confluence

OREGON SEA GRANT

SUMMER 2013 | VOLUME 2 NUMBER 1

AQUACULTURE IN OREGON

Thriving in the Throes of Change

FROM THE DIRECTOR

Jonathan Swift is quoted as having said, "He is a bold man [or woman] that first ate an oyster," and many might say the same about other kinds of shellfish. Raise your hand if you've always liked oysters, mussels, clams, and scallops—even when you were a kid. Hmmm… not many hands up.

Here in Oregon, we've always been blessed with an abundance of all kinds of fresh, delicious, nutritious seafood, including shellfish. But is that abundance threatened by the rising specter of hypoxia (too little oxygen), ocean acidification (too much carbon dioxide), and disease? Fortunately, Oregon Sea Grant researchers are on it; we have several scientists not only looking into the causes and effects of hypoxia, ocean acidification, and disease, but seeking ways to counter them.

In this issue of *Confluence*, we take you on a guided tour through the many facets of aquaculture in Oregon—which includes not just edible seafood but also ornamental fish. You'll learn about how researchers are trying to protect baby oysters and other shellfish

from the effects of acidification and disease; how an aquatic veterinarian is saving the lives of ornamental fish and improving the business of exporting and importing them; where aquaculture has been and where it may be headed; you'll even learn about a popular Japanese candy that contains oyster protein and may help you, um, run farther.

In addition, we have a story about how our Extension seafood product development specialist helped an Oregon seafood company launch a new product that's so good, it's a finalist for a national award.

And, as always, you can learn more about these topics and others from our online edition of *Confluence*: **seagrant.oregonstate.edu/confluence**

Stephen B. Brandt
Director, Oregon Sea Grant

IN THIS ISSUE:

On the cover: Oyster shells in baskets along Netarts Bay, Oregon.

CONFLUENCE: *The junction of two or more rivers; an act or process of merging; from the Latin word "confluere," meaning "flow together."* We chose the name *Confluence* to reflect the merging, or flowing together, of Oregon Sea Grant's three "rivers": research, education, and engagement. Integrating the three supports our mission of helping people understand, rationally use, and conserve marine and coastal resources.

CONFLUENCE
VOLUME 2, NUMBER 1 SUMMER 2013

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The Whiskey Creek Shellfish Acid Tests

Ocean acidification and its effects on Pacific oyster larvae

BY NATHAN GILLES

Alan Barton drains seawater from a large tank, filtering its oyster larvae as he goes. He will then sort the larvae by size, using custom-made screens.

The sun chips away at the marine layer on this swiftly warming May morning in the bay. On the estuary's muddy banks, clammers dressed in knee-high rubber boots dig in the dark sludge, while throughout the bay other aquatic farmers dredge for their prize: oysters.

The oysters are *Crassostrea gigas*, commonly called the Pacific oyster. These "giant oysters" measure from 3 to 15 inches long. They're huge moneymakers for global aquaculture, and they have a special relationship to this place. This is Netarts Bay, Oregon, the center of the state's oyster industry and home to the Whiskey Creek Shellfish Hatchery, one of the nation's largest producers of Pacific oyster larvae. Hatcheries such as Whiskey Creek are linchpins for industry. That's because the Pacific oyster is originally from Japan, and here on the west coast its delicate larvae grow wild in only a handful of places. For oyster growers from California to Canada to succeed, hatcheries must raise larvae. Unfortunately, as an incident at Whiskey Creek proved, the larvae are under siege.

In 2007, Pacific oyster larvae at Whiskey Creek started dying en masse. Oregon State University scientists later pinned the crime on ocean acidification. This is the term many are using to describe what's happening in the world's oceans as excessive atmospheric carbon dioxide (CO_2)—a product of human industry's hunger for fossil fuels—is dissolved in seawater. Once it's in the ocean, CO_2 forms carbonic acid, which lowers the water's pH level, making it more acidic. The consensus is that ocean acidification is just getting started. As CO_2 is continually pumped into the air, the world's oceans are expected to slide further toward the acid side of the spectrum, and that, say researchers, won't be good for animals like the Pacific oyster. That's because oysters and other mollusks make their shells from calcium carbonate, which is becoming increasingly susceptible to breaking down in our ever-more corrosive seas. This is what happened at Whiskey Creek: the seawater in which the hatchery was raising its larvae had succumbed to ocean acidification; the larvae struggled to make shells, and died. But this isn't the whole story.

Today, with Oregon Sea Grant's help, OSU researchers are continuing to investigate ocean acidification's nefarious ways. They're gaining a better understanding of oyster larvae's response to the phenomenon. They're developing better seawater monitoring techniques. And they're connecting with stakeholders in an effort to develop useful diagnostic tools for hatcheries and growers. Yet getting to this point took time. When the hatchery's larvae started dying, it was mystifying.

Acid's first inklings

The tide is very low. The moon has pulled back the saline blanket covering Netarts Bay, revealing a normally concealed landscape of sandbars, muddy flats, and Whiskey Creek's intake pipes.

"It's usually not like this," says hatchery employee Alan Barton, gesturing at the bay.

"There's usually water over all this."

