ADAPTING to a *changing*

ocean

by Nick Houtman

In 2007, Netarts Bay just west of Tillamook became the epicenter of a warning of seismic proportions to the West Coast seafood industry. In rearing tanks at the Whiskey Creek shellfish hatchery, nearly all oyster larvae died that summer and the next. Alarms went off in oyster farms up and down the coast.

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Oyster farming may not match Dungeness crab or pink shrimp as a moneymaker, but in West Coast states, annual revenues typically exceed $110 million, and the industry employs more than 3,000 people.

Mark Wiegardt operates a small oyster farm on the southern end of the bay and works at the hatchery with the owner, Sue Cudd, his wife. He remembers it like a bad dream. “We had three or four months when we had zero production. We’d never seen anything like it,” Wiegardt told Oregon Sea Grant’s Confluence magazine in 2013.

The story of the oyster die-off and how Chris Langdon, George Waldbusser and other Oregon State University researchers collaborated with the hatchery to find and respond to the cause — acidified ocean waters — has been told in news media outlets and magazines across the world.

Today, production continues, thanks to a simple but innovative solution. Using a sensor-based system developed by Burke Hales at OSU, Whiskey Creek monitors water piped in from the bay. The pH (a measure of acidity) is adjusted automatically by pumping sodium carbonate — aka washing soda or soda ash, available in bulk at the local feed store — into the rearing tanks. Some have called it the TUMS® solution.

Down the coast at the Hatfield Marine Science Center in Newport, scientists are finding signs that other commercially harvested marine animals — abalone, shrimp, cod, rock sole, Dungeness crab — may be affected by ocean acidification and its siblings — low dissolved oxygen (aka hypoxia) and toxin-producing plankton blooms. In research elsewhere, even salmon have shown behavioral changes in acidified water.

As CO_2 rises in the atmosphere, there may be no long-term fix for this problem. Globally, the oceans absorb about a quarter of annual CO_2 emissions and are now 30% more acidic than they were in pre-industrial times. Scientists have also shown that in the last two decades, persistent summer winds along the West Coast have brought deep-ocean water — more acidic and lower in oxygen than surface waters — with increasing frequency onto the continental shelf.

Chris Langdon is one of the leaders of oyster research that is addressing ocean acidification.

Like sailors trying to stay ahead of a gathering storm, scientists and seafood businesses are faced with racing to adapt to these trends. In 2016, Oregon State marine ecologist Francis Chan and a team of colleagues reported in the journal Nature that highly acidified waters were exposing fish and shellfish in estuaries and other near-shore waters to “some of the lowest, but also some of the most dynamic pH environments currently known for surface marine systems.”

It’s likely, say Chan and other scientists, that populations of organisms repeatedly exposed to these conditions are able to adapt. However, they add, environmental stress can also reach thresholds, beyond which organisms are less resilient or simply die. The canary in this mine may be Whiskey Creek’s oysters.

More Creatures. More Research.

Netarts is among those places that can lay claim to being the heart of Oregon’s shellfish industry. For thousands of years, the estuary supplied native people with

Whiskey Creek hatchery in Netarts Bay is the largest shellfish hatchery in the U.S.. They collaborate with OSU researchers to monitor pH levels of water pumped in from the bay.

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oysters and clams. Middens, some six-feet thick, testify to the historical abundance of shellfish in addition to the bounty of crabs, fish, seals and other animals in the bay.

When white settlers arrived in the 1860s, they began harvesting the native Olympia oyster for commercial purposes, even exporting them to San Francisco by ship and mule train. A shantytown called Oysterville emerged at the head of the bay. Within a few decades, Olympia populations had plummeted. In the 1920s, growers began replacing it with a larger, faster-growing variety, the Pacific oyster from Japan.

Today, Netarts hosts oyster farms, a state-managed shellfish preserve and Whiskey Creek, one of the country's largest shellfish hatcheries, named for the bay's major tributary. The region is also home to retirees, a state park, RV resorts and campgrounds. A narrow sand spit shelters popular clam digging and fishing spots from the open Pacific.

