean as he has subdued and plundered the continents. In the artificial world of his cities and towns, he forgets the true nature of his planet and its long history in which man has occupied a mere moment in time.”

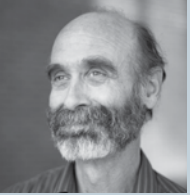
Since then, we have learned more about what this “mere moment in time” means for the oceans. The signs of human impact are evident. Among them are rising sea levels, acidified and warming waters, depleted fish populations and dying coral reefs. In contrast to this dire list, we know the oceans still have stunning diversity, beauty and abundance. When author and marine biologist Carl Safina addressed the Song for the Blue Ocean conference at Oregon State in 2012, he talked of witnessing the seasonal migrations of fish and birds from his home on the shore of Long Island. He said, “I still find sanity and solace and delight in the power and resilience of living things.”

Last fall, as friends and I approached the shoreline at Ecola State Park near Cannon Beach, we saw an unexpected display: humpback whales were breaching, one after another, close to shore and far away. Others lay on the surface, slapping their tails on the water. People stood on a windy bluff watching, mesmerized. Some were excitedly talking to friends on their cellphones. Parents were pointing as children ran in the grass. Exclamations came rapidly: “There’s another one!” “Did you see that?” “Over there!”

Looking for an explanation, I sent a message to Bruce Mate, director of Oregon State’s Marine Mammal Institute. The whales had come unusually close to shore, he said, because a huge area of warm water — a phenomenon known technically to scientists as “the blob” — had reduced their prey farther out to sea. They were simply looking for food — the plankton, krill, herring or anchovies that were still to be found in coastal waters.

As ocean waters warm and become more acidic, humpbacks may have a harder time of it. And they’re not alone. Salmon, oysters, sea stars and corals face threats. Things are changing, and scientists are racing to understand what’s happening throughout the ecosystem, from micro to macro, from virus to whale. Oregon State’s Marine Studies Initiative serves as a rallying cry and organizing focus for this urgent work.

More than 65 years ago, Rachel Carson captured the grand scale of what’s at stake for humanity, that we live on a water world, “a planet dominated by its covering mantle of ocean, in which the continents only here and there emerge above the surface of the all-encircling sea.”



Nick Houtman

Editor

Science for the Ocean

A precious resource in precarious times

BY CYNTHIA SAGERS, VICE PRESIDENT FOR RESEARCH



I was in college before I ever stepped foot in an ocean. It was during a spring-break trip to Vero Beach, Florida, with my sister and best friend. Before then, my impressions had come from a movie, *Captain Nemo and the Underwater City*, which I saw at the Pastime Theatre in Maquoketa, Iowa, when I was

9 years old. The sea on the silver screen was mysterious and romantic yet completely alien to me.

Ten years later on that trip to Florida, I finally was able to see for myself how amazing it is — this massive, warm, salty, endless body of water. For hours, we would sit in the cool sand and watch the waves. It was fascinating, powerful and terrifying. Visions of rogue waves and shark attacks ran through my mind. But the idea of a giant mass of water that moved by itself — undulating up and down, back and forth, hither and yon — captivated me.

Later in the mid-90s, while teaching an evolutionary biology class at the University of Arkansas, I took my class to collect marine fossils on the south end of town to a place where the ancient Gulf of Mexico had lapped the land at the edge of a shallow sea. My students discovered shark teeth, corals, mollusks and bryzoans (aquatic invertebrates that form colonies), ancestors of species that still ply the world’s oceans. I asked the students, “Why had these animals gone extinct? What can they show us about the precarious times in which their descendants live?”

The ocean remains a wonder to me. As an ecologist, I have worked on land, but I understand that the ocean — like forests, wetlands and grasslands — is vulnerable to disruptions and that we are just starting to understand its complexity and dynamics.

For more than 60 years, Oregon State researchers have studied the oceans to learn how they work. Our faculty share their insights and discoveries with people whose lives intertwine with the sea: fishermen who struggle daily in a dangerous occupation; coastal communities facing erosion from winter storms and the ongoing risk of subduction zone earthquakes and tsunamis; government agencies charged with managing marine resources as a public trust.

This special issue of *Terra* is dedicated to Oregon State’s Marine Studies Initiative. The stories stem from a research enterprise in which nearly a third of last year’s record-breaking \$309 million in funding — approximately \$89 million — is tied to the oceans and all they encompass. As you read through the magazine, you’ll see that Oregon State is a world leader in this work. Like my former college students, I hope you’ll be fascinated by discoveries from the deep and the research that will help preserve one of our planet’s most precious resources.

Facing Cascadia

By preparing for the inevitable, we will save lives

BY PATRICK CORCORAN, OREGON SEA GRANT EXTENSION



In Japan, nearly 20,000 people died in the 2011 Tohoku earthquake and tsunami. The tragic aftermath struck home in the Pacific Northwest, which faces a similar risk from the Cascadia subduction zone. But we often forget the silver lining. In Japan, there were nearly 200,000 people in the inundation zones, so 90 percent of the people effectively evacuated those areas before the tsunamis arrived.

We can have the same success in the Pacific Northwest if we ever walk the resilience talk the way the Japanese do. But we are a long way from that standard today. People, institutions and communities that understand these risks and take sustained efforts to build resilience to them will not only adapt and survive — they will thrive.

As a hazards outreach specialist with Oregon Sea Grant, I help communities build resilience to coastal natural hazards. These include storms, floods, landslides, fires and our looming catastrophe, the Cascadia earthquake and tsunamis. To prepare as individuals and communities, we must reach the Cascadia standard — if we're ready for that, we're prepared for anything. But that's a high bar, which requires our best thinking. And the clock is ticking.

In my work, I consider the underlying factors that make a community vulnerable, and I explore ways to minimize them. This isn't hazard response, which focuses on what to do during a disaster. Nor is it hazard recovery, which deals with the aftermath. The question for hazard resilient communities is not, "How many fatalities should we plan for?" but "How can we plan so fewer people will die?"

Residents of the Pacific Northwest are the only population on the planet to learn so recently (about 25 years ago) that they are subject to a recurring natural disaster the magnitude of Cascadia. This hazard has literally fallen into our laps. If our ancestors had known about Cascadia in 1800, they would have settled this country differently. But they didn't, and now we have many of our valuable things in vulnerable places, especially on the coast.

Too often, I find that people do not want to know. Consciously or not, Northwest people and institutions are going through Elizabeth Kubler-Ross's stages of death and dying — denial, anger, depression, bargaining with the devil and acceptance/ moving on. Manifestations of these behaviors are

everywhere: putting valuable things in vulnerable places (denial), being upset about one's property being in an inundation zone (anger), sadness over lost property value (depression), seeking clever engineering solutions to justify unwise decisions (bargaining with the devil).

But there are also signs of adapting to the realities of the landscape and re-establishing a long-term presence. For example, Waldport High School relocated to higher ground (acceptance and moving on).

Going forward, we may always have some of our valuables in the tsunami zone. Lately I work less with communities on the physical phenomenon — the nature of the geological risk — and more on the psychological, emotional and social impediments to preparing for this event. A key first step is for people to understand enough about the physical phenomenon to actually expect it to happen during their lifetimes or that of their children. Once people actually expect to experience a long, large earthquake, they will naturally prepare for it. People will imagine the scenario, its impact and what they want their loved ones to know and do. Once people actually expect a tsunami to arrive on the beach 15 to 30 minutes after a long, large earthquake, they will naturally think about the impact and what they want their loved ones to know and do.

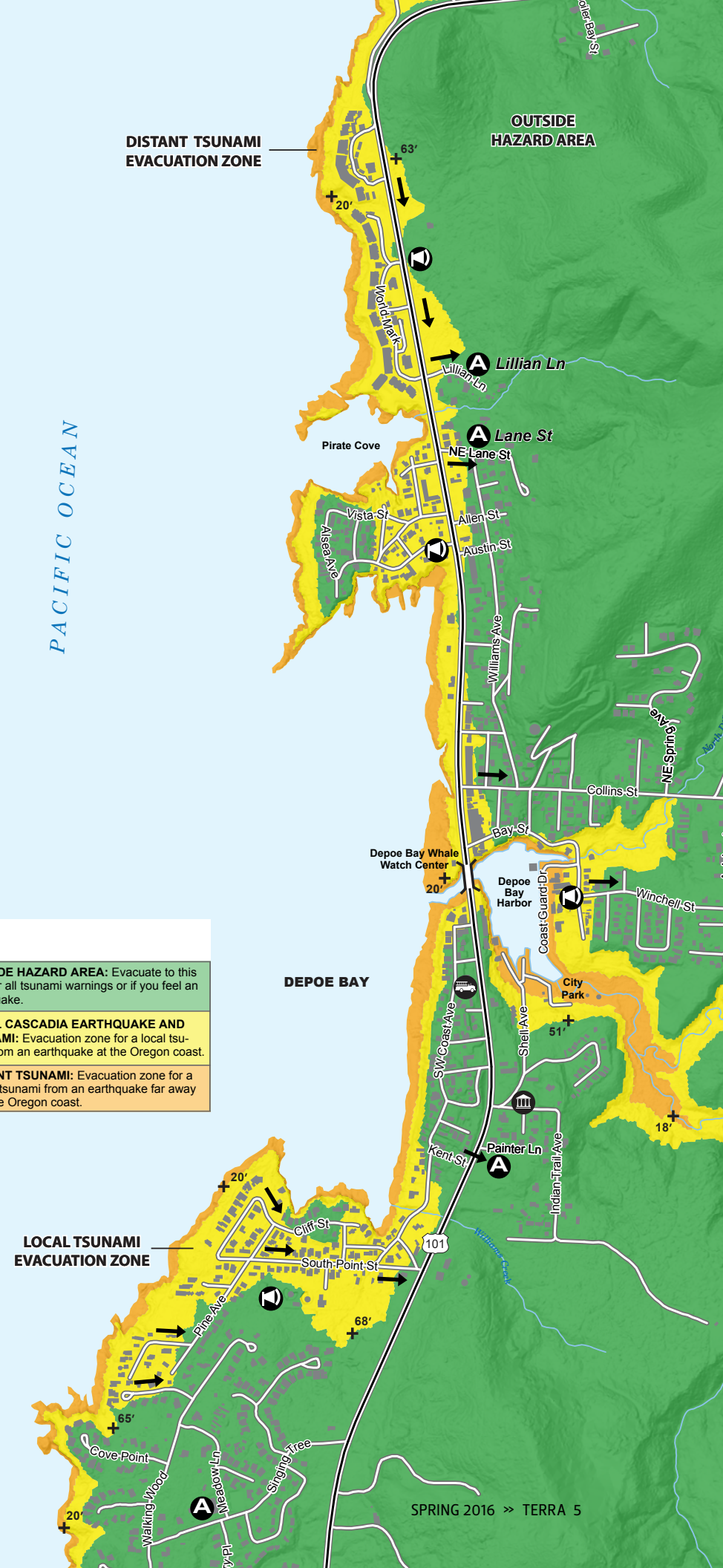
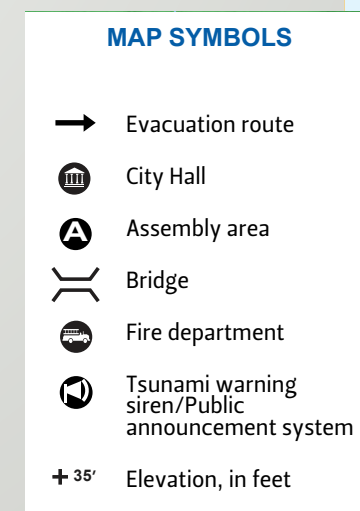
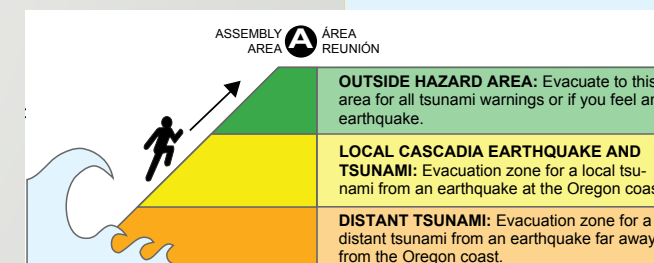
We have no system in place to consider a community's vulnerability to Cascadia, nor for building resilience to it. A promising solution is to take our risk management approach to its logical extreme. We can expect this to occur and imagine the impacts of Cascadia to people and things. We can view Cascadia from a systems perspective (transportation, health care, water, energy, food), start adapting to it as a matter of policy and build resilience over time. By actually expecting this to happen, we will naturally come up with adaptations and strategies for thriving in Cascadia.

Patrick Corcoran lives in Astoria and works in the Clatsop County Extension office. As a coastal hazards specialist with Oregon Sea Grant and an associate professor in OSU's College of Earth, Ocean, and Atmospheric Sciences, he works with communities to help them anticipate and prepare for catastrophic events.

PREPARATION FOR INDIVIDUALS AND COASTAL COMMUNITIES

1. Find out from the local emergency management office if there are evacuation routes identified for the community.
2. Plan to evacuate to high ground or inland, away from the coast and outside of the tsunami zone.
3. Map out evacuation routes to safe places from the home, workplace or other places people visit frequently.
4. Practice using evacuation routes, including at night and in bad weather.
5. Find out about the evacuation plans of local schools.

At right, maps of tsunami inundation zones, landmarks and evacuation routes guide local planning for Depoe Bay. Download more maps, reports and preparedness tips for coastal communities at Oregon Tsunami Clearinghouse, oregongeology.org/tsuclearinghouse/.



An Educational Leap into the Shimmering Sea

Oregon State Marine Studies Initiative will prepare ocean-literate problem solvers

BY MARK FLOYD | PHOTOS CHRIS BECERRA

The ocean is key to life on our planet, supplying every second breath of oxygen and transporting heat from equator to pole. Over 1 billion people receive their primary source of protein from the sea, and humans will be looking increasingly to marine aquaculture to feed a hungry planet. Over 90 percent of goods travel by ship across the global oceans, and we are looking to the sea for renewable energy. The sea is in our blood, inspires our arts and literature and is key to our future.

However, the challenges facing the world's oceans are well-chronicled: warming temperatures, increasing acidification, rising sea levels, outbreaks of harmful algal blooms, larger waves and storms, severe erosion, over-stressed fisheries. The list goes on and on.

The science documenting these issues is solid, and few, if any, academic institutions in the world have the breadth of expertise to study them as does Oregon State University. The question, though, isn't, "What is causing these extraordinary changes to the ocean?" It is, "What are we going to do about them?"

Put yourself in the shoes of a city manager in a coastal community. The freshwater piped to your city's residents flows through low-lying areas that are likely to be inundated with seawater in the next 50 years, according to the most conservative estimates of sea-level rise. What should you be doing about that now?

Oregon State professor Bruce Menge, left, and graduate student Elizabeth Cerny-Chipman investigate an epidemic of sea star wasting disease at Seal Rock.