Barton is standing on the estuary side of a two-lane road hugging the bay, with Whiskey Creek behind him. In front of him, a small slope declines toward the bay. Jutting from it are two intake pipes. They hang mid-air over a still-submerged bed of aquatic eelgrass. Normally, these pipes help pump between 100 and 200 gallons of water per minute into the hatchery. Not today. Today, other pipes—still underwater—do it all, pumping bay water, under the road and to the hatchery, where it's treated and then dumped into massive tanks filled with Pacific oyster and other shellfish larvae.

Barton is wearing a T-shirt bearing NASA's logo. It's an odd choice for such a down-to-earth guy, which is exactly what he purports to be.

"I don't do science," says Barton. "I work in a hatchery." Although that may be true, everyone agrees he was the first to solve the mystery.

In 2012, Barton and the hatchery gained national attention when he and several OSU researchers published a paper announcing they'd discovered that the bay water drawn from those intake pipes was killing the hatchery's Pacific oyster larvae.

Getting to that conclusion took time. At first, the only thing anyone knew was that something was horribly wrong.

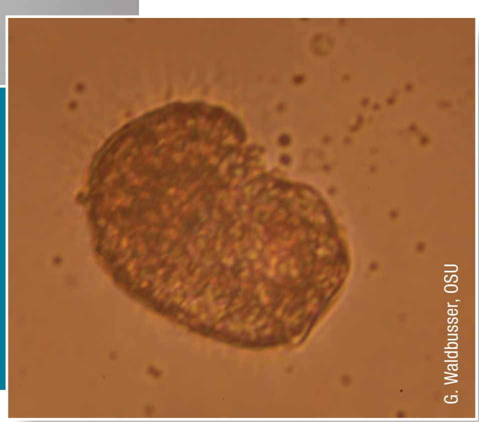
"We had three or four months when we had zero production. We'd never seen anything like it," says Mark Wiegardt.

Wiegardt owns a small oyster farm on the bay's south end. Since 1997, his wife, Sue Cudd, has owned and operated Whiskey Creek, with what he says is modest input from him. True to his words, as Wiegardt is outside, leisurely relating the tale of the hatchery's bad acid trip, Cudd bustles among the rows of enormous tanks. Using trays covered in fine netting, she's sifting tank water for nearly microscopic organisms no wider than a strand of human hair. The result of her sieving is what looks like a mess of fine mud. But it isn't mud; it's Pacific oyster larvae, millions per tray. Larvae that at two weeks of age are put on ice, placed in insulated boxes, and next-day shipped to oyster growers the world over, growers who then raise the animals to maturity before the tasty critters end up as someone's dinner.

All that's happening inside. Outside, Wiegardt is hunched over his truck bed, separating oysters for breeding and describing how the hatchery and its OSU helpers uncovered the larvae killer.

Wiegardt says the troubles began in the late summer of 2007. "To be honest, we didn't know what was causing it," he says, "but *[Vibrio] tubiashii* was present, so at first we thought it was that."

A bacteria named *Vibrio tubiashii (V. tubiashii*) was the initial culprit on the hatchery's wanted list. *V. tubiashii* preys on Pacific oysters and occasionally blooms when conditions are right. Suspecting a pathogen was at work, Wiegardt started sending samples off for testing. Sure enough, the water tested positive for *V.*



G. Waldbusser, OSU

Above: Once sorted, larvae are collected in tubes and—"like decorating a cake," says Alan Barton—are oozed out in small bundles that are then refrigerated and next-day shipped the world over. A typical bundle contains anywhere from 40 million to 150 million larvae.

Right: Pacific oyster embryo, seen under a light microscope. Formation of first shell has just begun.

Along with growing oyster larvae, the Whiskey Creek hatchery also grows their food. Above left, Sue Cudd inoculates a tank before starting a new batch of algae. Above right: Mark Wiegardt inspects one of the hatchery's 8,000-gallon, seawater-filled tanks.

tubiashii. To ward off future outbreaks, Whiskey Creek installed an enhanced system to cleanse the incoming water. This helped, but, says Wiegardt, "There were definitely still problems."

With their new defenses up and running, Whiskey Creek hired Barton as monitor. Then came another die-off, only this time the water was nearly clean of *V. tubiashii*. Something else had to be at work.

At the time, Barton was perusing Richard Feely's work. Feely, an expert in chemical oceanography at the University of Washington, had concluded ocean acidification's low pH waters were corrosive to calcium carbonate, a necessary ingredient in oyster shells. That's when Barton thought maybe the larvae slayer was ocean acidification. To test this, he sent water samples to OSU Professor Burke Hales, also an expert on ocean chemistry. After testing the water, Hales—who continues to work closely with the hatchery, and was a co-principal investigator on that 2012 paper—confirmed Barton's suspicions. "Pretty soon," says Wiegardt, "it became obvious…we had a pH problem."

Understanding how the hatchery's corrosive waters made their mayhem came soon after.

Straight to shell

"The first 24 hours following fertilization are the most important," says George Waldbusser. "That's when the larvae build their initial shells."

Waldbusser is an assistant professor at OSU's College of Earth, Ocean, and Atmospheric Sciences specializing in, among other things, bivalves' responses to acidifying waters in estuaries. He was an author with Barton on that 2012 paper. He's currently being funded by Oregon Sea Grant (OSG) and the National Science Foundation to research ocean acidification's effects on oysters and other bivalves. And he's heading up the investigation at Whiskey Creek. He also has a pretty good grasp on what it takes for Pacific oyster larvae to form their calcium carbonate shells.

