SEA STAR

WASHINGTON SEA GRANT

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CARBON COMES HOME

How a serendipitous connection led ocean acidification researchers to an island farm

Meg Chadsey inspects a pile of kelp at SkyRoot Farm on Whidbey Island.

"Back in the early 2000s, Washington State was ground zero for ocean acidification," Meg Chadsey, ocean acidification specialist at Washington Sea Grant (WSG), says. "Fossil fuel emissions were making seawater more acidic across the globe, but local sources of carbon dioxide were making the problem even worse in Puget Sound." Oyster larvae began dying by the billions, unable to withstand the corrosive water. It was such an alarming event that in 2012 former Governor Christine Gregoire created the Washington State Blue Ribbon Panel on Ocean Acidification to figure out how to slow down the problem and deal with its consequences. One of the panel's recommendations was to explore *phytoremediation*—to experiment with growing kelp, which takes carbon dioxide out of the surrounding water as it grows.

Chadsey and a team of researchers from the Puget Sound Restoration Fund, NOAA Pacific Marine Environmental Laboratory and the University of Washington took this idea and ran with it when they applied for a grant from the Paul G. Allen Family Foundation. They received funding and eventually got an experimental kelp farm up and running at the north end of Hood Canal. Even after the seaweed was growing, however, the team still had one major issue to tackle: what were they going to do with their harvest?

"We had to get it out of the water," Chadsey explains. "If we simply left all that kelp to rot, it would actually make acidification conditions around the farm worse. As biomass is decomposed by bacteria, it breaks down to carbon dioxide, and everything that was captured by the plant goes right back into the water column."

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LOOKING TO THE PAST TO UNDERSTAND FUTURE TSUNAMI THREATS

Tsunami [tsoo-nah-mee]

noun An extremely large wave caused by a violent movement of the earth under the sea

Cambridge Dictionary

By Elizabeth Phillips
WSG Science Communications Fellow

The shaking started soon after everyone had gone to sleep. Houses collapsed, coastal shorelines sank, and those who did not immediately run for higher ground were likely killed by the onslaught of water that roared through coastal Washington all the way to Hood Canal.

The 1700 Cascadia tsunami was the last big event of its kind to hit the Pacific Northwest. Scientists such as Carrie Garrison-Laney, a coastal hazards specialist for Washington Sea Grant and liaison to the Pacific Marine Environmental Laboratory, pieced together the story of this and other past tsunamis using long-buried sediments that were left behind by the powerful waves. Garrison-Laney combs bays and inlets looking for evidence to shed light on how destructive past tsunamis may have been so she can share her findings with coastal residents and emergency managers — and help them better prepare for future events.

A sediment deposit from the 1700 Cascadia tsunami and ruler marking centimeters (photo not to scale).

The tsunami of 1700 was generated by an underwater earthquake along the Cascadia fault, a 620-mile-long geologic feature offshore British Columbia, Washington, Oregon and northern California, in which the dense crust of the Juan de Fuca plate is being thrust under the North American continental plate. The fault is quiet right now, with no earthquakes, meaning the plates are "locked." But eventually, "The forces pushing the plates together will overcome the forces locking them together, creating an earthquake," Garrison-Laney says. "When this happens, coastal areas will subside, and part of the ocean floor will get pushed up and displace the overlying water."

Of course, that water has to go somewhere. "It's like being in a bathtub, and water sloshes around and spills out of the tub if you move quickly," Garrison-Laney explains. In other words, a powerful tsunami will be generated, with potentially devastating impacts along the coast.

Digging for Answers

Garrison-Laney got her start as a tsunami scientist in the late 1990s when she joined her advisor at Humboldt State University to study a freshwater pond near a beach south of Crescent City, California. She was interested in earthquakes, but hadn't thought much about tsunamis. They looked at sediment cores from the pond and were intrigued when they saw sand layers every 18 inches or so.