You know that an earthquake and tsunami akin to those that devastated Japan in 2011 will someday strike the Pacific Northwest; thus, you organize evacuation drills. It is then that you recognize that your community's hospital, elementary school and nursing home are situated smack in the middle of a tsunami inundation zone. How will you deal with an immobile population?

An unprecedented harmful algal bloom has resulted in the delay of the Dungeness crab harvest for over a month this winter off Oregon and for nearly five months off California. Luckily, when the season opened and crabbers were able to brave the bad weather, they found an ample supply of crab. But what will happen economically if, next year, the bloom doesn't abate and ships never leave port?

It is questions like these that, in part, triggered Oregon State to launch its Marine Studies Initiative (MSI). The university is building on its half-century of leadership in marine sciences to create a bigger, broader and bolder program that merges the natural sciences with social sciences, business, engineering, education and the humanities.

"In the broadest terms, this is about building coastal resilience," says Robert Cowen, director of OSU's Hatfield Marine Science Center and one of the co-leaders of the MSI. "We have the opportunity to educate and motivate the next generation of students and citizens to develop innovative approaches to solving ocean-related challenges."

The Marine Studies Initiative will build the university's capacity to teach students, conduct more interdisciplinary research and provide service to coastal communities and businesses. A hallmark goal of the initiative is to enroll 500 students on the Hatfield Marine Science Center campus by the year 2025.

To reach that goal, OSU needs to increase the number of students in the pipeline, which means attracting more students to the Corvallis campus who are interested in ocean-related topics, according to Jack Barth, a professor and associate dean in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State and co-leader of the MSI with Cowen.

"We envision that students may study at Hatfield for a term or a year at a time, which means that we need to have some 1,200 students involved in a marine studies curriculum in the university as a whole," Barth says. "We've already begun hiring faculty on campus, and in Newport — a process that will continue over the next few years."

These faculty members won't necessarily be ocean scientists, Barth emphasizes, but they will teach in areas that complement the science and help address emerging issues. For example, with funding from the OSU Provost's Office, the university has hired Ana Spalding, a marine policy specialist, in the College of Liberal Arts; Steve Dundas, a coastal economist, in the College of Agricultural Sciences; and Jamon Van Den Hoek, a spatial planner specializing in coastal processes, in the College of Earth, Ocean, and Atmospheric Sciences.

Graduate student Elizabeth Cerny-Chipman is studying the influence of climate change on whelks and mussels in the intertidal zone.



The university's goal, Barth said, is to train students to be well-rounded and able to look at coastal and marine issues from a multi-faceted perspective.

"Ultimately, we'd like our graduates who are asked a question about sustainable fisheries to be able to relate to all of the people around the table — the fisherman, the processor, the environmentalist, the tourist and the restaurant owner," Barth says. "It requires a broader understanding of all the issues."

That breadth of training is part of what will distinguish Oregon State students under the Marine Studies Initiative, according to Cowen. The experiential learning potential for students will be unprecedented.

"Students studying at Hatfield will have access to a diversity of habitats, scientists and state and federal agencies unlike anywhere else in the country," Cowen points out. "They also will be studying in a community that is highly engaged and intimately connected to the ocean, whether it is through fisheries, tourism or some other tie."

The Marine Studies Initiative is building partnerships up and down the Oregon coast, from Astoria in the north with its Seafood Research and Education Center to Port Orford in the south with its new OSU Field Station. Oregon's four coastal community colleges will be key players, partnering with OSU to provide greater access to higher education for Oregon's coastal residents. "It's really about realizing that Oregon's ocean touches all of us, whether via supplying seafood, providing inspiration and awe, or

making our Oregon climate one of the best in the world," Barth says. "The Marine Studies Initiative will center our attention and energies on important ocean issues and challenges."

During the next several years, the university plans to add 20 to 25 faculty members at the Hatfield Marine Science Center and an equivalent number on the Corvallis campus. Construction of a new building in Newport for classes, faculty and research will begin in 2017, as will construction of a housing facility that will be located off campus. A marine studies degree program will be developed and launched over the next year.

Future plans for the Marine Studies Initiative include creating marine options for a broad range of traditional degrees including business, engineering and economics; establishing three centers of excellence around such topics as ocean acidification, coastal resilience and safe food from the sea; and a new building on the Corvallis campus.

"The defining characteristic of the MSI is how the university will reach more broadly across disciplines for its academic and research programs," Cowen says. "We will still have fisheries biologists, ecologists, oceanographers, and population scientists. But they will be working hand-in-hand with resource economists, political scientists, cultural heritage specialists and engineers."

Mark Floyd is a science writer in News and Research Communications at Oregon State University.

OSU Opens Port Orford Field Station

Students, divers and scientists can explore the spectacular waters of the southern Oregon coast through a new Oregon State University field station in Port Orford. An outgrowth of efforts to support research at the nearby Redfish Rocks Marine Reserve, the station provides space for experiments and classes as well as a fill station for scuba tanks.

"People have a comfortable place to stay and access to wet and dry labs and classroom and office space where they can work," says Tom Calvanese, station manager.

The station will support the Marine Studies Initiative with facilities for education and research on marine ecology, economy and social and scientific issues, he adds. Student research projects underway or completed have focused on the impact of catch shares on the local fishing fleet, juvenile rockfish and the foraging behavior of gray whales. Since 2011, Calvanese has been studying the movement of adult rockfish in the reserve.

The station is located at 444 Jackson Street and includes a house used formerly as a bed and breakfast. Additional funding was provided by the Oregon Department of Fish and Wildlife, Travel Oregon and the Wild Rivers Coast Alliance.



ENDURING VIGIL

Buoys and gliders stand watch on the Pacific Ocean

BY NICK HOUTMAN

Tully Rohrer prepares a buoy for spring deployment. Weather monitoring, energy and communications systems reach almost 20 feet above the water. (Photo: Chris Becerra)

At 8:46 p.m. on a Sunday night last December, Tully Rohrer received an SOS from a machine. It came as text messages on his cell phone and indicated that one of the ocean-monitoring buoys he had helped to deploy off the Oregon and Washington coast a few months earlier had come loose from its mooring.

The faculty research assistant in the Oregon State University College of Earth, Ocean, and Atmospheric Sciences (CEOAS) knew that seas had been high the previous week. At times, waves exceeded 30 feet. But the buoys had been designed to withstand this kind of battering, so he wasn't worried. He had gone for a bike ride with his fiancée and had just finished dinner when the messages started arriving.

Five other members of Oregon State's Ocean Observatories Initiative (OOI) team — Ed Dever, Chris Wingard, Walt Waldorf, Jon Fram and Craig Risien — had received

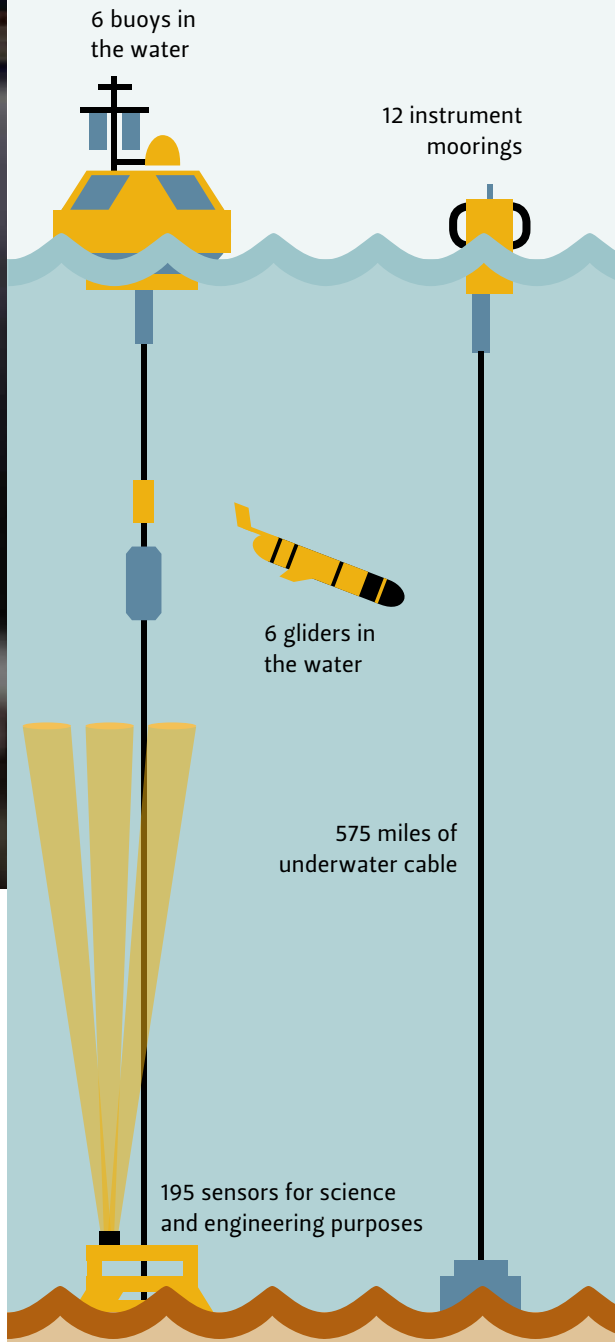
the same messages as Rohrer. In a rapid-fire email exchange, they shared ideas about what had happened and where the buoy was headed. "We notified the Coast Guard so they would add it to their updates to mariners. And we started looking for ships that could help us recover it," says Rohrer.

Jumping into a boat and going out to rescue the wayward buoy wasn't a practical option. Although the top was only 5 feet above the water, the buoy was equipped with flashing lights and radar reflectors and painted bright yellow. It wouldn't be hard to locate. But seas were still high, and it was loose on the Pacific where waves and fog swallow ships and where currents head north this time of year. Normally secured to the seafloor by hardware strong enough to lift a small car, it carried a state-of-the-art package of computers and communications equipment.



Endurance by the Numbers

Funded by the National Science Foundation, the Endurance Array is comprised of a complex network of instruments.



Over the next few days, the buoy continued to send regular text messages, noting its latitude, longitude and distance from home. The previous October, the team had left it moored to an anchor platform in water nearly 2,000-feet deep about 35 miles due west of Grays Harbor. When it crossed into Canadian waters, the researchers notified that country’s Coast Guard.

It was the first time one of the buoys in the recently completed network known appropriately as the Endurance Array had come loose. Developed jointly at the Woods Hole Oceanographic Institution (WHOI) and Oregon State, these floating sentinels are designed to withstand hurricane-force winds and crashing waves.

Complementing a fleet of a dozen gliders and a 900-kilometer (575-mile) network of underwater moni-

toring stations known as the Cabled Array (the first to cross an active subduction zone), the buoys send steady streams of data back to shore with measurements of water chemistry, temperature, plankton, weather, wave heights and other ocean features. Paired with devices that descend from the surface to the seafloor and back again like small elevators, they illuminate roiling currents and the nutrient-rich upwelling waters that feed the coastal ocean’s bounty of fish and fowl.

As part of a Pacific Ocean monitoring system managed by Oregon State and the University of Washington, they stand a constant vigil for science. Mooring positions located north and south of the Columbia River enable the Endurance Array to capture the river’s influence on the coastal ecosystem.

Ed Dever, left, and Ian Black must remove barnacles, algae and other organisms before sending an underwater glider back to the Pacific. (Photo: Chris Becerra)

But machines malfunction, run into logs and other flotsam and are subject to the opportunistic behavior of ocean creatures large and small. Sharks have left teeth marks on underwater gliders in the Atlantic. Even barnacles can create problems. When the thumbnail-sized crustaceans glom onto the slick sides of gliders, the winged instruments have been known to be thrown off course. All it takes is the gentle force of barnacles opening their shells and waving their frond-like appendages in the water.

To recover an off-course glider or a wayward buoy, scientists may charter fishing boats or other research vessels. On rare occasions, a glider might end up accidentally in fishing nets. In one memorable case, a recreational fisherman snagged an Oregon State glider and then returned the device to the water, but not before taking out a green waterproof marker and writing “Go Ducks” on the side.



Last December, Rohrer and his team tracked the northward-drifting buoy to the waters just west of Tofino on Vancouver Island. A University of Washington oceanography class happened to be nearby on the UW's research vessel, the R/V Thomas G. Thompson. "We sent them information about the buoy's location and its lifting points (handles on the buoy for safely lifting the 8,000-pound instrument), and they were kind enough to recover it for us," says Rohrer. "Walt drove a truck up to Seattle to pick it up."

Machine Shop Oceanography

You can't see the ocean from the Ocean Observing Center in Corvallis. Located a few miles south of downtown on Highway 99, the nondescript industrial facility appears

more machine shop than window on the sea. But this is a state-of-the-art facility where a team of a dozen or so scientists, mechanical and electrical technicians and software programmers maintain the buoys and gliders of the Endurance Array. Researchers here actually do have a window on the ocean, a kaleidoscope made up of the multifaceted data that stream 24/7 from the machines at sea.

"We deploy and recover the buoys twice a year," says Ed Dever, professor in CEOAS and project manager for the array. "We go out in the spring, take out the buoys that we put out in the fall and deploy a new set. And we do the same thing in the fall. The whole season is based on these two deployments and recoveries."

When the machines come back from spending six months at sea, they need to be scrubbed and disassem-

bled. Instruments are sent off to be repaired or recalibrated. Then the process happens in reverse. Structural members must be repainted or recoated with antifouling compound. Once reassembled, the gleaming towers of sensors, wind and solar generators and battery packs are tested before being trucked over the Coast Range to Newport where they are loaded on ships for deployment.