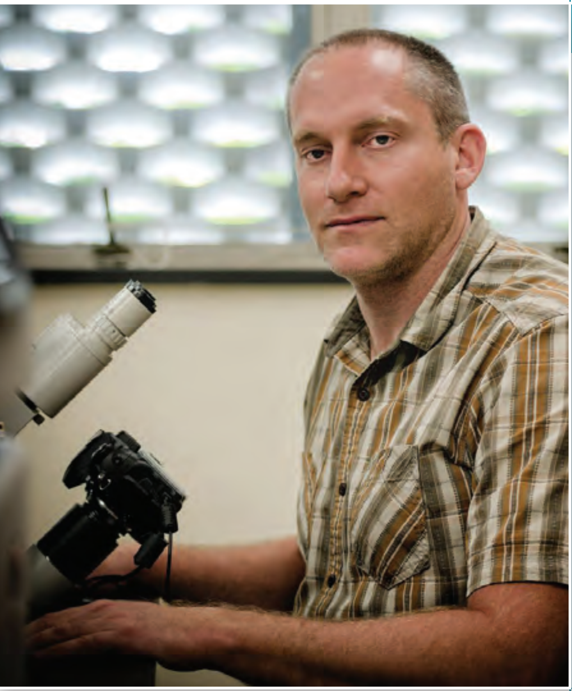
"What it comes down to," says Waldbusser, "is how fast they can make their shells."

When Pacific oyster larvae are fertilized, they don't yet have shells. But they need them quickly. Without shells, the larvae can't form things like internal organs and feeding and swimming appendages—which they obviously need to survive. Waldbusser says they're also running on borrowed time. What energy the larvae still have from their lives as eggs won't last forever. The race is on; it's straight to shell, or die trying.

Pacific oysters make their shells from calcium carbonate, the chemical make-up of other mollusk shells as well as corals, snails, and pteropods. Seawater is usually supersaturated with the stuff, but, says Waldbusser, the larvae can't wait for calcium carbonate to leisurely form their shells around them. That takes ages. So the larvae push the process along. In addition, Pacific oyster larvae can't use just any calcium carbonate. Those initial shells need aragonite, the less stable of calcium carbonate's two major forms.

"Aragonite isn't anything that's in the water," explains Waldbusser. "Aragonite is made out of calcium and carbonate and it's how those are put together that forms the shell."

To put it all together and make aragonite, oyster larvae capture carbonate, bicarbonate ions, and even CO_2 from seawater by bombarding it with protons.



George Waldbusser

They then combine these with calcium they've gathered using silk-like proteins they produce. Then the little animals chemically mix it up and, voilá, they've got aragonite. This process, says Waldbusser, is energetically expensive relative to the energy the larvae still have. If they use too much, the larvae die. That appears to be what happened during Whiskey Creek's die-offs.

Low-pH water severely curtails the available ions. (Globally, ocean acidification has resulted in a 16 percent reduction in carbonate ions, according to Feely.) Aragonite itself is also particularly vulnerable to acidification, being more soluble than calcium carbonate's other major form, calcite—which adult oysters use to continue shell building. That makes it much harder for larvae to form shells before they run out of energy. How the larvae respond to this stressful situation is the subject of Waldbusser's current OSG-backed work.

Little victims

Waldbusser is trying to imitate the variable conditions—namely, dissolved CO_2's ups and downs—the hatchery larvae are normally subjected to, often on a daily basis.

Waldbusser is trying to imitate the variable conditions—namely, dissolved CO_2's ups and downs—the hatchery larvae are normally subjected to, often on a daily basis.

Graduate researchers Iria Giménez (left) and Becky Mabardy set up a lab at the Hatfield Marine Science Center for experiments on how ocean acidification affects oysters.

To mimic the bay's fluctuations, Waldbusser and his grad students have been subjecting day-old oyster larvae to varying degrees of exposure to CO_2-enriched water. They've pummeled larvae with CO_2 levels ranging from not too bad to horrible. They've examined how quickly they can gas the organisms to determine whether sudden bursts of CO_2 are worse than a slow build-up (preliminary results suggest that yes, it's worse). The whole thing is very stressful for the little guys, and that, says Waldbusser, is the point.

"We're trying to understand, over the entire larval period, how does a stressor translate into stress on the organism?" he says.

Once thoroughly assaulted, the larvae are flash-frozen in their various distressful throes; the tiny creatures' shells are then smashed—harder than it sounds, considering they're smaller than grains of sand—and dowsed with chemicals to further destroy the aragonite husks. Then they're blended in a centrifuge, and their lipids and proteins are chemically expunged. What's left is a globular mass of once-very-stressed tiny oysters, now reduced to a mere smudge of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA).

"We're trying to capture a general [picture of] stress," says OSU grad student and Waldbusser team member Iria Giménez.

Giménez oversees the stress-inducing research. She says the idea underlying it is pretty simple: measure stress in a very general way by comparing the amount of RNA to DNA in the larvae.

DNA is the "blueprint of life"; the intertwined and interlocking molecules tell the body which proteins to synthesize and when. To do that, DNA needs help. Enter RNA.