"We thought, 'hmm, interesting — where did this sand come from? How did it get here?'" Garrison-Laney recalls. She examined the diatoms — tiny marine microfossils — embedded in the sand to show that the sand came from the beach and had been accompanied by a big pulse of ocean water that stayed in the pond for a time, before gradually transitioning back to freshwater. Each sand layer that she examined was an example of this cycle having repeated itself. Garrison-Laney and her colleagues could tell that it was very turbulent when the sand was deposited in the pond because there "were chunks of stuff ripped up and incorporated into the layers — sticks, pine and spruce cones, material from a landslide" that had been tossed around before getting buried in the sand. They also found traces of sand nearly a mile inland from the coastline. All of the evidence, including radiocarbon dating of the twigs, pointed towards a pattern of recurring tsunamis flowing into the pond over the last 3,000 years.

Carrie Garrison-Laney

Piecing Together the Tsunami Mystery

Much of Garrison-Laney's current work involves studying geologic evidence of tsunamis from coastal areas in the Salish Sea to determine where and when these sediments were deposited. She compares this evidence with computer models of tsunami inundation at the same locations, with the goal of reducing some of the unknowns for vulnerable coastal communities.

If you think you're safe in Seattle, think again. As Garrison-Laney's research suggests, the "inside waters" of Puget Sound could be within reach of Cascadia tsunamis. The area is threatened by tsunami hazards from local faults as well; in fact, the network of faults that crisscross Puget Sound between Olympia, Tacoma, Seattle and South Whidbey Island make the area one of the most vulnerable to earthquakes and tsunamis in the country. An earthquake about 1,100 years ago on the Seattle fault generated a tsunami, and computer models of this event generated waves up to 20 feet high in Elliott Bay with widespread inundation along the shoreline and in the industrial ports and low-lying areas of the Duwamish River.

Hitting the Road

Tsunami research may be fascinating, but it's only useful when it is communicated to emergency managers and the public. To ensure that the latest information and best tsunami science is making its way to coastal communities, Garrison-Laney and partners from Washington Emergency Management Division, the Washington Geological Survey (Department of Natural Resources), and NOAA's National Weather Service took to the road last spring in a series of public talks called The Tsunami Road Show. From Ilwaco to Port Townsend, nearly 1,000 people attended eight talks presented in four days. The partners presented a holistic message about tsunami science and research, shared the latest inundation maps for Washington, and provided concrete suggestions for how to prepare. "Even just having this information in your mind can help save your life when the big one hits," Garrison-Laney says.

HOW TO BE TSUNAMI-READY

- Know the fastest evacuation routes to get to high ground quickly
- Work out an emergency plan for home and work
- You might be on your own for a while, so think about how you will communicate with family, friends and neighbors — is there a network that you could use?
- Sign up for tsunami monitoring system to receive alerts via phone, text or Twitter
- Learn to interpret messages from the U.S. Tsunami Warning System:
  - *Tsunami Watch:* issued for any earthquake magnitude 7.5 or larger if the epicenter is in an area capable of generating a tsunami; hazards not yet known; stay tuned for more information and be prepared to act
  - *Tsunami Advisory:* issued when a tsunami that could affect the area is imminent, expected or occurring; hazards include strong currents and waves dangerous to those in or very near the water; stay out of the water, away from beaches and waterways
  - *Tsunami Warning:* issued when a tsunami with the potential to generate widespread inundation is imminent, expected or occurring; hazards include dangerous coastal flooding and powerful currents; move to high ground or inland[1]
- Prepare a "Go Kit" that can cover your basic needs for 14 days — this will improve your odds of survival substantially. Here's what to include:
  - Warm clothes
  - Sturdy shoes
  - Bottled water and/or water filter
  - Flashlight
  - First aid kit
  - Non-perishable food
  - A few items that will lift your spirits (like chocolate that can be shared)

1. Source: NOAA National Weather Service

Island farm • continued from front page

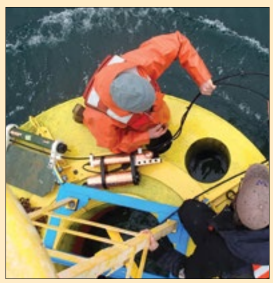
Elizabeth Wheat

Sure, the team had ideas for what to do with the kelp. They could convert it into biofuel—but the process would take additional time, money and connections. They could encourage people to eat it, as Chadsey did at an event with the Seattle Culinary Academy and through an educational kelp tasting kit, which WSG created with students in the UW Department of Communication. But the researchers' 14,000-pound harvest would be an awful lot of seaweed to eat.

