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Community Spotlight:

NETARTS BAY, OREGON

Alan Barton, manager of Whiskey Creek Shellfish Hatchery, looking out at Netarts Bay. The pipes draw water from the bay into the hatchery for filling the tanks. In the past, the water was used directly from the bay. Today, the hatchery has to buffer all of the water for use.

Credit: Impact Media Lab / AAAS

A Crippled Oregon Shellfish Hatchery Spawns Better Ocean Monitoring Systems

One day near the end of 2007, Sue Cudd, co-owner of Whiskey Creek Shellfish Hatchery, watched millions of new oyster larvae hatch, filling a tank at their facility in Netarts Bay, Oregon. When she returned the next morning, almost every single one of the hatchlings had sunk to the bottom of the tank, dead or near-dead from exhaustion. Employees at Whiskey Creek were among the first in the country to observe this phenomenon, but it rocked other hatcheries as well over the next few years, driving an estimated $110 million loss for the industry country-wide over the course of the late 2000s.

A problem this big wasn't addressed overnight. To recover, Cudd and her employees spent years looking for a solution, which required forging new partnerships and developing new technology. And while they are adapting in the short term, the underlying problem – human-induced climate change – continues to progress.

FACT BOX

Overview: When oyster larvae at hatcheries began dying en masse, employees sought clues as to the underlying cause. After partnering with scientists and studying local ocean chemistry, they were able to identify the root cause – ocean acidification – and adjust their farming practices accordingly to restore oyster production levels. The technology developed from this setback at hatcheries spawned a new network of valuable ocean monitoring tools that will support future adaptation strategies.

Location: Netarts Bay, Oregon

Community characteristics: Fishing community

Major climate threats: Ocean acidification

Responses: Developed new tools for ocean monitoring and modified strategies for shellfish hatchery management

Project Status: Adaptation strategies began in early 2010s; ocean health monitoring ongoing

Key stakeholders: NOAA Ocean Acidification Program, Oregon State University scientists, oyster farmers, Pacific Coast Shellfish Growers Association, U.S. Integrated Ocean Observing System

Key resources: NOAA Ocean Acidification Program, State of Oregon, U.S. Integrated Ocean Observing System, Washington Ocean Acidification Center

Oyster are quite sensitive to changes in ocean water. For these creatures, the immediate period after they hatch is extremely critical in terms of survival. Much of their energy in these first 6 to 12 hours is dedicated to building their shells, and the amount of energy they must allocate for this task depends strongly on local ocean chemistry. This extreme sensitivity to ocean chemistry means that shellfish have been hit particularly hard by climate change, as oceans become more acidified.

Alan Barton, manager of Whiskey Creek Shellfish Hatchery, holds bags of adult oysters as he stands in front of Netarts Bay. The oysters must be raised under the controlled conditions of the nearby hatchery, since the ocean water in the bay is too acidic for oyster larvae during their early stages of development.

Credit: Impact Media Lab / AAAS

Over the last 200 years, humans have released more than 600 billion tons of carbon into the atmosphere – mostly in the form of carbon dioxide. The world's oceans have absorbed about a quarter of these emissions.[1] This injection of carbon dioxide into the world's oceans has caused their acidity to increase by about 25% since the beginning of the Industrial Revolution. Chemically speaking, more carbon dioxide in the water means fewer carbonate ions are available, which ultimately means it takes oysters more energy to form their calcium carbonate shells; to make matters worse, oyster larvae do not consume nutrients in their early stages, meaning they have a limited energy budget to form their shells during this period. Therefore, the dramatic change in ocean chemistry, and its impact on shellfish, is impossible to ignore at places such as Whiskey Creek Shellfish Hatchery.

By 2008, oyster harvests at Whiskey Creek had plummeted by about 75%. The hatchery's production manager, Alan Barton, was at a loss. "At the time, we never thought about carbon chemistry in our industry at all. We never needed to," he says. "So we were looking at biological factors, like disease and bacteria."

Barton has treatment systems installed to kill bacterial pathogens, but that did little to restore oyster production. Eventually, employees at Whiskey Creek noticed that major oyster mortality rates were coinciding with the summertime ocean upwelling (churning of deep water to the surface) that occurs off the coast of Oregon. This prompted Barton to reach out to an ocean chemistry expert at Oregon State University, Burke Hales.