RNA acts as a kind of messenger molecule, and, says Giménez, how many messengers a particular organism has at any given time tends to be a pretty good sign of just how quickly that organism is growing. And because stressed-out animals grow more slowly than normal ones, a low amount of RNA—as measured as a ratio of RNA to DNA (since the amount of DNA stays constant)—can tell you if an animal is freaking out and how badly.

"When they [oyster larvae] are under acidification stress," she says, "that growth is being depressed. They aren't growing as much, so the amount of RNA is less, so the ratio is less."

Waldbusser says that as far as he knows, this is the first time this methodology has been used to measure ocean-acidification-induced stress in Pacific oyster larvae on such short time scales. These snapshots are important, he says, because of how critical those first 48 hours are to these organisms. But it's not all make-shell-or-die for Whiskey Creek's larvae; there are some remedies.

The hatchery solution

Intake pipes pumping in bay water release a steady surge into the hatchery tanks in front of Stephanie Smith. At the OSU grad student's feet are five large bags with the words "Dense Soda Ash" written on them. This is the remedy for Whiskey Creek's upset waters.

"They put soda ash in this," says Smith, pointing at a large tank. "They then pump the soda water in until they get the state they want."

Smith, who also works with Waldbusser, says the bags of soda ash act like large antacids, raising the water's pH level. This process, referred to as "buffering," is part of a monitoring and treatment system that's been lovingly named the "Burkolator," after its creator, Burke Hales. Smith is one of the Burkolator's keepers. Above the roar of laboring pumps and incoming water, she explains its mechanics.

The Burkolator is a series of sensors all routed through a single computer. It calculates pH and different measures of dissolved CO_2, and it quantifies what Smith says is, without question, the most important metric for the hatchery: the aragonite saturation state. This is a measure of the "corrosivity" of the mineral, or its ability to be broken down by low-pH bay water. The state is determined by the availability of carbonate ions, where fewer ions means less aragonite and a

(Continued on page 8)

The return of *Vibrio tubiashii*

What OSG scientists are learning about the oyster-harming pathogen

In 2007, when Pacific oyster larvae began dying at the Whiskey Creek Shellfish Hatchery in Netarts Bay, Oregon, a pathogenic bacteria called *Vibrio tubiashii (V. tubiashii)* was originally blamed. Researchers later determined the culprit was in fact low-pH water (see "The Whiskey Creek Shellfish Acid Tests" in this issue). But that doesn't mean *V. tubiashii* is off the hook.

With Oregon Sea Grant's (OSG) backing, Chris Langdon, Oregon State University professor and head of the Newport Aquaculture Laboratory at the Hatfield Marine Science Center, is continuing to investigate *V. tubiashii*. He's being joined by OSU microbiologist Dr. Claudia C. Häse, an expert in bacterial pathogens; and Dr. Ralph Elston, an affiliated professor at the University of Washington and founder of a company that performs scientific testing for the aquaculture industry.

V. tubiashii presents continuing puzzles for researcher Chris Langdon.

The researchers are testing to see what effects metalloprotease, a particular protease (or enzyme) that *V. tubiashii* produces, might have on bivalve larvae. To do this, the researchers are subjecting the larvae of three different oyster species—including Pacific oysters—to a special mutant breed of *V. tubiashii* that doesn't produce the enzyme.

Langdon says that, much like *V. tubiashii*'s sudden appearance in 2007, there's been another big surprise in the knowledge that's slowly building for this bacterial pathogen. He says the current OSG research confirmed some but not all of their original suspicions.

"[Under laboratory conditions] the initial suspected toxin [metalloprotease] does not seem to be as harmful as we originally thought," says Langdon. But he says it's possible that other factors are involved in determining the toxicity of *V. tubiashii* under hatchery conditions, including the low-pH seawater linked to the Whiskey Creek larval die-offs.

"There's still a lot we don't know about this bug," he says.

lower saturation state. Smith says that when a low state is noticed, that's when you add the soda ash.

However, this doesn't always help.

The acid test

"July and August, I call that the acid test," says Wiegardt. "It's the toughest."

Wiegardt's acid test is part of a natural process called upwelling that, in Oregon, happens almost like clockwork every year in late summer. Driven by strong winds that propel ocean currents, upwelling occurs when deep ocean water is pulled into the shallow waters on Oregon's continental shelf. From there it enters Netarts Bay. This upwelled water is often high in dissolved carbon dioxide and low in pH and carbonate ions. Not even industrial-strength antacids will help.

"In the summer, this whole bay is a disaster, and buffering isn't enough," says Barton. However, upwelling might not be the only reason for this disaster.

Leaving Whiskey Creek

Netarts Bay is full of aquatic plants that could be big players in nearshore ocean acidification. That's what everyone at Whiskey Creek suspects.

"As you can see, we draw out of a puddle of eel grass," say Barton, pointing at the pipes and sea grass in front of him. Barton, Waldbusser, Giménez, Smith, and pretty much everyone else suspect that the natural respiration of ocean plants such as this eelgrass, which take in CO_2 during the day and respire it at night, is causing some weird daily fluctuations in CO_2 levels—the same fluctuations Waldbusser and Giménez are mimicking. Smith says the Burkolator has registered these oscillations. Taking what's been learned in the hatchery's controlled environment into a real-world ecosystem, she plans on further studying these ups and downs and how they're affecting Netarts Bay's wildlife. The OSU scientists also hope to get their research out of the hatchery in another way.