Chadsey was mulling over this conundrum at the WSG office when UW graduate student Amy Brodbeck, a former WSG science communications fellow, overheard her. Brodbeck knew the exact person to help solve the puzzle: Elizabeth Wheat, a marine ecologist-turned-farmer who is a popular lecturer at the UW Program on the Environment.

CHALLENGES IN KELP MONITORING

Measuring the impact of growing kelp on pH is a difficult task



Researchers at work on a mooring.

By Max Showalter
WSG Science Communications Fellow

For senior oceanographer John Mickett, the challenges of using kelp to mitigate local effects of ocean acidification started before this project even began. Mickett and his team at the UW Applied Physics Laboratory (APL) were in charge of designing, building and deploying moorings to monitor environmental changes in response to kelp growth. But, while the task was straightforward, the path was not.

The first major hurdle was figuring out the best location for the mooring relative to the kelp bed. In order to monitor ocean acidification parameters—including pH and carbon dioxide levels—the mooring must contend with moving water that is influenced by tides, currents and wind. The water surrounding the kelp only sticks around for about 15 minutes before flowing through.

"It's a tradeoff," Mickett says. The high levels of water movement in Hood Canal make it a great place to grow kelp. "But that water flow takes the signal that the kelp creates—higher pH, higher oxygen—and it just whisks it away so fast."

To address this problem, the team used data of water speeds and directions to figure out where the kelp-influenced water travels, and ultimately decided to place the moorings just north of the kelp bed for maximum signal.

In the first season of the project, however, this didn't work out exactly as planned. "It looks like the sensors weren't able to detect the magnitude of change that the kelp causes," Mickett says. "Not only is the signal really small, but the level of background photosynthesis is much bigger. If you take a really big signal and put it on top of the kelp, it's going to be harder to parse it out."

Whatever the outcome, Mickett is confident the results of the project will help us better understand how to mitigate effects of ocean acidification in the future: "Even if it's just on a small scale … if kelp can help, it's great."

Below: The kelp farm in Hood Canal.

When it comes to the environmental impacts of conventional agriculture, Wheat sees a lot of room for improvement. "Farms are responsible for producing about 11 percent of our greenhouse gas emissions," she says—emissions that contribute to the ocean acidification problem that Chadsey and team are trying to solve. But Wheat has long been interested in experimenting with alternative agricultural methods that could turn her farm into a net sink rather than source of carbon. While most U.S. farms end up releasing carbon from the soil into the atmosphere through practices such as tilling, it is possible to flip that equation on its head: to recharge the soil in ways that capture atmospheric carbon dioxide and put it into the ground.

It turns out, some parts of the world recharge their soil with seaweed, letting it decompose into the soil. "In places where farms have been diminished, like Ireland, farmers have a long history of going down to the ocean and collecting plant matter to create better growing conditions," Wheat says. "Many fertilizers that you buy from the store actually have kelp meal in them, because kelp contains a lot of essential micronutrients that promote plant health."

Which is why Wheat happily accepted two truckloads full of seaweed at her home, SkyRoot Farm, on Whidbey Island. Soon after, students from one of her UW classes came out and set up an experiment to investigate the best way to incorporate the kelp's micronutrients and carbon into the soil. "We're really excited about the possibility of using kelp to help sequester carbon," Wheat says.

Will the aquaculture experiment show that growing kelp can reduce local ocean acidification? Time will tell. But in some ways, solving the open question of what to do with the seaweed crop has meant that the researchers' endeavor has already been a win. "This was a serendipitous connection that made this project rewarding and twice as much fun. Even if phytoremediation doesn't prove successful, it underscores the fact that there are other reasons to grow kelp," Chadsey says.

"It's always going to be good to get carbon out of the water and back onto land. That's where the carbon started before we began releasing it by burning fossil fuels—so, ultimately, we need to get the carbon back there." In other words, as Chadsey likes to say, we need to bring the carbon back home.