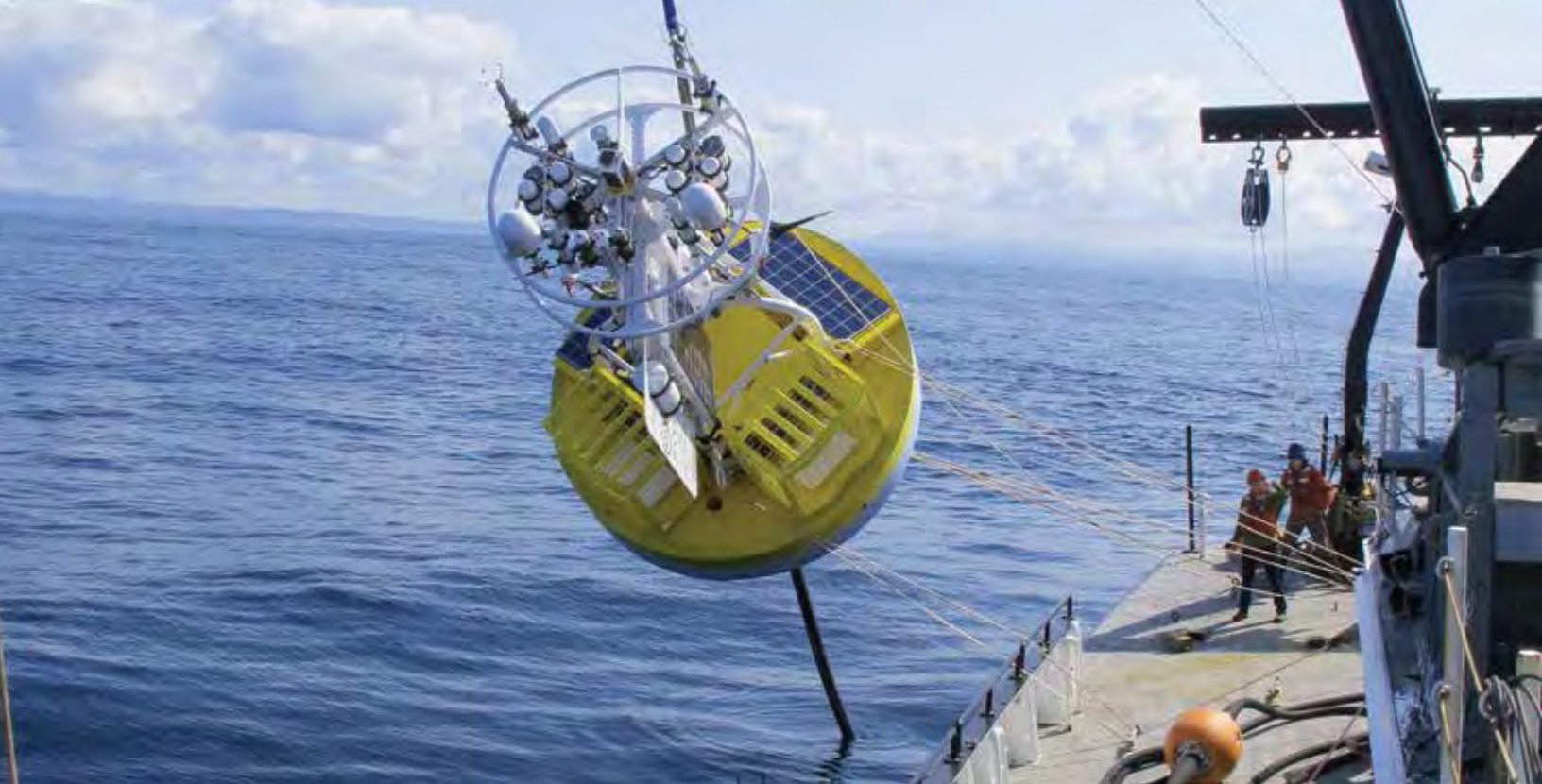
At sea, nothing happens without a plan. "We plan for everything and try to plan for the unknown as well," says Rohrer. "Our lives may depend on it." Whether the crew is deploying or recovering a buoy, every piece of equipment has its place on deck, and every task runs step-by-step. Safety is paramount.

To take a 10,000-pound buoy (hardware plus a 6- to 8-inch layer of barnacles and seaweed) out of the ocean

At the Ocean Observing Center in Corvallis, technicians clean and reassemble components of the ocean-monitoring network known as the Endurance Array. (Photo: Chris Becerra)

requires a deft hand at the helm, a trained team on deck and well-tested lifting gear. "Our crew is really good at this," Rohrer adds. "When we go out, we put our winch on the deck and fill up a giant water bag at one-and-a-half times the load it will ever see. We make sure it won't break. You put a lot of faith in every little piece of equipment. It's old seamanship."

A moment of truth comes early as the ship approaches a buoy. A technician sends an acoustic signal to the seafloor to release the buoy from its anchor. This usually works, but if the anchor platform has been covered with silt by



A Research Ship for the 21st Century

New OSU-designed regional vessel will share data in real time

Our view of the oceans is expanding rapidly: Underwater gliders patrol the Pacific, moored buoys monitor hot spots and satellites view swirling currents from near-Earth orbit. But, says Clare Reimers, we still need ships to put people on the water, to conduct the kind of science that requires a human touch.

Reimers, a professor of oceanography at Oregon State University, is the lead scientist in a National Science Foundation-funded project to design and build the next generation of coastal research vessels. “We’re getting a much better understanding of the ocean by combining direct observations and experiments with constant monitoring through satellites and other means,” she explains.

As chair of the Fleet-Improvement Committee of the University-National Oceanographic Laboratory System (a nonprofit organization of 62 academic and national laboratories), Reimers has helped to make long-term plans for the nation’s academic research fleet. It includes four classes of global and intermediate ocean-going ships as well as regional and coastal vessels.

In 2010, the need for a new regional ship became acute during the Deepwater Horizon oil well blowout in the Gulf of Mexico. Demian Bailey was coordinating research ship activities for the National Oceanic and Atmospheric Administration (NOAA) when he ran into a problem. “We needed data in near real time so we could tell vessels where to sample. We also needed it for our models of the oil plume trajectory and to provide the public with answers they were demanding,” he says. But the ships did not have that capability. Oceanographers had to make their best guesses on how to proceed.

Bailey is now the project manager for the Regional Class Research Vessel initiative at Oregon State. In addition to new sensors and more efficient energy systems, the new vessel will stream data in near real time to scientists anywhere. “We’re looking at these ships kind of like satellites,” he says. “We’re creating a new form of connectivity to shore. We call it ‘data presence.’ We’re going to be providing researchers a wide variety of high-quality, processed data in real time from the atmosphere through the water column down below the seafloor.”

Designers expect the new ship to use 15 to 30 percent less fuel than today’s vessels of comparable size, such as the Oceanus at Oregon State, which was built in 1975. While at sea, it will be able to stay in a single location — a capability known as dynamic positioning — through the use of computer controlled propulsion and satellite-based navigation.

The ship will also have state-of-the-art handling systems for deploying and recovering a wide range of oceanographic instruments and sampling devices, including remotely operated underwater vehicles that can tie to the vessel’s navigation system.

“We’ll always need ships,” Bailey adds. “We’ll always need people on the water. These ships will be very efficient, versatile and stable. That means they’re safer, and scientists can work longer. They can work when it’s rougher.”

Reimers, Bailey and their team of maritime engineers are working with Glostien Associates Inc., a naval architectural firm in Seattle. Over the next year, they plan to identify shipbuilding yards that could compete for constructing up to three of the new vessels. One will be located in Newport. The aim is to award a contract in 2017.

ocean currents, the mooring line may not release. Then all bets are off. Plan B may include inspection by a remotely operated vehicle. Another tactic: Tie the anchor to the ship and gently rock the vessel to free it from the sediment. Even “fluidizing” the mud around the anchor with a commercial rig designed to recover crab pots has been tried successfully.

When the mooring is released, the ship maneuvers close to the buoy, and a member of the team reaches over the side with a titanium hook on the end of a carbon-fiber pole. “The hook is basically a carabiner (a metal loop used to secure mountain climbers to safety lines) on steroids,” says Rohrer, who enjoys climbing at places like Oregon’s popular Smith Rock when he’s not at sea.

Once clipped to the buoy, a line is run through an A-frame on the rear of the ship to a winch. As the mooring line comes onboard, the ship must be moved without endangering any of the instruments trailing like crab traps below the buoy in the water.

With everything onboard, the scrubbing begins. Barnacles — both gooseneck and the harder-to-remove acorn species — and kelp must be removed before they dry out. “It takes a lot of elbow grease, a lot of people working together to keep morale up,” says Rohrer. “It’s sensitive, valuable gear. You can’t just sandblast or pressure wash it. You clean up as much as you can on ship. It becomes gross pretty quickly if you don’t.”

International Waters

The Northwest’s ocean monitoring system doesn’t stand on its own. It’s part of the National Science Foundation’s Ocean Observatories Initiative (OOI), which was more than 20 years in the planning and maintains seven loca-

Safety lines tighten as a hoist lifts a buoy off the research vessel Oceanus. (Photo: Oregon State University)

tions in the Pacific and North and South Atlantic oceans. These places are exceptionally sensitive to currents, climate and geology. For the first time, the OOI gives scientists a round-the-clock view of what they could previously glimpse only occasionally from ships or satellites when the weather cooperated.

The local network is designed to study an overarching question: How will a highly productive coastal ocean evolve under a changing climate? The answers will shed light on similar regions of the world’s oceans and affect the Northwest’s rich fishing, seafood and tourism industries, not to mention the spectacular diversity of Oregon’s coastal waters. After arriving at the Ocean Observing Center and routed elsewhere, OOI data are made available to the scientific community and to the public.

Success comes down to the crews of technicians and scientists who face the same wild forces that mariners have struggled with for centuries. As for the buoy that escaped last winter, analysis continues into what went wrong. “It was either fatigue from so many big-sea days in a row or it’s possible that it was struck by a log or something during the storm. There was wood embedded in the tower,” says Rohrer.

In May, the Endurance team recovered the rest of the components of the broken mooring. Over the summer, they will examine the evidence to pinpoint the cause of the failure. The buoy will be reconditioned and sent back to its post. It’s all part of the dance that oceanographers do to unlock the secrets of the sea. **terra**



Architectural design of proposed research ship by Glostien Associates Inc.

The sheer, misty cliffs of the Pribilof Islands are breeding grounds for vast colonies of seabirds like the thick-billed murre and the black-legged kittiwake. (Photo: Momatiuk Eastcott/Animals Animals)

Predation in a Patchy Sea

Ocean life in four dimensions

BY LEE SHERMAN GELLATLY

One howling, fog-shrouded night on the Bering Sea, two small boats pitch and roll on a convulsion of waves. From the bridge of the fishing vessel Frosti, marine ecologist Kelly Benoit-Bird is staring hard off to starboard, where a halo of light dances on the slate-gray ocean. She can see the expedition's second boat, the fishing vessel Gold Rush, lurching wildly in the glow of its deck lanterns. Through her binoculars, she can just make out fisheries ecologist Scott Heppell, her research partner for the expedition, looking back through the salty spray.

Hour after hour, the researchers and their teams ride the gale, each of them keeping a tense eye on the other's boat as it "thrashes violently in the swell." At long last, dawn leaks through the mist. The storm is spent. But the trouble isn't over. For the marine scientists leading this Oregon State University research cruise to the Pribilof Islands — a lonesome archipelago in the shadow of the Arctic Circle — storms at sea are business as usual, typically causing no more than a hiccup on an expedition. Not this time. The storm's monstrous force has sheared off a critical piece of gear for Benoit-Bird's two-season study of predator-prey interactions.

"Our acoustic transducers went straight to the bottom," she notes wryly. "The Bering Sea is unforgiving."

The scientists were 200 miles from the closest port. As is the norm for deep-ocean researchers, they swallowed their disappointment and improvised, changing their data-collection protocol so the two boats could share the remaining electronic instrument, which processes data from acoustic signals beamed from the boat into the dark, icy waters in search of life.

"I often study processes that happen in the dark," says Benoit-Bird. "One of the great advantages of using acoustics is that we can observe things not only when there's no sun, but also at depths where light levels are always low. There are great opportunities to learn new and unexpected things when we make observations at places and times at which others have not."



Northern fur seals hunt in the open ocean, returning to the rookery in the Pribilof Islands every few days to feed their young. (Photo: Nature in Stock / Minden Pictures / Yva Momatiuk & John Eastcott)

A Patchwork of Prey

What drives Benoit-Bird’s work as a “pelagic” (open ocean) ecologist is the enigma of predator-prey synergies at sea. Big picture, she’s searching for the “rules” that predators share as they exploit ocean food sources wherever they live, whether it’s the frigid Arctic Ocean, the temperate Pacific or the balmy South Seas. Why do marine animals congregate where they do? What combination of characteristics makes one school of fish or aggregation of plankton more attractive than another? How do ocean dwellers even find their prey out there in the watery vastness?

For the Bering Sea study, she zeroes in on an unlikely trio of air-breathing pelagic hunters — a marine mammal species and two species of seabird — that breed and feed in this bleak seascape separating Alaska from Siberia. In partnership with the Bering Sea Project — a joint endeavor of the National Science Foundation and the North Pacific Research Board — she has come to the Pribilofs, along with eight other investigators and their teams, to study how northern fur seals (*Callorhinus ursinus*), black-legged kittiwakes (*Rissa triactyla*) and thick-billed murres (*Uria lomvia*) choose their feeding grounds and



Thick-billed murres nest precariously on narrow ledges high above the Bering Sea in the Pribilofs. (Photo: Momatiuk Eastcott / Animals Animals)



Black-legged kittiwakes are small, cliff-nesting gulls that breed in large colonies, feeding their young with food foraged at sea. (Photo: U.S. Fish and Wildlife Service)

what those choices might mean for sea life and fisheries management in this remote, rapidly changing ecosystem, home to one of the world’s richest concentrations of life, much of it dependent on sea ice that is disappearing at an alarming rate as the Earth warms.

Notes Benoit-Bird, “This research is critical in places like the Bering Sea where the biology of the system is rapidly showing effects of climate change.”

For each of the three target species — all with offspring waiting on the islands for food — the act of hunting looks quite distinct. Fur seals, insulated in their ultra-thick coats, dive down deep and forage far out to sea, coming back every few days to nurse their pups. Thick-billed murres —

the squat, black-and-white birds often called the “penguins of the Northern Hemisphere” — are clunky flyers but expert swimmers, able to dive 500 feet in pursuit of fish, squid and crustaceans to eat themselves, or to bring back whole for their chicks. In contrast, black-legged kittiwakes, a species of gull, can fly like the wind across miles of open ocean to and from the sheer cliffs where their young wait for a meal of whole fish; yet they’re capable of only the feeblest dips beneath the surface of the sea when they forage.

“As we studied these three species with very different overall foraging strategies,” she says, “we asked, What is it they share in common? Does that commonality tell us something about the general rules of



Photo: Rob DeGraff

Meadows of the Sea

Climate change could alter seagrass-seaweed balance

In the estuaries of the Pacific Northwest, seagrasses grow in underwater meadows, perfect havens and nurseries for sea life. So far, seagrasses are holding their own against “macroalgae” — large seaweeds that in some regions have bloomed wildly, smothering native species like eelgrass. A study of four Oregon and Washington estuaries (Coos, Yaquina, Netarts and Willapa bays) by OSU researcher Sally Hacker found stasis between the grasses and the weeds, perhaps because “tidal action and local currents are mediating the smothering effect” seen elsewhere. But she warns that climate-related changes to ocean upwelling “could have potentially profound effects on the future production” of Oregon’s estuaries.

Kelly Benoit-Bird uses sophisticated acoustic tools to study marine life. (Photo courtesy of Kelly Benoit-Bird)



predator-prey dynamics? What are the decision-making rules that guide their behavior?”

Her search for answers starts at the bottom of the food chain, the animating bedrock of all marine life. At the base of the chain are uncountable legions of plant-like “phytoplankton” (untethered, single-celled photosynthesizers sometimes dubbed the “grass of the sea”). Next are their animal-like counterparts, the zooplankton (mostly tiny animals with limited mobility that drift with the currents and tides). Comprising the third category are itty-bitty free-swimming creatures called “micronekton” (roughly, “tiny swimmers,” as derived from German and Greek). Then come the so-called “forage fish,” diminutive species like sardines, anchovies and

herrings (the ones that often end up at the supermarket, sauced in oil and packed in tin cans), along with juveniles of other fish like pollock and even the plus-size krill that inhabit the Bering Sea. Sardines and their ilk swim in great silvery schools, their mouths wide open to expedite eating the multitudes of planktonic wanderers in their path. When the forage fish are, in turn, devoured by bigger creatures, energy transfers up the food chain. (In the case of baleen whales, the chain is shorter because the whales graze directly on zooplankton.)