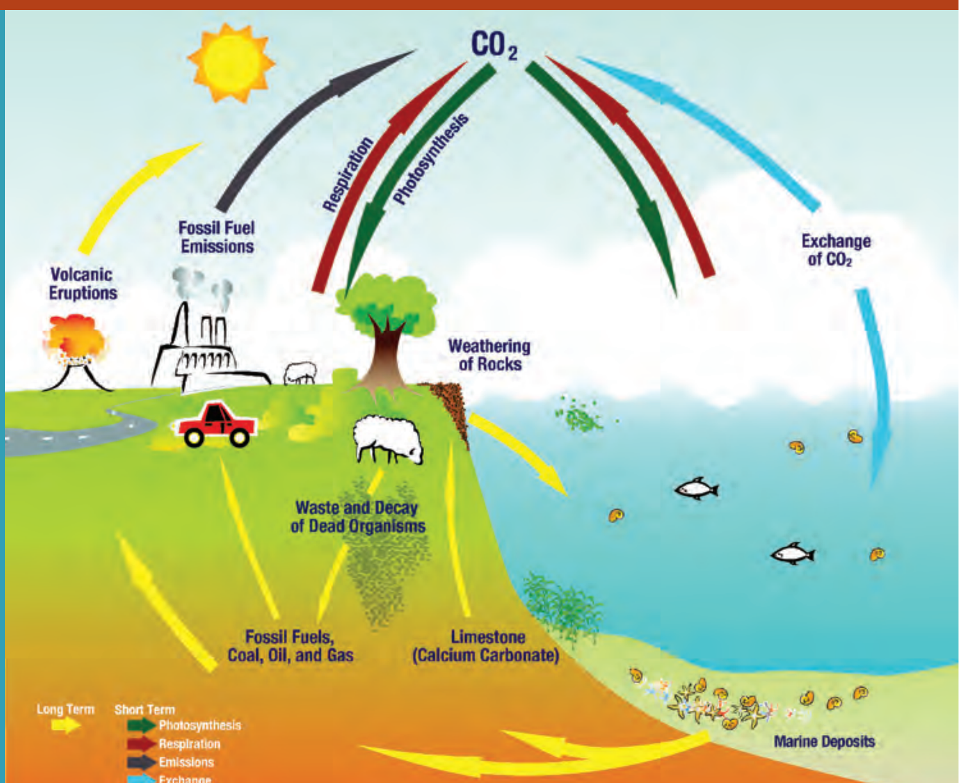
As of this writing, OSU grad student Becky Mabardy, with OSG support, just finished conducting a survey of shellfish industry stakeholders that she says has revealed some interesting results.

"They feel like the science is sort of locked up in the academic community and it's not made accessible," says Mabardy.

To change this, Mabardy is investigating what would be the best medium in which to convey OSU's research, and—be it on an app or a website—what information from the myriad collected will be most useful to people in the shellfish industry. She says she suspects the most valuable data will be about local conditions, which—as Whiskey Creek's long, strange trip illustrates—can deviate wildly from global averages.

That also seems to be where the science is going. As Giménez puts it, "All those [local] things really matter. The oysters don't care about mean global changes; they care about what's happening right here and right now."

WHAT CAUSES OCEAN ACIDIFICATION?



Carbon is continually exchanged between the atmosphere, ocean, biosphere, and land on a variety of timescales. In the short term, CO_2 is exchanged continuously among plants, trees, animals, and the air through respiration and photosynthesis, and between the ocean and the atmosphere through gas exchange. Other parts of the carbon cycle, such as the weathering of rocks and the formation of fossil fuels, are much slower processes occurring over many centuries. For example, most of the world's oil reserves were formed when the remains of plants and animals were buried in sediment at the bottom of shallow seas hundreds of millions of years ago, and then exposed to heat and pressure over many millions of years. A small amount of this carbon is released naturally back into the atmosphere each year by volcanoes, completing the long-term carbon cycle. Human activities, especially the digging up and burning of coal, oil, and natural gas for energy, are disrupting the natural carbon cycle by releasing large amounts of 'fossil' carbon over a relatively short time period.

Source: National Research Council. 2010. Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean. p. 3. Washington, D.C.: The National Academies Press.

PRICED OUT OF OUR OWN SEAFOOD

Chris Langdon talks about aquaculture and its future

Chris Langdon's lab isn't the sort of cramped space that comes to mind when one hears the word "lab."

Langdon runs the Newport Aquaculture Laboratory at the Hatfield Marine Science Center in Newport, Oregon, and his lab is a whole cluster of rooms and greenhouses jam-packed with water tanks of several shapes and sizes. Among the inhabitants of these seawater-filled tanks are various types of algae and bivalves—especially oysters, which Langdon has been breeding for the past 17 years. There are Pacific and Kumamoto oysters, both prized for their tasty meats; and there are oysters from the Gulf of Mexico, which he's testing to see what effects the 2010 BP oil spill had on them. All of this helps improve aquaculture—something Langdon takes very seriously, and something he says will be essential in the years ahead to feed the world's burgeoning population in a changing climate.