IS WASTE FROM HISTORIC SAWMILLS TOXIC TO NATIVE EELGRASS?

By Mackenzie Nelson
WSG Science Communications Fellow

Imagine Washington's landscape more than 100 years before the Space Needle was built. The trees stood tall from the mountains to the coastline, lush forests that promised entrepreneurial success for settlers who sought to establish roots in the Pacific Northwest by taking part in the logging industry that built the state. The area's Douglas fir, hemlock, spruce, cedar and Ponderosa pines supplied lumber that was in great demand following the start of California's 1848 Gold Rush and succeeding population boom along the Pacific Coast. Sawmills were built along Washington waterways to more easily transport the product. By the 1850s, over two dozen sawmills had been built along Puget Sound.

While sawmills no longer operate on the same scale, these relics of Washington's history are still impacting local ecosystems today, including the health of *Zostera marina*, an eelgrass species native to Washington waters. Eelgrass is well known as an indicator of ecosystem health in the Salish Sea (which includes both Washington's Puget Sound and the inside waters off of Vancouver, British Columbia), but eelgrass is more prosperous in some areas than others. In 2016, with funding from Washington Sea Grant (WSG), researchers David Shull, Sylvia Yang and Mike Adamczyk from Western Washington University set out to understand why, with the hypothesis that higher concentrations of sulfide in the water is partly to blame for the reduction in eelgrass in some areas.

After they embarked on this project, the researchers began to wonder: could the higher levels of sulfide found in some areas be a legacy of Washington's logging history? Historically, Washington's sawmills released wood waste into the nearby Salish Sea. This

Eelgrass • continued on back page

Loggers cutting down a tree in Washington, circa 1909. Credit: Boston Public Library; Below, a blood star atop an eelgrass bed.

FIELD NOTES

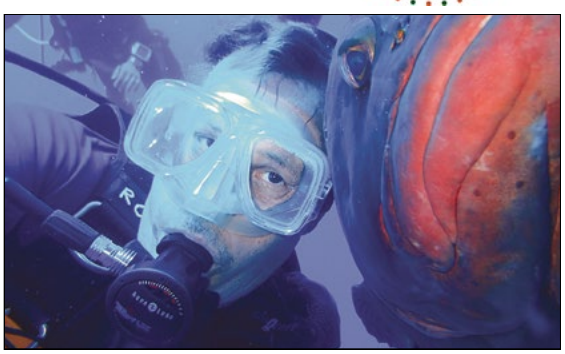
WSG is pleased to announce Russell Callender as our new director. Callender, who took the helm in September, is a committed champion for coastal science and conservation, bringing more than 25 years of experience in science, policy and management to the position—including several years as the assistant director at the Virginia Sea Grant Program. Before assuming the directorship, he was at NOAA for 18 years, most recently as the assistant administrator for NOAA's National Ocean Service. Callender holds a doctoral degree from Texas A&M, as well as master's and bachelor's degrees from Stephen F. Austin State University, all in geology. He looks forward to working on the ground at state and regional scales while continuing to influence coastal science, education and marine conservation. Welcome aboard!

We are proud to introduce WSG's 2018–2019 fellows. This year's WSG State Fellows are UW graduates Danielle Edelman, Brittany Flittner, Julie Ann Koehlinger and Henry Peterson; Washington State University graduate Felicia Olmeta-Schult; and Western Washington University graduate Katrina Radach. Their respective host offices for the next year are the Makah Tribe, Washington State Department of Ecology's Spills Program, Olympic Coast National Marine Sanctuary, Washington State Department of Health, Washington State Department of Ecology's Shorelands and Environmental Assistance Program and The Nature Conservancy. UW graduates Roxanne Carini, Michelle Chow, Valerie Cleland, Molly Grear and Ben Hughey have been selected as Knauss Marine Policy Fellowship finalists and in early 2019 will each be placed in a legislative or executive office in Washington, D.C.