The mystery that long has tugged at Benoit-Bird’s imagination is how, in the unfathomable depths and limitless distances of Earth’s oceans, do seabirds, seals and other predators manage to find their most suitable prey? How do they locate the

best feeding grounds, places where the energy used in pursuit of food doesn’t exceed the energy gained in consuming it?

To answer these questions Benoit-Bird, winner of a 2010 “Genius Award” from the MacArthur Foundation, extends her senses with technology. She and her collaborators use acoustics, optics, night vision, robotics, radio tagging, net sampling and computer modeling, in addition to direct observation, to locate and analyze clusters of marine organisms such as tiny, transparent, shrimplike krill that otherwise would remain hidden to human observers on the surface. Not satisfied with the limitations of off-the-shelf instruments, she and her team design or modify much of their own equipment in her lab.

One of her tools is the echosounder, a device that sends pulses of sound waves into the briny darkness. When the sound waves bump into something solid, they bounce back to the boat. This “backscatter” gives the scientists clues to what’s out there in the inscrutable sea. Even in the dark or the fog, the acoustic gear lets scientists estimate the vertical depth, horizontal breadth and density of the clusters they call “thin layers” or “patches.” These patches appear to be pivotal, although their etiology is not well understood. “We don’t fully understand the mechanisms that form the layers,” Benoit-Bird says. “It’s a mix of physics and behavior on behalf of the critters.”

However they originate, these layers are pivotal in open-ocean predation dynamics. “A central issue in ecology is the mechanisms underlying the distribution of predators in their habitat,” Benoit-Bird writes in the scholarly journal *PLOS One*. “Patchiness may be critical for understanding predator-prey relationships in pelagic marine systems.”

It turns out that the seal, the murre and the kittiwake, despite vast tactical differences, use the same overall, patch-related strategy

to feed, Benoit-Bird and her team discovered. The mammalian and avian hunters picked patches where prey animals were tightly packed. The scientific terms are “local density” or “local concentration.” For shorthand, she calls them “hotspots.” There was nothing random about the predators’ tactics, no swimming around in hopes of an accidental catch. Rather, the Pribilof hunters were seeking aggregations or “blobs” of fish — what Benoit-Bird describes as “concentrated balls of prey.”

“They will choose a small area where a hundred fish are swimming close together over a large area where thousands of fish are all spread out. It’s not about the thousands of fish. It’s about how tightly packed they are. It’s about how many fish can you get in a single dive before you have to come up for air.”

The Cycles of Time

Benoit-Bird’s Pribilof study focused not only on three predator species, but also on three spatial dimensions — length and width (horizontal) and depth (vertical). But there’s a fourth dimension, one that’s trickier to grab onto in the churning, ever-shifting sea yet critical to understanding predator-prey dynamics. That dimension is time. Benoit-Bird argues that the “snapshots” most scientists capture at sea are only that — momentary glimpses that shift by the time you blink.

“We can tow a net through one spot and then do it again in the exact same spot and it comes out different,” she says. “That’s because everything is moving.”

The ocean’s perpetual motion — its currents, tides, waves and upwells, confounded by seasonal hurricanes, monsoons and typhoons — are complex enough. The plot thickens further when you add climate-related changes in ocean temperature, oxygen and acidity. This dizzying set of spatial, chemical and physical variables gets even knottier when you try to factor time into the predator-prey picture. How, for example, do the cycles of the moon and the sun affect marine organisms?

Acoustic tools and the animals they are used to study, from zooplankton to marine mammals. (Graphic by Kelly Benoit-Bird and Gareth Lawson)

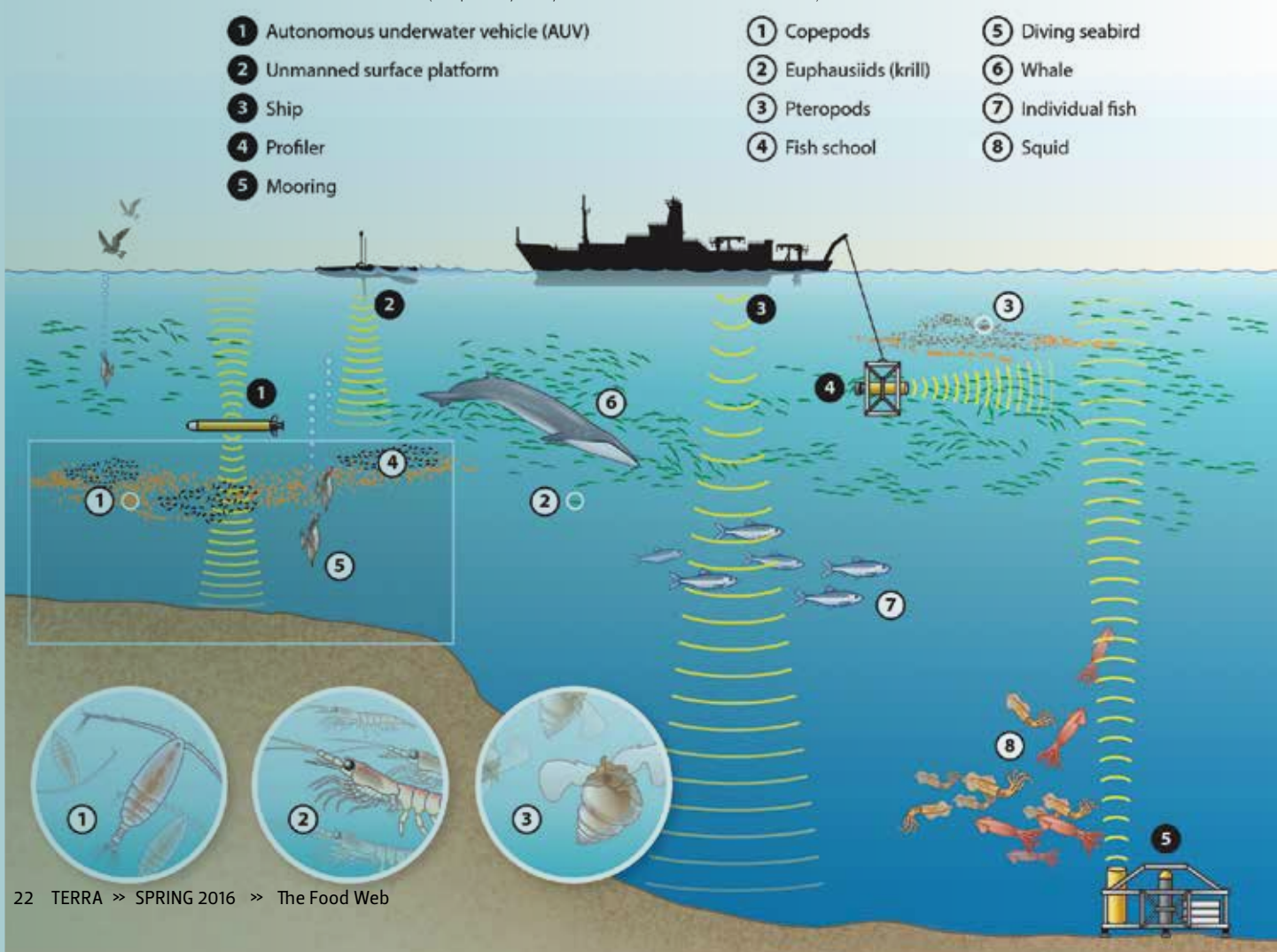


Photo: Paul Stein

The Price of Tradition

Dolphins slaughtered for their teeth

The 2010 Academy Award-winning movie *The Cove* — which documented dolphin slaughter in Japan — included scenes of OSU researcher Scott Baker conducting DNA analysis covertly in his hotel room. Baker’s stealth genetic science helped ID the marine mammal species being sold in local meat markets. More recently, Baker has studied the killings of thousands of dolphins in the Solomon Islands. The animals’ teeth, worth 70 cents apiece on the local market, are valued for traditions such as dowry necklaces like the one shown above. Baker warns that local dolphin populations could be at risk. “There is an urgent need to improve the monitoring of these catches, with the eventual objective of implementing a management procedure,” Baker says.

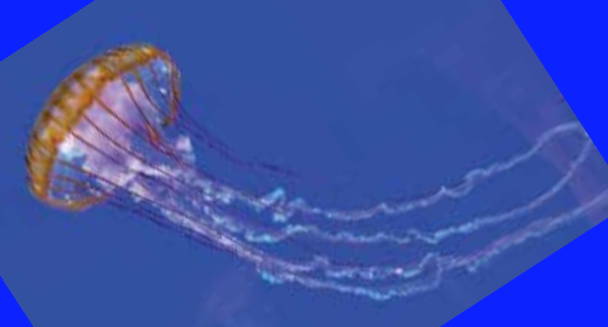


Photo: Volvox

Bloom of the Jellyfish

Gelatinous “jellies” compete with sardines and other forage fish

Huge spikes in jellyfish numbers cause mayhem for fishermen, clogging their nets and wasting their effort. These “blooms” may stem from changing climate and ocean conditions, as well as overfishing of forage fish (sardines, anchovies, herring and the like). These tiny fish normally keep jellies in check by competing for the same food. When jellyfish populations explode, they divert protein across the food web in the way a “roundabout” diverts cars to multiple routes, say OSU researcher James Ruzicka and postdoctoral scholar Kelly Robinson. Forage fish, on the other hand, move protein up the web more efficiently, creating an “energy expressway.” Jellies, they argue, should be part of fisheries management strategies.

“The fourth dimension is crucial in pelagic systems,” she asserts. “That’s because even immobile organisms can be moved by currents and, unlike terrestrial habitats, there are few fixed features where animals can hide or hold fast. Space and time together may underlie the timing of outbreaks such as toxic algae, or blooms of jellyfish and other marine life. They may affect the stability of predator-prey interactions or the competition for resources.”

To begin teasing out the temporal influences, Benoit-Bird voyaged to another island archipelago, this one nearly 3,000 miles south of the Bering Sea. She started by looking at 24-hour migrations of creatures as they move up and down in the water column. Do feeding patterns shift from day to night, dawn to dusk? she wondered. For two summers, she and her team spent three weeks, day and night, counting layers of plankton in the warm seas around the Hawaiian Islands. She identified 200-plus discrete layers of phytoplankton, which shone with a sparkling, indigo fluorescence. She found almost 275 layers of zooplankton, mostly “copepods” (teardrop-shaped crustaceans whose name means “oar-feet”), which reached concentrations as high as 100,000 individuals per cubic meter of water. She also sampled layered concentrations of micronekton and studied their overlap with spinner dolphins (*Stenella longirostris*), which cooperatively herd patches of prey with their rapid, whirling movements and precision choreography.

“In this Hawaiian system, there is a very short period around dusk each night when almost everything interacts with everything else,” she says. “As the sun goes down and temperatures cool, the winds pick up, and everything starts to mix. Organisms that were strongly stratified horizontally start moving up and down vertically. It goes all the way from the phytoplankton to the zooplankton up through the fish and the dolphins. This 30-minute timeslot is the main time when energy is being transferred from one group to another. We think it could be as much as 90 percent of the daily energy exchange between predators and prey, all driven by the switch from day to night. It’s pretty amazing.”

Swimming the Blues

As powerful as it is, Benoit-Bird’s acoustic gear is only able to narrow down the possibilities of what’s drifting or swimming in each patch. She can get a rough idea of size and biomass, for instance. Pinpointing the exact species requires the team to manually collect samples by towing specially designed nets behind the boats. The trouble with nets is they can mangle fragile zooplankton like “pteropods” (marine snails nicknamed “sea butterflies” for the gossamer “wings” or flaps with which they swim) and juvenile squids, whose big-eyed, bell-shaped bodies are crowned by bursts of delicate tentacles.

That problem is what inspired another OSU marine researcher,

Robert Cowen, to design an underwater camera system that takes exquisitely detailed photos of zooplankton without touching them. Cowen, along with colleagues at the University of Miami and the San Diego-based underwater-instrument manufacturer Bella-mare, have designed a state-of-the-art system for studying zooplankton in their natural habitat, photographing them in place while they float. In this way, they can be measured, classified and counted digitally instead of manually. Of special interest to Cowen, director of the Hatfield Marine Science Center, are the medium-sized zooplankton or “meso-zooplankton,” which include “ichthyoplankton” (larval fish), whose oceanic lives remain largely a mystery because of their rarity and fragility.

“Our imaging system, towed behind a research vessel, can sample large volumes of water at very high resolution without disturbing the organisms,” he says. “This allows us to quantify their density, size and distribution and observe them in their natural position and orientation within the water column.” Specially designed “shadow-illumination” lighting lets Cowen and his team capture crystal-clear, highly contoured images of the vividly colored and outlandishly shaped creatures for later characterization.

Still another OSU marine scientist is adding new pieces to the predator-prey puzzle — this time on the opposite end of the size spectrum. While Cowen is investigating creatures barely visible to the naked

eye, Ari Friedlaender of the Marine Mammal Institute is studying the feeding behavior of blue whales, the largest animals to ever live on Earth. Using their comblike plates of cartilage (“baleen”) to filter thousands of gallons of krill-rich seawater into their massive mouths, blues were long thought to be indiscriminate grazers — randomly swimming around in search of an opportunistic meal — according to Friedlaender. But by radio-tagging blues in southern California, he and his research partners have unveiled the whales’ highly sophisticated foraging habits. By waiting for the densest, highest-quality prey and then feeding in intense sessions of deep, super-consuming lunges, the blues maximize their energy intake while minimizing their energy output.

The implications for the endangered blue whale (and, by extension, other marine predators) are clear, according to Friedlaender. “The decisions these animals make are critical to their survival,” he says. “If they’re disturbed during intense, deep-water feeding, it could have consequences for their fitness, overall health and reproductive viability over time.”

Adds Benoit-Bird: “We’re still trying to learn basic ocean dynamics even as those dynamics are changing rapidly. We need to understand the drivers of predator-prey abundances in marine systems so we can gauge ecosystem resilience, manage fisheries, protect exploited species and predict and mitigate the impacts of climate change.” **terra**



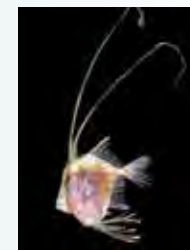
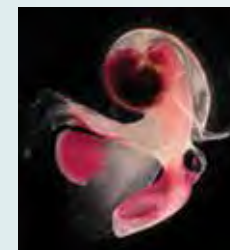
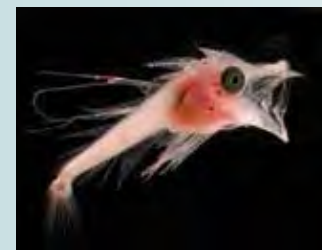
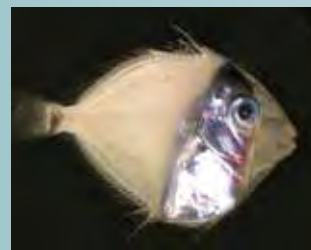
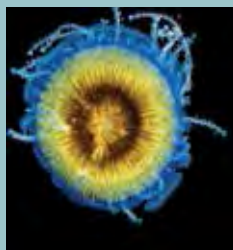
Photo: Kirt Edblom

Lifestyles of Marine Microbes

How one-celled ocean organisms affect the global carbon cycle

Floating in the seas are zillions of microscopic creatures called “protists,” a catchall term for a group of algae-eating organisms that are neither animal, plant or fungus. As ubiquitous as they are, scientists don’t yet fully grasp their role in the marine carbon cycle, according to OSU researcher Stephen Giovannoni. The microbes’ biology, he says, “comprises diverse lifestyles that shape the carbon cycle through elaborate but poorly appreciated food-web connections.” How the microbes will respond to ongoing climate change is uncertain at the moment — a question that needs urgent study, Giovannoni asserts.