Hales had been studying ocean chemistry for 30 years, and a lack of commercially available products for his work had compelled him to devise his own tools. Four keys indicators important for studying ocean chemistry include: total dissolved carbonates (TCO_2), the pressure of dissolved CO_2 gas (p CO_2), total alkalinity, and pH (which describes acidity); collectively, these factors are used to calculate a quantity called omega, which describes how favorable the water is for shellfish to make their calcium carbonate shells.

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[1] Le Quere, C. *et al.* (2018). Global Carbon Budget 2018. *Earth System Science Data* 10, 1-54. DOI: 10.5194/essd-10-2141-2018

If any two of these four qualities of water are known, it's possible to calculate the other two. Although tests to measure pH have been in use for roughly 200 years by scientists, this parameter remains difficult to measure with adequate precision, especially in the ocean environment. Hales therefore developed tools to measure the easier two of these four factors, pCO_2 and total organic carbon. When Barton reached out to him to help monitor water properties at Whiskey Creek, however, Hales realized he was going to need a more comprehensive tool to measure these variables in conjunction with one another.

Larvae tanks at Whiskey Creek Shellfish Hatchery in Netarts Bay, Oregon.

Credit: Impact Media Lab / AAAS

Therefore, Hales and his research team combined his pCO_2 pressure and TCO_2 tools to create a dual system. Unbeknownst to him, the hatchery operators had dubbed his new device the Burke-o-Lator, a name that took hold and persists today. The Burke-o-Lator is a tabletop laboratory, about three feet long, that can analyze seawater in real time as it flows by, or it can analyze water samples brought in from remote locations. This tool is what would eventually help Whiskey Creek recover its oyster production levels, nearing those it saw prior to the events of 2007.

By monitoring seawater at the hatchery with collected samples in 2009 and subsequently with an instrument at the hatchery itself, the Burke-o-Lator revealed that the hatchery tanks were being replenished at times when the seawater had recently upwelled off the coast and was particularly corrosive to the larvae. When Barton compared the more accurate ocean chemistry measurements from the Burke-o-Lator to logged data of oyster spawns at Whiskey Creek, he found a strong correlation between omega and oyster survival. Using these valuable insights, Whiskey Creek was able to alter its schedule and replenish the tanks at times when seawater was more favorable for shellfish to build their shells, and to buffer the water when bad conditions were unavoidable. "The hatchery was [at 25% production] for couple of years and now they're nearly at 100% of historical production because of this information. So that's a big success story," says Hales.

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News of the Burke-o-Lator spread, eventually reaching officials at the National Oceanic and Atmospheric Administration's Ocean Acidification Program (OAP) and U.S. Integrated Ocean Observing System (IOOS), who jointly wanted to fund the creation of additional Burke-o-Lators to help more hatcheries. In 2013, the northwest regional branch of the Integrated Ocean Observation Network, known as NANOOS, received funds for Burke to construct three new Burke-o-Lators, two of which were sent to California and the third to Alaska.

Due to regional ocean processes, seawater in the polar regions is expected to experience faster rates of acidification compared to other regions, a trend that's now being felt strongly by the fishing communities and hatcheries along the south coast of Alaska. The Burke-o-Lator in Alaska is situated at Alutiiq Hatcheries, which now uses the tool on a daily basis. When seawater is most damaging to hatchlings, employees add sodium bicarbonate to the water to make it less acidic. "We simply dilute soda ash in a bucket, add it to our tanks each day, monitor it to make sure we reach the level we want and do it the next day. If the Burke-o-Lator tells us it's fine, we don't do anything at all," explains Jeff Hetrick, director of Alutiiq Pride Shellfish Hatchery (APSH).

The tool is also being used to monitor seawater not just at APSH, but across the broader region. In partnership with seven native communities and the Prince William Sound Science Center, Kachemak Bay Natural Estuarine Research Reserve, and Kenai Fjords National Park, Alutiiq Hatchery is using its Burke-o-Lator to analyze water samples collected all the way from Cordova in the Gulf of Alaska to Utqiagvik in the Arctic Ocean, spanning more than 4,000 miles of Alaskan coastline. These efforts may reveal isolated pockets along the coastline that can still support shellfish and may eventually yield important clues as to why these areas remain a haven for the animals. According to Hetrick, the data collected so far suggest that ocean acidification is already ubiquitous across much of the Alaskan coast. Alutiiq Hatchery has also partnered with the University of Alaska Fairbanks to conduct exposure experiments with a wide range of organisms, including king crab, oysters, littleneck and razor clams, and more.