In July, the WSG Crab Team reported evidence of invasive European green crab at three new sites in the Salish Sea: A green crab shell was found at Fidalgo Bay, a live green crab was captured at Dungeness Landing near Dungeness Spit and, most recently, another crab was found near Port Townsend. "The fact that we are seeing green crab at new sites is certainly concerning, as is their persistence in places like Dungeness Spit," WSG Crab Team program coordinator Emily Grason says. "It is important to do as much as we can now to avoid allowing populations to increase dramatically."

A new study, Projected Sea Level Rise for Washington State – A 2018 Assessment, provides the clearest picture yet of what to expect in sea level rise along Washington coastlines. Led by WSG and the UW Climate Impacts Group as part of the Washington Coastal Resilience Project, with funding from the NOAA National Ocean Service, the report includes projections for more than 150 sites and incorporates each area's unique geology-driven land motion, including uplift at Neah Bay and sinking in Seattle. "I hope that these projections will find their way into planning processes at the community scale," says Ian Miller, WSG coastal hazards specialist and report co-author.

WSG welcomes Deborah Purce as our new program specialist. Purce's first exposure to WSG was as a 2008 NOAA Coastal Management Fellow, when she developed shoreline public access tools and policy guidelines at the Washington State Department of Ecology. She also worked in coral reef restoration in the Dominican Republic, researched bivalve physiology in Mexico and was a Fulbright Scholar studying marine protected areas in Chile. As program specialist, Purce manages WSG's competitive fellowship programs and supports the selection and implementation of research and outreach grants.



Russell Callender and his friend Jerry.

WSG formed a Diversity, Equity and Inclusion (DEI) workgroup, co-chaired by WSG social scientist Melissa Watkinson and assistant director for programs Kate Litle. Initial planning within the group includes identifying internal and external goals and long-term actions for each of our programs. WSG will host an all-staff DEI training, facilitated by an external trainer this winter. WSG and the DEI workgroup are committed to improving diversity, equity and inclusion in all areas of our work, including research, outreach, education and communications.

We had a busy and productive three days at the 2018 Northwest Wooden Boat Festival, which was attended by 25,000 people. Pairing up with colleagues from Washington State University Extension and Washington State Parks, we "covered the waterfront" at two different booths located at opposite ends of the festival. We talked with recreational boaters about small oil spills and the Pumpout Washington program, and many families took a turn at the Sea Grant Wheel of Fortune, learning about safety training workshops and water quality programs.

WSG education specialist, Maile Sullivan, coordinated another successful year for NOAA Science Camp, with 124 middle school campers and 19 high school Junior Leaders participating this year. Thanks to programming designed by Olivia Graham, a doctoral student at Cornell University studying eelgrass wasting disease in Washington, the junior leaders had an opportunity to get out into the field and learn about eelgrass ecology, biology and cultural significance through hands-on research. The students collected eelgrass and measured water temperature and salinity, and then went back to the lab to learn how to process the eelgrass blades for disease analysis.

Left: Junior Leaders study eelgrass in the field.

PREVENTING SPILLS IN THE SAN JUANS

By Elizabeth Phillips
WSG Science Communications Fellow

"This is a boating mecca," says Washington Sea Grant (WSG) boating specialist Aaron Barnett as he surveys the Friday Harbor Marina during a warm summer day in late July. An ever-shifting array of ferries, whale watching boats, yachts, fishing vessels, sailboats, dinghies and kayaks pull in and out throughout the day. Families of all ages roam the wooden docks as gulls call to each other and the pungent smell of low tide mixes with wafts of diesel fuel. This bustling activity is why Barnett sees Friday Harbor, located in Washington's San Juan Islands, as a perfect place to talk with boaters about the importance of preventing small oil spills and sewage discharge and to provide them with free resources to keep Puget Sound's waters clean.

Spilling oil or boater sewage introduces pollution into our waters that can sicken humans and pets; contaminate shellfish, crabs and salmon; and undermine jobs and recreational pursuits that depend on clean water. Even small spills accumulate into big numbers: in 2017, 1,331 gallons of diesel, gas, oil and hydraulic fluid were spilled into Washington waters from small vessels.