"We are pushing 7 billion [people] now and probably will go up to 9 or 10 billion [by mid century]," says Langdon. "And factors like global warming are going to affect our food supply. And the best source is probably from the ocean." But, he says, more of that ocean food needs to come from aquaculture and not from fishing wild stocks.

About 80 percent of wild fish stocks are overexploited or fished to their maximum sustainable levels. This is a serious problem if we want seafood to remain an important part of our diet—a problem that Langdon says can be partially solved by investing in aquaculture. And many countries are doing just that.

"Aquaculture is the fastest-growing agriculture activity in the world," says Langdon, "growing at about 10 percent a year—except in this country, where it's hardly growing at all."

Asia currently dominates world aquaculture, accounting for about 89 percent of the total global production of about 66 million tons (65 percent of the world's aquaculture is in China alone). Meanwhile, U.S. aquaculture accounts for only about 1 percent of global production, but this tepid growth isn't for lack of trying on Langdon's part.

Over the years, Langdon has left his mark on aquaculture. He's developed innovative ways to feed oyster and fish larvae on microparticulate diets—because these tiny organisms need tiny food. He's also helped develop an environmentally sustainable way to raise abalone with a special breed of red seaweed (the technology is being used commercially in Hawaii). And for years he ran the Molluscan Broodstock Program, the first selection program to successfully improve the Pacific oyster—a major boon to oyster farmers. Although the program lost its government funding a couple of years ago, oyster producers are now pooling their resources to fund it. And, he says, if you've bought seafood lately and noticed its high price tag, increasing aquaculture production through programs like these might be what the U.S. needs if we're to continue consuming reasonably priced protein from the sea.

That's because the U.S. currently imports about 91 percent of its seafood. (The National Oceanic and Atmospheric Administration estimates our "seafood deficit" at $10.4 billion annually.) At the same time, the U.S. is increasing its exports to seafood-hungry countries such as China, whose legions of consumers have started to dominate the world market and set the global price.

"We are getting priced out of our own seafood because of global competition," says Langdon, "and that trend is only going to get more and more severe, because China's standard of living is increasing dramatically and there isn't enough seafood around to meet that demand."

But, he says, aquaculture could still be part of the solution.

THE TRAVELING ORNAMENTAL DEFENDER

BY NATHAN GILLES

Eric Rasmussen

Veterinarian Tim Miller-Morgan is on a mission to help the ornamental fish industry

On the dark muddy waters of the Rio Negro, the Amazon River's largest tributary, aquatic veterinarian Tim Miller-Morgan finds his temporary home and transportation for the fortnight ahead. It's a two-story riverboat that looks like it came straight out of Fitzcarraldo, *the epic film about an ill-fated, but nonetheless triumphant, Amazon expedition sprinkled with allusions to Joseph Conrad. This fact isn't lost on Miller-Morgan and his companions; they make light of the ominous boat and their own impending expedition by joking about the thematic connection. But their Amazonian journey will be more heartfelt than another* Heart of Darkness. *Over the next two weeks, Miller-Morgan and his companions will travel 500 miles up the Rio Negro with Projeto Piaba (motto: "Buy a fish, Save a tree!"), a nonprofit created to encourage the ecological catch and transport of Amazonian fish destined for private and public aquariums.*

"The idea was to evaluate the health [of the fish] at each stage of the chain of custody," says Miller-Morgan, reflecting on the Rio Negro trip from his office at the Hatfield Marine Science Center (HMSC) in Newport, Oregon.

Miller-Morgan's specialty is aquatic medicine and health management among fish and invertebrates. He's the Oregon Sea Grant Extension veterinarian as well as the clinical veterinarian for all aquatic animals at Oregon State University (OSU). He leads HMSC's Aquatic Animal Health Program and teaches aspiring aquatic vets the trade's ins-and-outs. But outside OSU, he's best known for his extension work with ornamental fish. This work has included researching the koi herpes virus (see sidebar) and examining how wild-caught fish are handled en route to the aquarium. He did this in the Amazon, where he met with local fishers and traders to help improve their husbandry techniques, and in the past two years alone he's also traveled to India, Japan, Singapore, Indonesia, Israel, Malaysia, and Norway to talk with hobbyists, business members, and professional aquarists about their ornamental fish.

The global ornamental fish trade is a huge but often forgotten piece of world aquaculture, worth about $15 billion annually. Yes, that's fish for public aquariums and private hobbyists: 6,600 separate species, freshwater and seawater, raised and caught, fish and invertebrates, traded in 100 countries. And while Miller-Morgan says that, overall, the industry is very conscientious about the living creatures they deal in, occasionally—sometimes at their own request—they need help to make things better. This was the case with one of the bigger changes Miller-Morgan helped make happen: the slow but steady improvement in how wild-caught fish are handled.

Ornamental origins

In 1999 Miller-Morgan was an OSU graduate student working at HMSC's Aquarium and the Oregon Coast Aquarium. As he tells it, he kept receiving calls from ornamental fish owners and businesses that were interested in having Oregon Sea Grant (OSG) get involved in the industry. That same year, the industry held its first Marine Ornamentals Conference in Hawaii. Miller-Morgan sensed the potential of the unprecedented meet-and-greet and decided OSG needed to attend.

"I thought, 'Well, it's Sea Grant, so maybe the Marine Ornamentals Conference would be the way to get into that [involved in the industry]," he says.