To understand how organisms in Netarts Bay and other estuaries will respond to increasing acidification, researchers expose shellfish, crustaceans and finfish to waters with varying amounts of oxygen and with low, moderate and high carbon-dioxide concentrations. By doing this with animals at larval, juvenile and adult stages, scientists are discovering if, when and how seriously these commercially important species are affected by changing acidity.

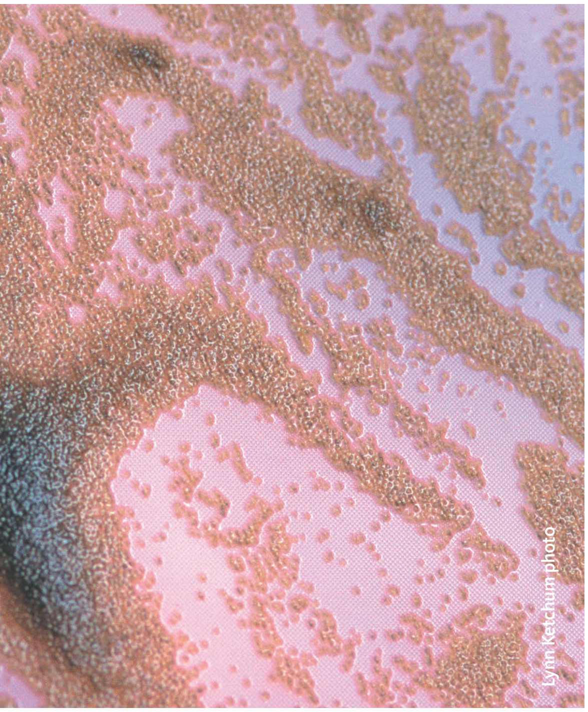
Since sensitivity can vary at each stage, impacts may occur well before these animals become adults. In human terms, imagine a baby affected by a mother's excessive alcohol or drug use in the womb. Or a child deprived of essential vitamins. If the young survive, their function as adults may be impaired, but the damage can be traced back to earlier stages of life.

Hannah Gossner, a master's student working with Chan, focused on Dungeness crab and red abalone. She found that in both species, respiration rates (a health indicator) decreased in response to increasing acidification and to low oxygen. However, crab appeared to be more strongly affected by hypoxia than by increasing acidity. Abalone, in contrast, showed sensitivity to both.

George Waldbusser, Oregon State marine ecologist, worked closely with Mark Wiegardt, Alan Barton and others at Whiskey Creek when oysters were dying there, and he has continued to explore the response of oyster larvae to acidified water. In 2013, he and master's student Elizabeth Brunner showed that larvae fail to develop normally in water acidified at levels that currently upwell on the Oregon coast.

As they grow, larvae run a race against time. Although tiny, about the width of a human hair, they must develop shells and other organs that enable them to withstand environmental stresses. High acidity can prevent them from reaching that threshold.

Working with Waldbusser at Whiskey Creek, Ph.D. student Iria Giménez Calvo exposed batches of oyster larvae to



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varying levels of acidity and tracked their growth responses. She produced a computer model, the ocean acidification stress index for shellfish, or OASIS. In the journal Elementa, she reported that the model can help shellfish growers predict how their operations will be affected by acidification.

It also turns out that native sea grass *(Zostera marina)* may assist oysters in resisting the effects of acidity. In trials with Whiskey Creek oysters on Netarts Bay, Waldbusser and his students found that the best growth occurred in beds of Zostera. That may be, he said, because when these sea grasses are actively growing, they reduce CO_2 in the water to pre-industrial levels. Such effects, he says, were seen for shorter periods of time with a non-native sea grass species.

With support from Oregon Sea Grant, Waldbusser has also been studying how Oregon pink shrimp respond to acidification. Graduate students working in his lab in Corvallis have found that shrimp grow more slowly when exposed to water with acid levels that occur now on the Oregon coast. Waldbusser is repeating those experiments. Shrimp, he stresses, is often Oregon's second largest commercial fishery, bringing in as much as $30 million in annual landed value.

In addition, finfish species have received attention from researchers. Tom Hurst of the Alaska Fisheries Science Center in Newport has been studying three commercially important fish species — walleye pollock, Pacific cod and northern rock sole. He found that pollock are resilient in the face of higher acidity, while cod and sole may be more vulnerable at early life stages.