An adult oyster releases sperm into the water in a tank at Whiskey Creek Shellfish Hatchery. The oysters are not native to Oregon, but imported for use as breeding stock.

Credit: Impact Media Lab / AAAS

Burke-o-Lators are now in place at 15 locations on the West Coast of North America, and at one site on the East Coast. Live maps[2] of Burke-o-Lator data are available for free online. Scientists, hatchery workers and other stakeholders can use the data to better understand ocean chemistry and develop adaptation strategies.

The manager of programs for NANOOS, Jan Newton, notes how these data are filling critical gaps in knowledge. Whereas most ocean monitoring systems in the past have been based on buoys in the open ocean, monitoring systems for near-shore ocean conditions have been lacking. She also says that the expanded use of Burke-o-Lators is helping to inform new numerical models. For example, the LiveOcean[3] model provides users with forecasts on a range of important ocean parameters, such as omega, pH, temperature and salinity. Scientists then can use the models to address gaps in observational data.

NOAA OAP and IOOS have also funded a second generation of the tool, called ACDC, which Hales is developing with Sunburst Sensors, LLC. It only monitors pCO_2, so it must be used in conjunction with other tools to provide a better understanding of ocean chemistry. But whereas the Burke-o-Lator requires an expert to operate it, the ACDC doesn't require as much expertise and training to use, making it much easier to deploy. ACDCs are deployed at five sites along the West Coast, as part of a testing phase.

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2 The U.S. Integrated Ocean Observing System (n.d.). *IOOS Partners Across Coasts Ocean Acidification.* http://www.ipacoa.org/

3 NVS Data Explorer (n.d.). http://nvs.nanoos.org/Explorer?action=overlay:liveocean_arag

Continued efforts to implement such ocean monitoring tools are critical, especially when recent forecasts for ocean acidification are taken into account. A 2015 report[4] analyzing shellfish hatchery vulnerability across the U.S. found that 16 out of 23 bioregions are experiencing rapid ocean acidification or at least one amplifier, a factor with the potential to enhance acidification, such as upwelling. While marine ecosystems and shelled mollusks around the Pacific Northwest and southern Alaska are expected to be impacted soonest by global ocean acidification, as has already proven to be the case over the past decade, other regions will likely be impacted strongly soon too, including the north-central West Coast and the Gulf of Maine in the northeastern U.S.

Algae cultures that will be used to feed oyster larvae at Whiskey Creek Shellfish Hatchery in Netarts Bay, Oregon.

Credit: Impact Media Lab / AAAS

From an economic standpoint, however, the East Coast is most susceptible to negative impacts. The report suggests that southern Massachusetts will experience the largest economic burden because it has a particularly high proportion of seafood revenues coming from mollusks. In contrast, the Gulf of Mexico region was identified as most socially vulnerable, where people will be least able to withstand adverse impacts; this is due to low adaptive capacity (owing to social factors such as low political engagement in ocean acidification and climate change), low diversity of shellfish fishery harvest, and relatively low science accessibility in the region.

While the forecast for ocean acidification and its impacts are bleak, continued monitoring and development of adaptation strategies when possible is crucial. Notably, monitoring tools and adaptation strategies used by the hatchery industry only help the animals being farmed – and not wildlife. Since the crisis at Whiskey Creek, Hales has partnered with others to do some experimental work in larval mussels, finding that they have the same response as oysters do. Mussels line much of the northwest coast of the U.S. and play a critical role in shaping these shoreline ecosystems. “They are the first organisms that gain a foothold on those rocks and allow everything else to exist, to feed on them. That’s the crisis that I think we’re headed for, potentially losing mussels off our coast here,” says Hales.

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While hatcheries can add soda ash to their water and optimize when they refill shellfish tanks, Hales emphasizes the need to address the root cause of ocean acidification and reduce carbon emissions. Since developing the Burke-o-Lator, he has shifted gears and now manages a wave energy testing facility off the coast of Oregon, in the hopes of helping society move away from carbon-emitting forms of energy generation.

“Reducing carbon dioxide emissions is the only real way to address this problem,” he says.

[4] Ekstrom J., *et al.* (2015). Vulnerability and adaptation of US shellfisheries to ocean acidification. *Nature Climate Change 5*(3):207-214. DOI: 10.1038/nclimate2508