He pitched the idea to OSG, which approved his first travel expenses.

It was in 2001, at the second Marine Ornamentals Conference, that Miller-Morgan first met representatives from Sea Dwelling Creatures. They told the veterinarian that they were interested in improving how their animals were shipped and cared for. Miller-Morgan said he would be glad to help.

Catching beauty

Fishers catch them off the coasts of Indonesia, Sri Lanka, Fiji, and the Philippines. They're green chromis, coral beauties, and clownfish, among others. The fish are taken to traders and suppliers, who pack the living gems in thick plastic bags filled with water. They are then air-shipped to their destinations; within 24 hours they can be anywhere in the world. In Sea Dwelling Creatures' case, it's their Los Angeles, California, warehouse.

Miller-Morgan's work at Sea Dwelling Creatures' warehouse began in 2003, when he and six other OSU researchers, with OSG's help, began examining the business's shipping and husbandry practices. The project also included Hollywood Aquarium, which is based in the Portland, Oregon, suburb of Lake Oswego.

Two young *piabeiros* (ornamental fishers) collect cardinal tetras in a small tributary of the Rio Negro in Brazil.

In Miller-Morgan's own words…

"The goal of much of this overseas work is to help ensure that better quality fish are imported into Oregon's local fish shops and to provide a more international perspective to the local fish retailers and hobbyists. In fact, on a number of these trips I have been accompanied by owners of local retail and import facilities as well as hobbyists. For example, the trips to Japan were with Tony Prew, owner of All Japan Koi in Hillsboro, who invited me to travel with him and assess health management on the Japanese farms. The other individual is Eric Rasmussen, owner of World of Wet Pets, in Portland. He accompanied me to Singapore, Malaysia, and the recent trip to Brazil. He provided the very important perspective of the local retailer and the end user to the exporters and fishermen in these countries. Local hobbyists and retailers are typically very disconnected from the international aspects of the industry. My travels and the ability to have local retailers and importers accompany me allow us to bring this international perspective back to the end users and aid them in understanding the broader issues in the trade that extend beyond just the price of the fish."

Edith Ploeg

Eric Rasmussen of World of Wet Pets, Portland, Oregon; Miller-Morgan; and WanLyn Cheah from Greenly Aquaculture, Jahor, Malaysia, collect ornamental fish in a jungle stream, Malaysia.

> In Indonesia, [Miller-Morgan] learned that his suspicions were correct: fish weren't being handled properly before leaving the country.

Scott Lapham

Miller-Morgan carries out fish health assessments on wild-caught marine ornamental fish at an export facility in Bali, Indonesia.

At the two facilities, the OSU group examined the skin and gills of the recently shipped Indo-Pacific fish. The researchers looked at the water the animals were shipped in. They gathered tissues samples and performed biopsies. They looked for bacteria in the animals' kidneys. And while collecting all this data, they also trained facility staff to refine their health and husbandry practices.

All told, Miller-Morgan and his fellow researchers looked at more than 400 fish. They saw animals that had undergone trauma, some that had preexisting conditions such as parasitism and bacterial infections, and others that were "dead on arrival." These results surprised them.

"One of the big concerns was that the shipping was a huge stressor," says Miller-Morgan. "We really didn't find that in our work." Instead, he says, most of the problems his group saw hadn't happened in shipping or at the warehouse, but in the countries from which the fish originated. "That made us want to do further work and look at the fish back up the chain of custody," he says.

So Miller-Morgan, with Sea Dwelling Creatures' consent and enthusiasm, worked his way back up the supply chain. This took him to Indonesia, where—as he would do in the Amazon years later—he met with fishers and traders. In Indonesia, he learned that his suspicions were correct: fish weren't being handled properly before leaving the country. He discovered that some animals hadn't been fed when they should have been. He found that the shipping water was often of poor quality and not the right temperature. He also concluded that many of the problems he saw could be easily changed with some simple adjustments.

In the years that followed, Miller-Morgan set up a series of training programs that would help reform the supply chain, from the fishers to the sellers. His group also helped train staff at both Sea Dwelling Creatures and the Hollywood Aquarium in animal husbandry techniques, which at one facility led to a 35 percent reduction in in-house mortalities and a 10 percent reduction in "dead on arrivals."

Today Miller-Morgan estimates he has helped build roughly 30 training programs, for industry members, hobbyists, veterinary students, and professionals alike.

Over all, Miller-Morgan says he's very encouraged by the ornamental fish industry's desire to do the right thing and improve its husbandry practices. And, he says, he's seen a steadily increasing concern for animal welfare, one that corresponds to higher profits for the industry.

"It's animal welfare," he says, "but it's also providing a higher quality product…and people will pay for better fish."

Reflections

Today, Miller-Morgan's Newport office is filled with souvenirs and placards from the places he's been and the training and research projects he's participated in. There's a pewter camel figurine from Dubai, ceramic koi from Japan, and awards, lots of them. He says there's still a lot the ornamental industry should do. One of his more recent research projects noted that some industry members and hobbyists were overusing antibiotics, which leads to antibiotic-resistant bacteria that have the potential to jump the species gap from animal to human. "Kind of disturbing," says Miller-Morgan. However, he says, on the whole, the industry is changing for the better, even if that change is often slow. As to his role in that change, he's modest.