Tiny zooplankton, often juvenile fish, feed on their plantlike cousins, the phytoplankton, at the base of the vast marine food web. Photos from the Cowen Lab show them in their wild and whimsical colorfulness, common names from left: blue button jellyfish, surgeonfish, octopus, armored searobin, sea butterfly and lookdown. (Photos: Cedric Guigand)



SPILLOVER

Oregon's marine reserves may help sustain valuable fisheries

BY LEE SHERMAN GELLATLY

On a typical, low-visibility day out among Oregon's rocky reefs, scuba divers float in a murky, monochromatic world. Sunlight filtering through the algae-rich brine of near-shore waters casts a green patina on everything.

These days, scientific divers are regulars at four of Oregon's reefs and headlands — Redfish Rocks, Otter Rock, Cascade Head and Cape Falcon — which have been set aside as sea-life sanctuaries, of sorts. (A fifth sanctuary site, Cape Perpetua, is too deep for dive studies.) The divers, trained and certified at Oregon State University and the Oregon Coast Aquarium, are studying resident finfishes, seaweeds and rock-clinging creatures (like urchins and sea stars), making detailed observations, measurements and census counts. Other OSU scientists are collecting physical ocean data on critical problems like acidification and hypoxia (low-oxygen "dead zones").

Welcome to Oregon's "marine reserves," five no-fishing zones that have become living laboratories for a long-term experiment in ocean protection, monitored by the Oregon Department of Fish and Wildlife (ODFW).

Besides diving with scuba tanks, the teams capture underwater video from remotely operated cameras and stationary "landers" lowered onto the seafloor from fishing vessels. Another research method in these protected ecosystems is catch-and-release fishing. Working topside with local charter-boat skippers and volunteer anglers, marine scientists like Brittany Huntington use an old-fashioned hook-and-line rig to collect data on the size, catch rates and population trends of local species.

In the Oregon Coast Aquarium's "Orford Reef" exhibit, divers practice underwater ecological monitoring as part of scientific diver training led by OSU in partnership with the Oregon Department of Fish and Wildlife (ODFW). (Photo: David Baker)



At first, there was a problem. The early samples at Redfish Rocks were skewed toward a single species. “We were catching 90 percent black rockfish using hook-and-line fishing,” says Huntington, an OSU courtesy professor who leads ecological monitoring for the ODFW Marine Reserve Program based in Newport. Blacks (*Sebastes melanops*) are only one of more than 60 species of rockfish, a type of “groundfish” (bottom dweller) and the mainstay of Oregon’s commercial fishery. So the scientists turned for help to a “stellar” local captain, Jeff Miles of Port Orford, whose lifetime of expertise quickly turned things around.

“Our hooks were catching black rockfish as they schooled in mid-water,” Huntington explains. “We’d have a fish on the line before our gear could reach the bottom.”

What was needed for accurate sampling, Captain Miles counseled, were long lines capable of catching the deep, seafloor-hugging species. After the team switched to long lines, the sampling suddenly got a lot more colorful. Along with the legions of black rockfish (which are really more of a pewter gray with black mottling), the teams were landing fish with colors usually identified with tropical reefs, colors that animate their hue-derived common names like copper, vermilion, blue, yellow-eye and canary. One species (*Sebastes ruberrimus*) sports a shade of orange as brilliant as a clown’s hair. Another (*Sebastes diploproa*) comes wrapped in red and silver, like a Christmas package. There’s a species (*Sebastes nebulosus*) reminiscent of a Van Gogh, midnight blue dappled with a starry blaze of yellow. Still another (*Sebastes babcocki*) is dipped in princess pink, like a little girl’s tutu. No wonder their genus name, *Sebastes*, means “magnificent” in Greek.

Crab pots wait on the dock in Depoe Bay. (Photo: Chris Becerra)

Just as surprising are their shapes and faces. The spiky dorsal fins jutting from their backs hint of prehistory, echoes of some long-extinct mega-reptile. Their comical, sourpuss mouths turn downward in a perpetual scowl.

That these fanciful, Technicolor fish inhabit the murky waters off Oregon is surprising enough. But there’s more: Some of them grow to be as large and lumpy as a soldier’s duffel bag. They can live 100 years or more. And unlike humans, whose fertility wanes over time, rockfish become egg-laying rock stars in old age. The increase is exponential. A 2-foot-long vermilion rockfish, for instance, can produce close to 2 million baby fish — 20 times more than its foot-long counterpart, according to the Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a four-university consortium of Oregon State, Stanford, UC Santa Cruz and UC Santa Barbara. Think of these supersized females as the “mother lode” of the fish world.

Nicknamed BOFFFFs — Big Old Fat Fertile Female Fish — the ancient denizens of coastal waters are one important reason the Oregon State Legislature set aside five rocky reefs as marine reserves, beginning in 2009 with pilot sites at Redfish Rocks and Otter Rock. Three more reserves — Cape Perpetua, Cascade Head and Cape Falcon — were signed into law in 2012. By banning fishing at these sites, state officials are providing “nurseries” for BOFFFFs, giving them a better chance to seed the reefs and, through a “spillover” effect, replenish the oceans — as well as the state’s multimillion-dollar groundfish fishery — as their eggs float far and wide with the currents.

“In the marine realm, most eggs and larvae drift,” notes Kirsten Grorud-Colvert, an OSU marine ecologist and expert on marine reserves. “So it’s almost guaranteed that they’ll leave the marine



protected area. Setting aside a place of refuge for these large, fertile fish can really provide a grounding for our productive fisheries by seeding populations beyond the reserves.”

Big Mamas

The gaudy, egg-brimming BOFFFFs are the beneficiaries of Oregon’s marine reserve network, a plan launched in 2008 by an executive order from then-Governor Ted Kulongoski. In subsequent years, the details were hammered out in city halls, school gyms and libraries up and down the coast by an unlikely amalgam of fishermen, local politicians, business owners, fisheries managers, surfers, conservationists, university biologists and Oregon Sea Grant Extension faculty, all scribbling on white boards and sticky notes. Often, the meetings got hot and contentious. Livelihoods were at

stake. Ecosystems were threatened. Finding a mutually acceptable sweet spot seemed as elusive as the threatened marbled murrelet.

“You get beaten up by both sides,” says Loren Goddard, a charter fisherman in Depoe Bay, a bustling harbor flanked by Otter Rock to the south and Cascade Head to the north. “Some of the fishermen feel like you’re a turncoat if you participate in planning the reserves. And you never get much respect from the environmental extremists.

“Somewhere in the middle lies the truth.”

Eventually, the agonizing birth pangs in Oregon’s coastal towns brought forth the current five-reserve network. In acting to protect certain pockets from overfishing and ecological degradation, Oregon joined a global “race against time,” in Grorud-Colvert’s words, to

Captain Lars Robison of Dockside Charters in Depoe Bay spruces up his boat, Samson, in advance of the summer season, which will include fish surveys for the ODFW Marine Reserves Program. (Photo: Chris Becerra)

conserve critical marine habitat. One initiative in particular has spurred nations collectively to create thousands of protected ocean sites across the planet, from Brazil to Canada, Israel to Kenya, Portugal to the Philippines. Signers to the international treaty — the Convention on Biological Diversity (similar in concept to the U.N. Climate Change Convention that met in Paris last year) — have pledged to protect and study important marine ecosystems.

Still, ocean protection is paltry overall, says Grorud-Colvert, who has reviewed dozens of case studies of marine reserves for PISCO. While the actual number of reserves is growing — taking a big surge in

2015 with the creation of important reserves in the Seychelles, New Zealand and Chile — the average size of marine reserves still is quite small. Together, they barely add up to a drop in the ocean. Today, only about 3.5 percent of ocean habitat world-wide has been designated either a “marine protected area” (some

ical benefits of marine reserves is mounting year by year. Take the island of Lundy off the coast of England, one of the case studies PISCO examined for a recent report. Out among Lundy’s rocky reefs and sandy seafloors — a temperate ecosystem not unlike Oregon’s — European lobsters (*Homarus*



Protected from fishing in a United Kingdom reserve, European lobsters are growing bigger. (Photo: Arnstein Rønning)

restrictions on human activity) or a “marine reserve” (an all-out ban on recreational and commercial activities), according to a recent paper by Grorud-Colvert and OSU Distinguished Professor Jane Lubchenco in the journal *Science*. And then there’s the problem of enforcement, which is tough enough when enforcers work on solid ground. Policing the oceans is infinitely trickier and costlier, especially in the larger reserves; hence, many of them go unpatrolled. Those caveats aside, scientific evidence supporting the ecolog-

gammarus) had dwindled in size and abundance after decades of intense harvest. But after the area was closed to fishermen, many of whom supported the restrictions in hopes of bringing back their struggling fishery, the clawed crustaceans rebounded quickly. One photo in PISCO’s European edition of *The Science of Marine Reserves* shows a “legal-sized” European lobster alongside a second specimen, identified in the caption as a “large” lobster. The large lobster, twice as big as its species mate, has claws the size of Paul Bunyan’s hands, antennae as

long as a set of ‘50s-era TV “rabbit ears,” and looks like it could eat the legal-sized lobster for lunch. But the full story of Lundy’s lobsters is not yet written. For instance, will the large-lobster effect spill beyond the reserve’s borders? Only long-term monitoring will tell.

The Human Species

Lobsters, rockfish and other sea creatures are only half of the marine reserve equation. Humans are the other half. That’s why the ecological monitoring (diving, hook-and-line sampling, underwater videography) is just one facet of Oregon’s two-pronged marine reserves research. The “human dimension” is the other. OSU courtesy professor Tommy Swearingen is leading a wide-scale investigation into how coastal communities and individuals are being affected, financially and personally, by the closures. “When I first moved here from Miami, I was struck by how different Oregon’s coastal communities are from Florida’s,” says Grorud-Colvert, who collaborates with the PISCO lab of Lubchenco and Bruce Menge. “These are working waterfronts with communities who are very tied to the ocean, and incredibly knowledgeable about the ocean.” One of those working waterfronts is Depoe Bay, where Loren Goddard and his business partner Lars Robison, co-own Dockside Charters. When they got wind of marine reserves coming to Oregon, they didn’t hesitate. They held their noses and jumped in. “We’ve been wresting a living from the ocean for a long time,” says Goddard, his gaze drifting toward the “World’s Smallest Harbor” where his boat *Affair* is tethered. “We were

insistent that the stakeholders, the people who actually spend their time on the ocean, had to have a place at the table. At times, we felt very underrepresented.” Robison, skipper of the boat *Samson*, was born into the fishing business nearly six decades ago. Alarmed by talk of sweeping proposals to lock up huge swaths of Oregon’s coastline, he and Goddard led the formation of the Depoe Bay Near Shore Action Team to make sure their voices would be heard. Goddard also was appointed to the Ocean Policy Advisory Board. Still involved a dozen years later, Goddard as action team chair, both men express skepticism about the benefits of marine reserves. Even so, Robison has skipped his boat for scientists and volunteers doing hook-and-line surveys as part of ODFW’s ecological monitoring. He’s willing to suspend his doubts and join the research effort to help bring more data to the discussion. Another of Oregon’s close-knit coastal communities is the town of Garibaldi on Tillamook Bay. If you drive through Garibaldi on Highway 101, you’ll see very few nods to



tourism. Mostly, it has the feel of an historic fishing town, its rustic wharf home to dozens of commercial and charter boats. In the early days of Oregon’s marine reserve debate, fishermen here were united in their opposition to the idea, according to researcher Elizabeth Marino, a cultural anthropologist at OSU-Cascades. When it came time to vote on establishing a reserve at Cape Falcon north of Garibaldi, she says, every fisherman on the local action team voted “no.” Marino, who has been conducting interviews in coastal communities as part of ODFW’s human-dimensions monitoring, suggests that the Garibaldi fishermen’s resistance may not be tied to the Cape Falcon reserve specifically, since Cape Falcon has never been a favored fishing ground. Rather, she suggests an explanation that’s more existential. Their fierce defiance may be an outward manifestation of a gnawing anxiety about losing a traditional way of life as the ocean gets carved up for things like wave-energy buoy systems, wind-energy farms, aquaculture enterprises and, perhaps, even more no-fishing zones.



Rockfish show up often during catch-and-release fish surveys in Oregon’s marine reserves. (Photos courtesy of ODFW)

Acidic Seawater Threatens Shellfish
Oysters and clams face an uncertain future

The Pacific Northwest, famous for its delectable fried oysters and succulent steamed clams, is one of several coastal “hot spots” where shellfish are subject to “acidification” — seawater whose chemistry is becoming corrosive because of greenhouse gases. Along with shellfish producers in New England, the Gulf of Mexico and East Coast estuaries like Chesapeake Bay, Oregon’s shellfish industry is at risk, warn OSU researchers George Waldbusser and Burke Hales. Their research has helped Northwest oyster hatcheries rebound from larval die-offs. “Ultimately, however, without curbing carbon emissions, we will eventually run out of tools,” Waldbusser says.

“The reserves are creating uncertainty regarding the future plans of marine conservation in Oregon state waters,” Marino says. “Ultimately, fishermen are worried about coastal economies shifting away from fishing and away from the values of fishing communities.

“But it’s important to note that fishermen consider themselves conservationists as well, although they’re ideologically different from conservationists who are not part of the fishing community. All the people I interviewed in Garibaldi expressed deep concern for the health of the ocean.”

Baby Fish

In marine reserve science, one of the biggest gaps happens to be one of the tiniest facets: baby fish. You can’t

miss a big fat fertile female rockfish when you’re out on the reef. But what happens to her millions of teeny-tiny offspring? Where do the 1- to 2-inch juveniles go after drifting with the currents as eggs and larvae? Are they settling into any of Oregon’s marine reserves?

That’s what Grorud-Colvert and her colleagues are trying to find out by using an ingenious piece of gear called a SMURF (Standard Monitoring Units for the Recruitment of Fishes). Made of a fine, green mesh rolled into a 3-foot-long cylinder and attached to an anchored line in the ocean, it’s full of nooks and crannies, making it a happy landing place for small fish to shelter.

“These little guys aren’t part of standard monitoring in marine reserves,” she says. “We want to see

which juvenile fish are coming in and settling in our protected areas.”