To educate boaters about keeping pollution out of Washington's waters, Barnett and WSG coastal policy specialist Bridget Trosin spend much of their time traveling around the state distributing free supplies to boaters and marinas. Their efforts are made possible through our partners: Washington Department of Ecology (managers of the broader spills program) and Washington State Parks (managers of the state boating program), and Puget Soundkeeper (managers of the Clean Marina program).

The small oil spill kits consist of a small absorbent pillow that can be placed alongside bilge pumps to prevent oily discharge from entering the water, a pair of nitrile gloves and a trash bag for disposing oily pads. Fuel bibs designed with a hole in the middle for the fuel nozzle are also available to make it easier to catch drips when filling up at the fuel dock. "We had a little bit of a spill filling up recently," boater Doug Looker says as he picks up a few fuel bibs during a stop in Friday Harbor. "If we had had something like this, we could have prevented it."

As of May 2018, Puget Sound was designated a No Discharge Zone, meaning that it is illegal to discharge raw sewage in inland waters and within three miles of the coast. To help boaters comply with these rules and offload their sewage, Barnett and Trosin also distribute specialized pumpout adapters that allow the pumpout hose to be securely attached during pumping, minimizing the potential for sewage spills. The adapter is one of the most popular items picked up at marinas and boating events. "These things are great," says boater Garner Miller; "It just screws into your deck fitting so you don't have to hold it, and there's no mess." Barnett also collaborated with other Sea Grant programs to develop an interactive online map that helps boaters locate one of more than 150 free pumpout stations at marinas around the state, including the most recent installation at West Beach Resort on the north side of Orcas Island.

These efforts seem to be paying off. In 2017 alone, 10.6 million gallons of sewage were prevented from being dumped into Puget Sound. After all, the best solution to pollution is to keep it out of the water in the first place.

Contact Aaron Barnett, WSG Boating Specialist, at 206.616.8929 or *aaronb5@uw.edu* for more information and to obtain your free small oil spills kit and pumpout adapter. Visit *www.pumpoutwashington.org* to view the pumpout map.

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Undergraduate student Laura Tripp uses the sulfide sensor in an eelgrass bed. Photo courtesy of David Shull

rapid increase in organic matter fueled bacteria in the sediment to break down sulfate into hydrogen sulfide, making these locations sulfide-rich. "We thought perhaps sulfide, which is toxic to eelgrass and can occur in high concentrations in these areas, might be part of the story," Shull says.

To study this effect, the researchers collected eelgrass from eight locations around Puget Sound and exposed them to varying levels of sulfides. Sulfide concentrations were manipulated in a number of ways, one of which included adding wood waste to the eelgrass tanks. "This mimicked places where there appears to be a strong effect of sulfide on eelgrass. This includes near historic pulp and paper mills, environments in which it's apparent that eelgrass doesn't grow very well," Shull explains.

The research found high sulfide concentrations reduce *Z. marina* germination and growth when combined with additional stressors, such as low light and dissolved oxygen. This was especially prevalent at night when photosynthetic activity decreased. However, eelgrass from some locations, such as Dumas Bay, were more resilient to high sulfide concentrations.

In the field, the team also found a variable distribution of sulfide concentrations in the sediment surrounding the eelgrass plant. With varying sulfide concentrations, it became difficult to take consistent sulfide measurements using the traditional methods, so the research team created their own tool to accomplish the task: their solution was the diffusive gradient thin-film (DGT) sensor. They layered thin sheets of a special kind of gel on top of each other, "So that you have what almost looks like a TV screen," Shull describes. Eventually, the result is a grey-scale gradient that gives an indication of the concentration of sulfide in the soil.

The results of this research could have important restoration implications; for example, the sulfide-resilient eelgrass from Dumas Bay holds promise to be successful stock to replant areas near historic sawmills. "Not all eelgrass populations are the same in the Salish Sea," Yang says. Which is why WSG funded a new project this year to research the genetic population structure of eelgrass and to study and how distinct eelgrass populations respond to environmental stressors. Getting a better understanding of these site-to-site differences will help fine-tune future restoration efforts.