At the University of Washington, scientists reported last winter that acidification reduced the ability of coho salmon to detect smells that they would typically avoid. By changing the way salmon avoid predators or detect prey, they added, higher acidity could have far-reaching consequences for salmon populations and marine ecosystems.

More trouble is brewing near the base of the marine food web. Researchers at the NOAA Pacific Marine Environmental Lab in Seattle have found evidence that acidified waters are weakening the shells of a type of plankton known as a pteropod — a significant food for salmon, herring and other fish. Their findings show how acidification impacts can amplify through the food chain.

Left: A close up of oyster larvae.

Right: Algae is the main food source for oysters. At Whiskey Creek, they grow their own.

Far right: Collecting oyster sperm.

A More Resilient Future

Compared to aquaculture operations like Whiskey Creek, wild fisheries are in a more precarious position, says Caren Braby, Marine Resource Program manager with the Oregon Department of Fisheries and Wildlife. "With oysters, you can control exposure of the animals to the environment in the hatchery. There are culture practices. With wild stocks like Dungeness crab, there is no such 'spigot' that you can turn on and off. They are exposed to whatever nature throws at them."

Oregon's Dungeness crab regulations provide an example of what it takes to manage a wild fishery in the face of

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changing ocean conditions. During the crab season, the Marine Resource Program monitors razor clams from selected locations every two weeks for biotoxins produced by harmful algal blooms. When toxins are found, crabs are then sampled — both the viscera and the white meat — to determine if they are safe to eat.

The process requires fishermen to bring crabs to regulators for testing. "That's one of the best examples of wild fishery impacts and management response, maybe globally," says Braby.

The future of both wild and farmed species may lie in understanding their genetics. At the Hatfield Marine Science Center, Chris Langdon, professor in the College of Agricultural Sciences at Oregon State, has been breeding oysters since 1996. Among the primary goals of the Molluscan Broodstock Program are rapid growth and resistance to disease — and now resilience in the face of acidification.

Working in Langdon's lab, Evan Durland, a graduate student, found that acidification had its greatest impacts at the larval stage. His experiments showed that high acidity affected hundreds of genes. Among them are genes responsible for creating a membrane critical for transporting calcium, which is vital in building shells.

Using such results to breed a more resilient oyster will take time. "It's unlikely that there are a handful of genetic markers that can be easily used to identify stocks tolerant of ocean acidification," says Langdon. "Selecting stocks based on hundreds of markers is very difficult."

Nevertheless, there may be a silver lining. In research funded by the National Science Foundation, Langdon, Waldbusser and a team of researchers found that the native Olympia oyster — the species harvested nearly to extinction in Netarts and other locations in the late 1800s — is much more resistant to acidification than is the Pacific oyster. Rather than reproducing by broadcasting eggs and sperm into the water, as Pacific oysters do, Olympia oysters internally fertilize and brood their young for 10 to 12 days before releasing them. "This is good news for the long-term viability of populations of native Olympia oysters," says Langdon.

The Pacific Northwest may be among the most well-equipped regions in the country to adapt to changing conditions, adds Waldbusser. "Despite the hazard being high in the Northwest, when you look at research by the states, Sea Grant budgets, how diverse the economies are, it turns out the adaptive capacity is quite high here."

With funding from NOAA, Waldbusser is working with Oregon State colleagues David Wrathall and David Kling to evaluate the social and economic vulnerability of the West Coast shellfish industry. "The natural science is important, but the economy and social structure are a big part of the story," Waldbusser says.

Perpetual Innovation

The nature of climate change and ocean acidification is its unpredictability, both in terms of the impacts and levels of change in the environment and how live organisms and animals respond and adapt to that change. The solution discovered in 2007 to address the oyster die-off of the time, is not a permanent solution. Already, breeds of oysters that seemed to be resilient to the pH level changes are becoming susceptible to disease again.

Staying in front of the science necessary to respond and adapt to change can seem like an uphill race in sand. But that is where the heart of the oyster's future resides. With relentless focus and perpetual innovation.

That invisible hard work is constant. It is critical. And, it is happening every day. | **OAP**