One early surprise was discovering juveniles of the boldly striped orange-and-red tiger rockfish (*Sebastes nigrocinctus*) at Otter Rock, the smallest of Oregon’s reserves. “The tiger rockfish is a deep-water species that can be found at depths up to 1,000 feet,” she says. “Yet we’re seeing juveniles at Otter Rock coming in to 50 feet of water and possibly even shallower — areas that are part of our marine reserves.”

Another early finding, this one at Redfish Rocks, suggests that certain rockfish hang around their home waters, while others swim farther afield. OSU master’s student Tom Calvanese is using acoustic transmitters to track movement patterns of fish through a project he calls

“Fishtracker.” In a recent interview posted on *National Geographic’s* “Ocean Views” blog, Calvanese says that tagged China rockfish (the midnight-blue and yellow “Starry Night” species) in his study stuck close to home, while the canary rockfish came and went for a few weeks before leaving for good.

The Last Fish

All of the monitoring, both ecological and human, will be wrapped up and reported to the Legislature in 2023. While scientists acknowledge that real transformation of underwater ecosystems may take decades, they expect their studies to show enough significant benefits to justify the reserves into the future.

Many fishermen, meanwhile, watch with a jaundiced eye. Ever

the skeptic, Goddard points to some of the fallout he sees from marine reserves. Boats that were once spread out are now clustered together, he says, because of “fleet shift” or “effort shift” — the flux in favored fishing grounds after the reserves became off-limits. As one Garibaldi fisherman puts it, “The reserves are putting pressure on the areas that are left.” A related phenomenon is “fishing the line,” where vessels drift just outside the protected area, taking fish that stray beyond what for them is a nonexistent barrier.

So far, anyway, Goddard isn’t seeing the spillover effect that researchers anticipate. But his partner Robison may have spotted a glimmer. “In the September fishery last year, we saw a lot of fish out there — a lot of rockfish every-

where,” he says. “I think maybe it was actually an effect of not getting fished as hard as other places — fish that weren’t being bothered.”

Goddard’s stance is strictly wait-and-see. He says he would “love to see” a spillover effect from Oregon’s marine reserves. “If the scientific evidence is compelling that reserves are beneficial,” he says, “then my attitude would change.

“We make our living doing this. We have a business that’s very viable. We want it to continue to be so. If we catch the last fish, then we haven’t done that. And none of us wants to be that person that catches the last fish.” **terra**



Green Power from Waves

Tapping the ocean’s vast energy potential

The whole world could be powered by a tiny fraction of the ocean’s untapped energy — if it could be harnessed. This is the vision guiding researchers at OSU who are developing and testing devices for capturing energy from waves, tides and currents that can be sent to the electrical grid through underwater cables. The work of OSU researchers such as Annette Jouanne and Belinda Batten has the support of U.S. Senator Ron Wyden, who has introduced the Marine and Hydrokinetic Renewable Energy Act in Congress. Half of Oregon’s goal for 25 percent renewables by 2025 could be met by wave energy.



Minerals from the Seafloor

Mining could upset delicate ecosystem functions

To meet the world’s demand for minerals, oil and geothermal energy, humans are now looking toward the seabed. Miles-deep deposits of manganese, iron, nickel, cobalt and copper already have spurred exploration by mining companies. The next step, lowering heavy machinery onto the ocean floor, is just around the corner, says OSU researcher Andrew Thurber. He cautions that the deep ocean’s role in Earth’s “biological pump” is just one of countless services it provides to the planet. “The deep ocean is very closely linked to the function of the surface of the Earth,” Thurber says. “It’s where the nutrients fueling our most productive fisheries come from, and also acts as the major sink for carbon dioxide released into the atmosphere.”



Medicines from the Deep

Strange sea creatures hold promise for cures

In the oceans’ darkest depths, superheated water seeps from cracks on the seabed. This lightless world supports exotic creatures like tubeworms and giant clams. It’s their very oddity that makes them exciting to OSU medicinal chemist Kerry McPhail. That’s because organisms from extreme environments have novel chemistries to match their novel habitats. The thick bacterial mats coating vent “chimneys,” for instance, are being studied in McPhail’s lab, along with a South African sea squirt (tunicate) and a Panamanian compound with anticancer properties. McPhail and OSU colleague Jane Ishmael are studying the potential benefit of using coibamide A from Panama to treat aggressive brain cancers.



Freshwater from Saltwater

New desalination technologies on the drawing board

Turning saltwater into drinkable freshwater is typically done in large facilities near big power plants to keep energy costs low. The water then is transported to its destination at added costs to the environment and economy. Now, a partnership between OSU and a private startup is moving the industry toward a cheaper, greener approach. With seed funds from Oregon BEST, researcher Goran Jovanovic is working on a novel “capacitive deionization” process that could remove salt from seawater using half the energy of prevailing technologies. “Recently, a large international company expressed an interest in adopting this technology for their clean-water needs,” says Jovanovic. “They will be supporting part of our R&D activities for the next two years.”

CHANGES IN THE WIND

Clues come from beaches, salmon and old ice

BY NATHAN GILLES

When Peter Ruggiero meets with people in coastal communities to discuss climate change, he asks them to consider what they like most about where they live. And then he asks them to imagine the future.

“We get people to think about the positive aspects of the coast, what they like about working and playing along the coast,” says Ruggiero, a geomorphologist (a scientist who studies land forms) at Oregon State University. “And then, in light of problems like sea-level rise and other climate hazards, we start thinking about strategies that can get them to their ideal,” how the community might maintain its cherished values.

Climate change can be a daunting, difficult subject, but the thing is, says Ruggiero, this exercise helps people approach it with a sense of purpose. “We’ve found this actually moves the needle. People become more optimistic and less pessimistic about climate change.”

Signs associated with a changing climate are starting to appear along the West Coast. Salmon struggle in warming waters. The ocean is

becoming more acidic. Fisheries have been closed by prolonged algal blooms, aka “red tides.” Rising seas and winter storms increase flooding and erosion.

The science may be complex, but the consequences are straightforward: If we continue to emit greenhouse gases into the atmosphere, these problems are likely to worsen. However, this isn’t just a doom-and-gloom story. Scientists are making strides in understanding the climate system and working with communities to use that knowledge to respond and adapt.

A Breath from the Past

A snowmobile traverses the slick white surface of a vast glacial ice sheet. In the distance, snow-covered peaks rise to a nearly pristine firmament of crisp blue under a sun that never sets. A team of scientists unloads gear at a makeshift camp and starts the arduous task of drilling slowly into the ice.

The lead researcher is Ed Brook. The location is Taylor Glacier in Antarctica. The Oregon State geosci-

entist specializes in the climate of the distant past and is enamored with very old ice. For him, the key to understanding our future lies preserved in what the ice contains: bubbles of ancient air.

Carbon dioxide found in old ice reveals a simple pattern: CO₂ concentrations in the air go up during warm periods and down during cold ones. Brook’s research has revealed a serpentine-like exchange of carbon between the atmosphere, ocean and land.

“Studying the past tells us how the world works, but the past isn’t completely prologue to the future,” says Brook. “There just isn’t a recent episode of dumping thousands of gigatons of carbon into the atmosphere in such a short period.”

Air in old ice reveals that in the past 800,000 years, CO₂ hasn’t risen above 300 parts per million. Often, as during one of Earth’s many ice ages, it’s been much lower. Current levels are about 400 parts per million and rising. This carbon traps heat and is expected to lead to higher temperatures.

The past may not be a prologue to our future, but work by Brook and other paleoclimatologists tells us a great deal about the climate system and how it occasionally “tips” from one regime to the next. In a paper published last year in the journal *Nature*, Brook and several OSU colleagues documented 18 such “abrupt” climate changes over the past 68,000 years.

Like Brook, Alan Mix has traveled to far-off places to extract cores, but he is devoted to a different material: sediment from the seafloor. In addition, the Oregon State geochemist loves old cartoons, specifically Wile E. Coyote.

The ever-optimistic cartoon character is infamous for pursuing — but never capturing — a certain speedy roadrunner. His predatory pursuits frequently send the carnivore over a cliff where he remains suspended in midair until, noticing his predicament, he promptly plunges to the canyon floor. This, says Mix, is what a climate tipping point looks like.



Climate change could be reaching a tipping point, says Oregon State professor Alan Mix. (Photo courtesy of Alan Mix)

Tipping points happen when the climate moves from one state of equilibrium to another, as it did when the Earth emerged from the last ice age. These changes, says Mix, often happen quickly, geologically speaking, and tipping points may occur before outward signs are noticeable.

“There may be tipping points that are loops, and the climate can get back up,” says Mix. “Or the tipping points may be one-way tickets, and the climate never gets back up. That’s when the coyote gets squished at the bottom. Of course the coyote always gets back up.”



Melting glaciers and crumbling ice sheets are contributing to sea-level rise across the globe, says Oregon State geologist Peter Clark. (Photo: Oregon State University)

But climate, he adds, is not a cartoon coyote. “If we cross the tipping point and lose the ice sheets, they won’t return, at least for a very long time,” says Mix. “For human purposes, global warming is pretty much permanent.”

In a study published last year in the journal *Science*, Mix and his former graduate student Summer Praetorius demonstrated what might have triggered a tipping point corresponding to the abrupt end of the last ice age.

Using radiocarbon dating of fossilized microorganisms found in ocean sediment cores, the researchers demonstrated that the warming of the North Atlantic and North Pacific oceans some 15,500 to 11,000 years ago occurred in a coordinated, synchronized fashion. As a result, they say, the global climate tipped over an edge. Ice melted and sea levels rose. Both are occurring today as well.

Warming Oceans and Rising Sea Levels

It’s the year 2100. Unchecked carbon emissions have led to a world that’s considerably warmer than it was

just a century earlier. Policymakers in 2016 had set their sights on this year when thinking about the future. However, there isn’t anything magical about the date. Climate change isn’t stopping. Carbon in the atmosphere continues to heat things up, and sea levels are still rising.

“One thing that the (paleoclimate) record does inform us about, as far as global warming, is an idea of what we call sensitivity — how sensitive sea level is to a given amount of warming,” says Peter Clark, a paleoclimatologist who holds the title of distinguished professor at Oregon State.

Clark was one of two coordinating authors on a comprehensive analysis of sea-level rise and climate change for the Intergovernmental Panel on Climate Change, the world’s leading climate research organization. Last winter, he made headlines with an article in *Nature Climate Change*.

Using climate models for the next 10,000 years, he and his co-authors, including Mix, outlined a sobering message: Even if humanity meets its goals of lowering carbon emissions, a substantial amount of atmospheric carbon that was already released will hang around, some of it for tens to hundreds of thousands of years. The loitering carbon will continue to trap solar radiation, warming the planet

and leading to melting glaciers and ice sheets and to rising sea levels.

Clark offers the analogy of boiling a pot of water on the stove. Turning on the burner applies heat to the water, but the water doesn’t warm right away. It takes time. In a similar fashion, greenhouse gases are warming the atmosphere. The question is how long it will take the oceans to rise and by how much, as air and water temperatures increase.

Melting glaciers and ice sheets and warming ocean waters (water expands as it heats up) all contribute to sea-level rise, but each unfolds at a different pace: glaciers over tens of years; warming water over hundreds to thousands of years; and ice sheets over several thousands of years. All lead to a long period of sustained and accelerating coastal flooding.

“This century we could see sea level rise by 1 meter (3.3 feet),” says Clark. “Over the following 2,000 years, we could see it rise continuously as high as 3 meters (10 feet) per century.”

Warming oceans don’t just affect rising sea levels. Collectively since 1970, our planet’s oceans have absorbed roughly 90 percent of the extra heat produced by human-caused warming. This, however, is a global aggregate. Tying regional warming events to climate change can be trickier.



Citizen Science vs. the “Blob”

Skipjack tuna, normally found in the balmy waters of the tropics, are reeled in by fishermen off the southeast coast of Alaska. Ocean sunfish and a thresher shark — more outsiders — are also hooked. Meanwhile, seabirds on the Pacific Northwest coast, normally chunky Cassin auklets, arrive en masse and emaciated.

Starting in late 2013, an expanse of exceptionally warm water more than twice the size of Texas and approximately 300 feet deep appeared off the West Coast, stretching from Oregon to Alaska. The “Blob,” as it came to be known, is believed to be the culprit behind a series of peculiar occurrences, including the reeling in of tropical fish off Alaska.

“However you slice it, the ‘Blob’ is extremely unusual,” says Oregon State professor Philip Mote, director of the Oregon Climate Change Research Institute.

The underlying meteorological cause, he adds, is believed to be a prominent ridge of higher-than-normal pressure that effectively parked itself off the West Coast, keeping the winds modest and the skies clear and giving the ocean ample time to soak up the sun. This ridge has been implicated in the historic drought in the West over the past few years. But while the drought is widely believed to have climate change’s fingerprints all over it, says Mote, the connection between the “Blob” and climate isn’t so clear.

To study that relationship, Mote and his colleagues are doing what most climatologists do: They’re running a series of computer models. Essentially colossal video game simulations of the Earth, these models tend to be bulky — “computationally expensive” — and, therefore, require powerful super computers to run them, or, as Mote and his colleagues would learn, a lot of average computers.

Coral Bleaching Goes Viral

When tropical waters warm or get polluted, coral reefs may take drastic measures. They can expel the algae that provide them with stunning colors — and vital nutrients. So-called bleaching events have been documented across the globe with increasing frequency and can be fatal to the corals.

Oregon State University researchers have discovered a new twist: Viral infections blossom as bleaching events unfold. “This research suggests that viral infection could be an important part of the problem that until now has been undocumented, and has received very little attention,” says Rebecca Vega-Thurber, microbiologist in the OSU College of Science.

The National Oceanic and Atmospheric Administration has estimated that by the end of last year, almost 95 percent of U.S. coral reefs were exposed to ocean conditions that can cause corals to bleach.



Acidification Likely to Intensify

West Coast waters are likely to see continued impacts from acidification, warming temperatures and low-oxygen conditions. That's the conclusion of a report in the journal *BioScience* co-authored by Francis Chan in the Oregon State College of Science.

"The changes really stem from the basic impact to physiology, no voodoo involved," says Chan. "We need to look at ocean acidification not just as one stressor, but that it's going to be affecting organisms in the context of other things."

Chan is co-chair and one of five OSU scientists on the West Coast Acidification and Hypoxia Science Panel, which advises policymakers on increasing acidity in coastal ecosystems.

Photo: Blaine Bellerud/NOAA Fisheries West Coast

Via a project at Oxford University called ClimatePrediction.net, thousands of citizen-science volunteers have lent Mote and his fellow researchers their computers' processors to run simulations during their machines' idle hours. "If you only run a climate model once, you can't be sure that your answers are repeatable," says Mote. "For this project, we've effectively run our model tens of thousands of times."

These multiple runs allow Mote to dutifully search for a climate culprit behind the "Blob." But citizen science has another benefit,

says Li Sihan, a graduate student of Mote's who is using ClimatePrediction.net in her research. "People often put scientists in a bubble or shrine. Or they do the opposite and deny our results without understanding how we came to them. With this project, people can see the models running on their computers, and that's exciting."

The effect of the "Blob" on sea life comes as a kind of proof of concept of an idea that fisheries biologists have been concerned about for decades: Warming oceans are expected to impact many species of fish, including salmon.

A recent analysis of juvenile Chinook salmon in the Pacific shows a strong relationship between warmer waters and salmon health. The study's results, published in the journal *PLOS ONE*, take issue with a long-held assumption: Juvenile fish will eat less in warmer waters. The researchers found the opposite.

"What we found is that, during warmer periods, there is less food for juvenile salmon," says Elizabeth Daly, a senior faculty research assistant with the Cooperative Institute for Marine Resources Studies, jointly run by OSU and the National Oceanic and Atmospheric Administration.

"With less food, you would expect that we would find less food in the stomachs of salmon, but that wasn't the case. We found that juvenile salmon are eating substantially more than in colder periods."

This is counterintuitive, admits Daly and her co-author, Richard Brodeur of NOAA's Northwest Fisheries Science Center. Basically, the extra food isn't doing the fish much good. In warmer temperatures, the metabolism of the fish ramps up, forcing them to consume more calories. This amounts to a metabolic tax on the animals. And because

food is scarce in warmer waters, the fish have to burn more calories to get more calories. That amounts to another tax.

"It's this vicious cycle that leads to animals growing slower," says Daly. "And the longer they stay at this smaller size, the more at risk they are to predators."

Daly's and Brodeur's work complements that of Bill Peterson, a NOAA fisheries biologist and courtesy professor at OSU. Peterson has shown that copepods, microscopic crustaceans at the bottom of the food chain, have fewer fats and are

less nutritious in warm periods. The chain reaction up the food chain could affect juvenile salmon, something Peterson says is happening due to the "Blob."

Adapting to Higher Seas

Normally prominent at low tide, the beach is nowhere to be seen. There's only the ocean and the wave, which builds slowly at first and then comes crashing in, whacking the side of the small, three-story seaside hotel, missing by mere inches the white plastic chairs on the first floor balcony. Now it's a clean run

up Hawk Creek to the Salem Avenue bridge, which the wave quickly overwhelms with a tempestuous gush of white water. For the town's residents, the bridge is the only access to the highway and to safety.

This incident of flooding was caught on video in the coastal community of Neskowin during a recent winter, but it could also be a glimpse into the town's future.

Since the mid-1960s, Neskowin has been losing roughly two meters (6.5 feet) of its beach a year to the Pacific Ocean, making the town of about 400 one of several erosion "hot spots" along the West Coast. Neskowin's loss has been pinned on large El Niños and on increasing wave heights, both of which — and there's disagreement among scientists here — might or might not be connected to climate change. But for the residents of Neskowin, placing blame isn't as important as better planning.

To ward off the Pacific's incoming assault, community members armored their homes, placing rock barriers called riprap between their beachfront houses and the waves. But they soon realized these walls weren't going to be enough. Many were concerned about rising sea levels. To learn more, they reached out in 2009 to the scientific community, starting with Oregon Sea Grant and Peter Ruggiero.

Property owners and local officials formed the Neskowin Coastal Hazards Committee, which was coordi-

nated by Sea Grant specialist Patrick Corcoran (See "Facing Cascadia," Page 4). They consulted with Ruggiero and other scientists who presented the latest findings about wave heights, sea levels, erosion and other threats to coastal properties.

After wrestling with the science and accounting for the needs and values of the community, the committee produced a 300-page adaptation plan, which describes Neskowin's ocean-related vulnerabilities and techniques for addressing them. In 2015, after review and revision by Tillamook County, the state Land Use Board of Appeals upheld the Neskowin plan. The guidelines were set by the science, but community members identified what factors — sea-level rise, population growth, housing, beach access — mattered most to them.

Far from being disheartened by the choices that lay before them, the Neskowin group was surprisingly optimistic. "People realize there are options," Ruggiero says. "Do you throw more rock out there or do you retreat from the coastline? There are huge decisions that people on the coast are going to have to make, but the decisions they make today will make a real difference in the future."

In his research, Ruggiero has tracked wave heights and beach erosion, which got him thinking seriously about what the West Coast might look like as climate changes. He realized that those planning for the future would need to account for many uncertainties.

Working with Oregon State bioengineering professor John Bolte and a computer model known as Envision, Ruggiero and teams of students have created multiple scenarios — including lessons learned in Neskowin — for exploring alternative futures in Tillamook County (See "Difficult Choices," Page 51). The researchers are conducting a similar project in Grays Harbor, Washington.

It's impossible, Ruggiero says, to know how much sea-level rise to expect by the end of the century. Projections range from a few inches to several feet. It all depends on how much CO₂ and other greenhouse gases will be emitted in the future.

Seawalls may work for a while, but as Peter Clark's work suggests, they are not a long-term solution in the face of continuous sea-level rise. That's why the question of climate tipping points is so important. Oregon State research around the world — in Antarctica, Greenland and the deep oceans as well as the Pacific Northwest — will help determine if and when such a point is reached. It is already helping Oregonians on the coast and elsewhere make decisions about the world they leave for future generations. **terra**

Nathan Gilles is a freelance writer based in Vancouver, Washington. He is also a communications specialist for the National Oceanic and Atmospheric Administration-funded Pacific Northwest Climate Impacts Research Consortium based at Oregon State University.

Microbeads Pose Pollution Threat

Doing something as simple as washing your hair may raise a new threat to aquatic health. Many personal-care products have been formulated with plastic beads the size of a sand grain — known as microbeads — which add a gritty texture. Microbeads are designed to be flushed down the drain.

An analysis by a team of researchers, including Stephanie Green, a David H. Smith Conservation Research Fellow in the College of Science at Oregon State University, concluded that 8 billion microbeads were being washed down drains in the United States on a daily basis. "We're facing a plastic crisis and don't even know it," says Green.

With growing awareness of this problem, a number of companies have committed to stop using microbeads in their "rinse off" personal care products. In January, Congress passed the Microbead-Free Waters Act.



Left: Waves threaten a structure in Neskowin during a storm in 2008. (Photo: Armand Thibault). Middle: Winter storms erode shorelines and pose a risk to homes and businesses. (Photo: Oregon Sea Grant). Right: A coastal bluff collapses near Lincoln City. (Photo: Oregon State University)

THE BLUE ECONOMY

Science, collaboration and technology
for ecosystem health

BY NICK HOUTMAN

“The Blue Economy approach offers the means for the sound utilisation of resources beyond national jurisdiction – the sustainable development of the common heritage of humanity; the resources of the High Seas.”

U.N. Blue Economy Summit, 2014

In the fall of 2002, as the Klamath River dwindled in the wake of a dry summer, dead fish began piling up in eddies and small tributaries. Over a two-month period, U.S. Fish and Wildlife Service biologists counted more than 34,000, mostly adult chinook salmon that had died on their way upstream to spawn. The actual number was undoubtedly higher. In most sections of the river, crews were unable to tally all the floating carcasses from day to day.

Commercial salmon landings had been declining in prior years, and on top of a continuing drop in Pacific groundfish (species such as rockfish, cod, whiting and sole), the news from the Klamath seemed like another swipe at a once thriving West Coast industry. Contentious debates erupted among fishermen, farmers, tribal leaders and politicians about water management,

fishery stock assessments and emergency relief for coastal communities.

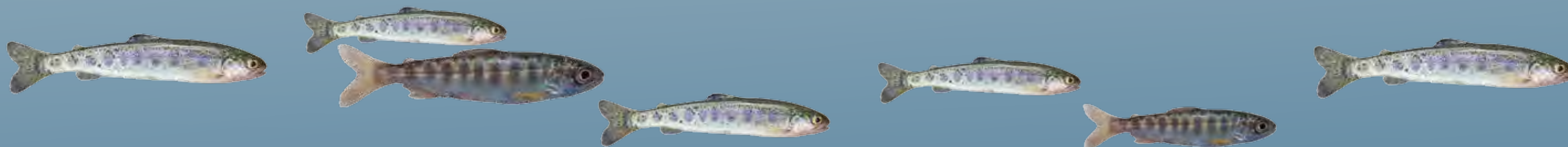
By 2006, as salmon runs in the Klamath continued to plummet, groundfish cutbacks had already hit those communities hard. And when the commercial salmon season was closed in California and most of Oregon in 2008, fishermen in the two states took another \$30 million hit.

By then, Oregon State University researchers were working on a long-term approach to a solution. “We had been asked if there was something we could do to address the salmon problem on the Klamath,” says Gil Sylvia, an Oregon State University economist and director of the Coastal Oregon Marine Experiment Station in Newport. “This is a fast-growing animal with a lot of uncertainties about it – so many stocks, so much complexity. Why aren’t we using more advanced methods to manage it?

“So one afternoon, a group of us developed a plan that became the basis for a program we call ‘Fish Trax.’ The idea is to enable fishermen to target healthy stocks – fish from rivers with strong runs – and to avoid weak ones, so fishermen can change the way they harvest rather than getting kicked off the water with total area closures. That’s the goal,” he adds.

The traditional maritime economy was clearly struggling, but programs like Fish Trax – which depends on genetics, digital data and collaboration among people who did not always see eye-to-eye – point the way to a new relationship with the ocean. Its proponents in community development and environmental policy are calling it the “blue economy.”

In an Ocean Week speech on Capitol Hill in 2009, Jane Lubchenco





laid out the goals: “Americans want clean beaches, healthy seafood, good jobs, abundant wildlife, stable fisheries and vibrant coastal communities This collection of services depends on healthy, productive and resilient ocean and coastal ecosystems.”

As the newly appointed administrator of the National Oceanic and Atmospheric Administration, the Oregon State marine biologist went on to define the characteristics of a “blue economy.” In short, fisheries, seafood production, recreation and other uses of the oceans would be joined at the hip with social sciences and ecology. Ecosystem services, climate change and ocean acidification would be factored into decisions about catching fish, allocating water

and dedicating the ocean for specific activities. Renewable energy companies and scientists would share the waves with trawlers and crabbers.

Fishing — a legendary mix of grit, skill and luck — would remain a critical component of the “blue economy” but would become more reliable and predictable. A disaster with a salmon run would be mitigated by science-based restoration efforts. And it would all depend on innovative technologies, such as acoustics, digital mapping, ocean-observing systems and data management.

Despite its struggles, the traditional marine economy is a powerhouse. In Lincoln County alone

in 2012 (the most recent year for which data are available), fishing and marine science jobs contributed \$230 million to personal income, according to the county’s Economic Development office. Tourism added another \$135 million.

Education and research are adding jobs in Newport, the county seat and home to Oregon State’s Hatfield Marine Science Center, the Oregon Coast Aquarium, NOAA’s Pacific fleet headquarters and the Oregon Museum of Science and Industry’s new Coastal Discovery Center. “When it comes to marine science and education,” says Gil Sylvia, “when you look at what’s been invested along the Oregon coast,

Scientists monitor marine reserves on the Samson, owned by Lars Robison in Depoe Bay. See more in “The Bounty,” Page 28.

there’s been over a \$2 billion investment in the last decade. It’s much bigger than people understand.

“And when you talk about the ‘blue economy,’ you have to define what you mean by ‘blue,’” he adds. “A lot of it is traditional maritime, the fishing and seafood industry. For example, Seattle is the largest seafood city in the United States when you’re talking about large fishing vessels and processors, but most of the fish are landed in Alaska.”

The Right to Fish

Migratory fish like salmon, which are subject to a thousand threats in rivers and at sea, pose a daunting challenge to those who aim to align fishing with ecology. But things don’t get much simpler with more sedentary species, such as rockfish. Studies of their reproduction are ongoing. And then there’s uncertainty about the future of the ocean. How will warmer temperatures and acidic waters affect the coastal food web?

“Over time, we know rockfish recruitment (successful reproduction) can vary widely from year to year,” says Kirsten Grorud-Colvert, assistant professor in integrative biology at Oregon State. She studies rockfish under an annual permit from the National Marine Fisheries Service and must estimate the number of young

fish she will catch. In her research along the Oregon coast, she uses devices that look like bags of garden fencing and are known as SMURFs — Standard Monitoring Units for Recruitment of Fish.

“From year to year, it’s tough to predict. Rockfish are so episodic in their recruitment,” she says. “This year we saw a species that we haven’t seen recruit much over the last five years — they have just been trickling in — go off the roof.”

Some species of rockfish can live more than 100 years, and as they grow, so does their reproductive potential. A 15-inch vermilion can produce about 150,000 eggs when it spawns. That might seem like a lot, but the real champions are the big old females. A 25-inch fish can produce more than 1.7 million eggs.



Photo: NMFS/Southwest Fisheries Science Center

Fishing the Food Web

Sardines, mackerel and other “forage fish” are more valuable as food for larger species such as cod and tuna than as a commercial catch in their own right. In 2012, an international panel recommended that harvest limits should “be more conservative than those for other species,” says Oregon State fish biologist Selina Heppell, a member of the Lenfest Forage Fish Task Force and the Pacific Fishery Management Council. “Forage fish need to fulfill their primary role as food for predators in the system,” she adds. Research is needed to set harvest limits that meet the needs of larger species.



Learning Opportunities by Design

An underwater robotics competition in North Bend, teacher workshops in Newport, a student-built unmanned sailboat in Astoria — all reflect an ambitious educational initiative known as the Oregon Coast STEM Hub. Organizers coordinate activities with school districts, community colleges, agencies, businesses and other groups to promote STEM (science, technology, engineering and mathematics) opportunities for students. “We connect educators and students to emerging coastal and ocean issues, marine technology and cutting-edge research,” says project manager Tracy Crews. The STEM Hub is located at Oregon State’s Hatfield Marine Science Center in Newport. See more at oregoncoaststem.oregonstate.edu/.

“Incorporating that into management is tricky,” says Grorud-Colvert. “Having areas like marine reserves where these older larger females can live is a powerful complement to other management approaches.”

She and other scientists are documenting the impacts of marine protected areas (MPAs), widespread globally but a relatively recent development along the Oregon coast (see “The Bounty,” Page 28). In *Science* magazine last fall, Grorud-

Colvert and Lubchenco reported that MPAs now cover 3.5 percent of the surface area of the world’s oceans. More than five decades of research, the researchers reported, shows that fully protected MPAs, aka marine reserves, effectively increase the diversity and size of fish populations and enhance some commercial fisheries outside the boundaries.

However, just producing more fish may not be enough. In a paper in the journal *Oceanography*, Oregon State graduate student Allison Barner joined Lubchenco and other scientists in raising another possibility: Combine marine reserves with rights-based fisheries management, processes for giving individuals or communities exclusive rights to harvest fish in waters adjacent to a reserve. This arrangement even has a name: Territorial User Rights for Fisheries (TURF)-Reserve. The result would be that, in exchange for protecting the reserve, fishing communities would reap the benefits by being able to catch the bounty spilling over into their fishing grounds.

TURFs have not been proposed for the Oregon coast, but the idea is likely to raise hackles in fisheries management circles. Gil Sylvia calls it “politically combustible.” Paul Klarin of the Oregon Department of Land

Conservation and Development says the seas have long been treated as a public commons with open access. He leads planning for Oregon’s coastal waters, efforts captured in a map showing areas dedicated to specific uses: fishing, marine reserves, energy production, navigation and underwater cables (more trans-Pacific cables land in Oregon than in Washington or California).

The rules are different in federal waters, which extend 200 miles off the coast. Starting in 2011, a type of rights-based fisheries management known as individual transferable quotas — rights given to individual fishermen and capped at a total maximum harvest — were allowed under U.S. law.

Since then, the scientists say, the Pacific groundfish industry has shown signs of improvement. Revenues have risen more than 12 percent (not including whiting, Oregon’s largest single fishery). And 21 species

have moved from “avoid” to “good alternative” or “best choice” under the Monterey Bay Aquarium’s Seafood Watch Program, which advises eco-conscious consumers on fish to buy.

Data in DNA

Data are the currency of the “blue economy.” Satellites scan the sea surface daily, and sensor arrays on buoys and underwater gliders send information continuously to labs on land. The result is an ever-changing picture of temperatures, waves, winds, currents and water chemistry (see “The Gear,” Page 10).

“Fishermen need to make decisions every day,” adds Sylvia. “Are we going to fish? Where are we going to fish? How are we going to fish? Data can be invaluable.”

Some of the most powerful clues come from marine organisms themselves. In their DNA are patterns that reveal how whales are related to each other, whether

or not corals can adapt to a changing environment and where salmon were born. If you’re a salmon fisherman, being able to distinguish one stock from another — those from the Klamath River, the Sacramento or the Rogue — could make the difference between holds that are empty or full when you return to the dock.

Through a research program known as CROOS (Collaborative Research on Oregon Ocean Salmon), Sylvia and his colleagues at the Oregon State marine experiment station are developing Fish Trax to provide that information. They aim to enable salmon fishermen to know where and when to target specific runs of fish, in effect to trace fish from rivers of origin to the sea. Salmon from each river tend to follow similar patterns as they move, and by analyzing the genetic fingerprints of captured fish, scientists can see where the animals tend to go.

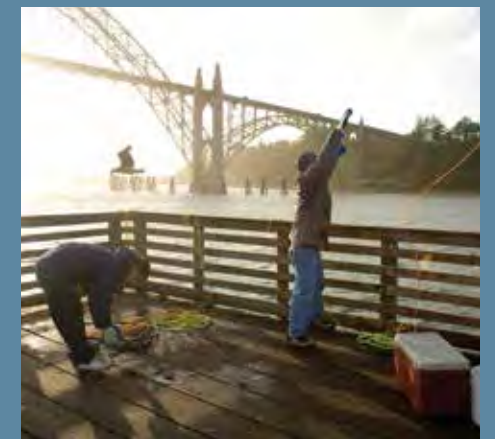
“Fish Trax created (Internet) portals



Photo: L.J. Majer

How Much Is a Sand Dune Worth?

With a grant from the National Oceanic and Atmospheric Administration, Oregon State University economists are studying the economic value of coastal features, such as sand dunes, wetlands and estuaries. Such “natural infrastructure” supports a variety of social and economic benefits, says Steven J. Dundas, principal investigator. Researchers will develop methods for estimating optimal levels of investment in each type of coastal feature.



Working Waterfront on Your Phone

In Coos Bay, North Bend and Charleston, aka Oregon’s Bay Area, you can take a tour of the working waterfront, courtesy of Oregon Sea Grant. Tide gates, shipyards and oyster beds are among the highlights offered through a printed map and a cell-phone app. “We connect people to parts of the waterfront they may never have seen,” says Jamie Doyle, Sea Grant Extension agent in Coos Bay. The app includes videos and maps that provide a behind-the-scenes look at the region’s “blue economy.”



for fishermen to access their own data. They can ask things like ‘Which stocks of fish did I catch at this depth in this location over a two-year period?’ And they can query the database and find out,” he says. However, that is just the beginning.

Fish Trax provides information to others as well: seafood processors, salmon hatchery managers, businesses and the public. “I see traceability as a way to share information with the marketplace and to improve and standardize quality,” says Sylvia. “And to use that information in selling and marketing the product. It’s a powerful tool for doing that. We can do it today because we have digital information systems, which are part of the ‘blue

economy.’ These systems open up immense possibilities.”

When the idea was first proposed, the reception was mixed. “The fishing industry loved it, but they were torn,” says Sylvia. “They worried about how the information would be used by managers. Could new knowledge be used to regulate the industry in unanticipated ways?”

Things came to a head during a meeting at the Hatfield Marine Science Center in 2006. Scott Boley, an Oregon State graduate and respected industry leader who died in 2007 (the Fish Trax website is dedicated to him), let people know that, while he had his doubts, the industry could benefit from it. “I’ve lost sleep over this. But things are so

bad, I don’t see how it couldn’t but help us in the long term, to change this fishery around,” Sylvia recalls Boley saying. “That was it. That profound statement got the agencies on board too, even though they had their doubts.” Sylvia and his team are continuing to develop Fish Trax with support from NOAA.

In its land-and-sea-grant mission, Oregon State brings together fishermen, agency managers, elected officials, scientists and engineers to create a “blue economy” for the future. “We get the luxury of looking five or 10 years down the road,” says Sylvia. “Industry doesn’t always have that luxury, but we do. It’s our job to plant and test ideas.” **terra**

Difficult Choices

In the face of rising seas, decisions matter

Many seashore dwellers face a tough question: How should they protect their property from rising seas and pounding waves? They can try to keep the surf at bay by building walls, or they can adjust to the slow but steady encroachment of the ocean.

Such choices are becoming particularly acute on the West Coast. For decades, winter storms have claimed roads and homes close to the water’s edge, especially those built on soft soils. As sea levels rise, accelerating erosion poses a challenge to existing as well as to new development.

In Tillamook County, homeowners and policymakers have been wrestling with this issue with assistance from faculty and students at Oregon State University. Through a program known as the Tillamook County Coastal Futures Project, they are exploring the long-term consequences of the rules that define how and where development can occur.

To prime their thinking, researchers and participants developed six scenarios — descriptions of policy options and the outcomes in the year 2100 — and showed the results with maps, charts and illustrations. Each scenario was analyzed through the lens of future population growth as well as ocean conditions that reflect potential changes in climate, El Niño and ocean waves.

“We had a diverse group of people,” says Peter Ruggiero, Oregon State coastal geomorphologist. “Some people favored policies that protected infrastructure, and some favored policies that affected recreation or habitat. The scenarios emphasized the tradeoffs between them.”

One scenario called “Status Quo” assumed that beaches, homes and businesses would be maintained using existing local, county and state policies. Another known as “Laissez Faire” allowed property owners to protect their homes and

businesses regardless of state law and local zoning. A third, “Realign,” assumed that development would retreat landward as seas rise. A fourth, “Neskowin,” mirrored policies adopted by that southern Tillamook County community, approved by Tillamook County Commissioners and eventually upheld by the state Land Use Board of Appeals.

Through each scenario, participants could visualize changes in things they care about such as beach access, the number and locations of structures and the extent of shorelines armored with concrete or rock walls. The estimated costs associated with each scenario were also presented.

“Our main effort was to develop an approach where the stakeholders could see the impact of each decision-making context on property and coastal resources,” says Ruggiero.

One significant finding, he adds, was a surprise. Zoning decisions made now will have dramatic effects on what coastal communities look like in 2100. In fact, the differences exceed the range of uncertainties associated with climate change.

“We found for some scenarios that the influence of different policies had more impact on the variability of these things that people care about — such as the number of houses impacted — than even the massive uncertainty associated with sea-level rise,” says Ruggiero. “It tells people that even under a 1.5-meter (5 feet) sea-level rise by the end of the century, there are still decisions that we make now that can change the coastline.”

With support from the National Oceanic and Atmospheric Administration, the Tillamook project has entered a second phase to explore impacts on so-called ecosystem services, the benefits associated with beaches, sand dunes and other landscape features.

Policy Scenario Narratives

Status Quo

Water Level Rise ↑

Hold the Line

Beach Nourishment

Laissez-Faire

ReAlign

Neskowin

Hybrid



Photo: Oregon Department of Fish and Wildlife

Making Art in Wild Places

“Creative Coast” students go to the sea for inspiration

Last spring, students studying music, video, theater and visual arts took a walk in the woods. When they came out, their creative spirits were infused with the sounds, textures, shapes and colors of the Hopkins Demonstration Forest.

Music student Ryan Zubieta listened to the sounds around him — water running over stones, branches clicking together, wind rattling the canopy — then recorded and edited them, finally converting them into a haunting piece of music that, he says, “retains the organic quality” of the original woodland sounds.

“Student projects involved not only sound capture but also acting and directing, video documentation, drawing and sculpture,” says Charles Robinson, a faculty member in the College of Liberal Arts.

The interdisciplinary “Creative Forest Project” of the School of Arts & Communication was recast this year as the “Creative Coast Project.” In April and May, students ventured to Cape Perpetua, where faculty members led workshops and then set the students loose in groups to create writings, films, music and plays. The partnership also includes the National Park Service team at Cape Perpetua, Oregon Sea Grant and OSU Extension.

Fly Fishing for Body, Soul, Mind

A convergence of science, literature and fitness

A fly-fishing line arcs above a river. The hand-tied fly — chosen to match whichever aquatic insect has hatched that morning — settles on the water. In casting that line, a fly fisherman enters into the life of the river, intuitively, intellectually, intimately.

A new “cross-linked” course at Oregon State University, The Art, Science and Literature of Fly Fishing, lets students “appreciate the complex network of human and nonhuman communities that govern this activity so central to Oregonians,” in the words of English professor Raymond Malewitz.

Malewitz, co-leading the experiential course with fisheries biologist Brooke Penaluna and health-sciences instructor Kathy Kim, calls it “a unique opportunity to bring together three different kinds of educational perspectives that are usually kept separate in undergraduate classes: scientific training on how flora and fauna interact in complex stream ecosystems; artistic training in the craft of writing about fly fishing and the history of fly-fishing literature; and kinesthetic training in the practices of fly casting in the Pacific Northwest.

“In linking the abstract and the concrete, the practical and the wonderful, the course established a new pathway for fully interdisciplinary education at Oregon State.”

Adds Kathy Kim: “Fly Fishing goes beyond catching fish. It is about immersing yourself in a natural world, understanding and solving the mystery of the aquatic environment, enjoying the solitude and finding adventures.”



Photo: Carl Heyerdahl



Photo: Doug Wilson

Deaths, Injuries Dog Crab Industry

Researchers work with fishermen to improve safety

Commercial Dungeness crab fishing on the West Coast is one of the riskiest jobs in the United States, based on fatality rates. But nonfatal injuries in the fishery often go unreported, a study from Oregon State University shows.

“The commercial Dungeness fishing fleet, which operates along the coast of Oregon, Washington and Northern California, is a vital economic commodity,” says OSU researcher Laurel Kincl, an expert in environmental and occupational health and safety in the College of Public Health and Human Sciences.

Examining 12 years of crab-fishing data, she found 28 deaths from 2002 to 2014. During that same period, 45 injuries were reported to the U.S. Coast Guard. About 70 percent of the fatalities were linked to the capsizing or sinking of vessels. Fishermen drowning or falling overboard accounted for the rest. Among injuries, fractures were the most common, followed by hypothermia, lacerations and digit amputations.

Along with Oregon Sea Grant and coastal-community researchers, Kincl is meeting with fishermen and surveying crabbing crews along the Pacific coast to learn more about safety and injuries in the industry. She and her colleagues plan to design and test interventions to help reduce injuries.

A Side of Seaweed, Please

Bacon-flavored dulse gives “seafood” a marketing twist

Imagine the taste of seaweed. Something briny, slightly “fishy,” you think. A flavor reminiscent of the pungent scent of the seashore, perhaps? The taste and smell of bacon sizzling in a pan probably doesn’t cross your mind.

But last summer when Oregon State University researchers announced the development of a new strain of seaweed tasting remarkably like bacon when cooked, the news caught the attention of foodies everywhere. It was hailed as the holy grail of good eating — a nutrition-packed marine plant as yummy as a fat-loaded meat product.

Its common name is “dulse,” a red seaweed native to the north Pacific and Atlantic coasts. Originally bred by OSU aquaculture researcher Chris Langdon as a food for abalone, that changed one day when OSU marketing professor Chuck Toombs toured Langdon’s lab in Newport. When he looked at the ruddy algae growing in row after row of 6,000-gallon tanks, he saw a marketing bonanza.

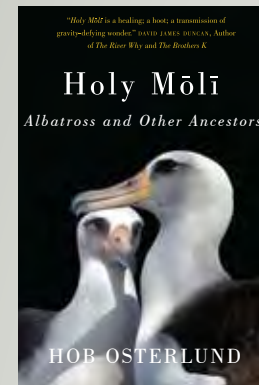
“Dulse is a superfood, with twice the nutritional value of kale,” Toombs enthuses. “OSU has developed a variety that can be farmed, with the potential for a new industry on the Oregon coast.”

Now, thanks to OSU’s Food Innovation Center in Portland, dulse products are already on grocery store shelves. Toss your salad with Tamari with Dulse Seaweed Dressing & Marinade, created by OSU research chef Jason Ball along with New Seasons Markets and Dulse Foods of Lake Oswego. In the pipeline are rice crackers and trail mix, among others.



Book Notes

Recent water-themed publications from OSU Press



Holy Mōlī
Hob Osterlund

Holy Mōlī is a natural history of the albatross, a moving memoir of grief, and a soaring tribute to ancestors by Kauai-based naturalist Hob Osterlund. Within its pages are lyrics of wonder — for freedom, for beauty and for the far-flung feathered creatures known to us as albatross.

A Naturalist’s Guide to the Hidden World of Pacific Northwest Dunes
George Poinar Jr.

With this new guide by OSU faculty member George Poinar Jr., hikers and beach walkers on the Pacific Coast will discover a teeming metropolis of life in what may seem a barren landscape to the inattentive eye.



Living Off the Pacific Ocean Floor
George Moskovita

This authentic memoir of George Moskovita’s seafaring life provides a unique glimpse of Pacific maritime life in the 20th century, small-town coastal life after World War II, and the early days of fishery development in Oregon. OSU science historian Carmel Finley and NOAA fisheries scientist Mary Hunsicker introduce the book.



Salmon Is Everything
Theresa May

After a devastating fish kill on the Klamath River, tribal members and theatre artist Theresa May developed a play to give voice to the central spiritual and cultural role of salmon in tribal life. Accompanying the play’s script are essays about creating and performing theatre on native and environmental issues.





Terra
102 Adams Hall
Oregon State University
Corvallis, OR 97331

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This closeup of an Antarctic minke whale's blowhole was photographed in Wilhelmina Bay, Antarctica, by Ari Friedlaender, an ecologist at Oregon State University's Marine Mammal Institute. You can see many more of his Antarctic photos in his book, *Unframable*, available online.