"I've seen changes based on the things we've done and the papers we've put out. But we have a lot more work left to do."

SAVING BEAUTY: researching the koi herpes virus

Early 2004 saw a high-water mark for the koi herpes virus (KHV). A strain of herpes in the same viral family as the human venereal disease, KHV was wreaking havoc on ornamental carp the world over. If an infected animal was introduced to a koi pond, within 14 days as much 95 percent of the majestic animals could suffer a gruesome end that included severe damage in the gills and lesions on the scales. And like its human-affecting cousin, KHV can lie latent in animals that otherwise appear healthy, which can lead to a steady subterranean propagation. Yet in 2004, not a lot was known about KHV. But that's changed.

In 2008, OSU aquatic veterinarian Tim Miller-Morgan—who had worked with koi hobbyists, via the Associated Koi Clubs of America, and with industry members to get a handle on KHV—lent his veterinary skills to OSU veterinarian and virologist Dr. Ling Jin, graduate student Kathleen Eide, and several others studying the disease. The researchers discovered KHV DNA in the brains, eyes, kidneys, and other organs of otherwise healthy koi, proving that, like other forms of herpes, KHV was a latent disease able to lie dormant in healthy-looking animals. Miller-Morgan says Jin and Eide's work has made his job as a veterinarian on the frontlines of the disease a whole lot easier. The researchers' work has led to the development of enhanced screening methods—things like sampling water and fecal matter, instead of the more-invasive methods of the past—and that makes life a little easier on the koi.

Tony Prew, All Japan Koi, Hillsboro, Oregon; and Rodger Meyer, a koi hobbyist from Portland, Oregon, examine some beautiful koi at Konishi Koi, a high-end koi retailer and farmer in Hiroshima, Japan.

Photos this page: Tim Miller-Morgan

Aquaculture in Oregon: a look back, and a look ahead

Aquaculture is a kind of water-based farming in which aquatic animals and plants are cultivated in natural or artificial freshwater, saltwater, or brackish environments. The practice, in its crudest form, likely evolved independently in several places around the globe, but most scholars credit early Chinese societies with the first documented aquaculture practices, beginning about 4,000 years ago. Today, China accounts for nearly 65 percent of world aquaculture production annually; the United States, only about 1 percent.

America's first aquaculture operations began in the 1850s with the development of techniques to culture brown trout and carp, but it took another century before large-scale fish cultivation got underway. Aquaculture in Oregon also has roots from the 1850s, when schooners began to visit coastal bays to harvest the abundant and valuable native oysters and sell them in growing cities such as San Francisco and Portland. As the native oysters were depleted, oystermen gradually adopted cultivation methods to maintain and expand oyster harvests to keep up with demand.

Native oysters are now nearly gone from Oregon's coastal waters. A Japanese species commonly known as the Pacific oyster (*Crassostrea gigas*) makes up the bulk of the commercial-oyster harvest here. Oregon's coastal waters are usually too cold for these oysters to spawn naturally, so oyster growers buy spat (tiny juveniles) to seed their oyster beds. Young oysters grow rapidly to harvest size on the ample food supply in coastal estuaries—a process that takes from one to three years.

Peter Marbach, Farmers Conservation Alliance

Rearing pond for the Oxbow Fish Hatchery in Cascade Locks, Oregon. The hatchery raises juvenile salmon and steelhead.

Oysters do well in Oregon's estuaries. Currently they are under cultivation on twenty farms in Coos Bay, Winchester Bay, Yaquina Bay, Tillamook Bay, and Netarts Bay. Oysters are grown in a number of ways in an estuary: directly on the bottom, attached to stakes set in the bottom sediments, in trays suspended from floats, in bags attached to racks, in lantern nets, and on lines suspended from floats, racks, or floating docks.

Fish aquaculture, mostly in federal and state hatcheries, developed rapidly in the Pacific Northwest in response to declining salmon populations in the Columbia River system and other coastal rivers due to hydroelectric dams, habitat destruction, and increasing harvest pressure. Today the Pacific Northwest has the largest hatchery system in the world. Private salmon-ranching facilities also operated on Coos Bay and Yaquina Bay up until the 1980s, but there are no commercial salmon ranches functioning now on any of Oregon's estuaries.

Various kinds of fish, including trout, bass, sunfish, koi, catfish, and tilapia, are also cultivated on private, inland farms across the state, from Bandon to the Wallowa Valley. Oregon currently has two dozen private freshwater aquaculture farms that raise fish for food, pond stocking, or ornamental water gardens. Fish can be raised in ponds, raceways, or tanks, either outdoors or in greenhouses or warehouses. Some enterprising farmers are even raising marine shrimp and freshwater prawns in indoor tanks.

The total worldwide annual sustainable commercial harvest of aquatic species from the wild is estimated to be about 110 million tons. About two-thirds of this becomes human food, while the remainder is used for animal feeds, oils, and fertilizers. Wild harvest is not expected to expand because most stocks are currently fully or over-exploited. In 2011, world aquaculture production exceeded 66 million tons. Unlike the wild harvest, sustainable aquaculture production is expected to continue to expand. As a result, worldwide aquaculture production for human food may soon surpass wild harvest for the first time in human history.

Depending on technological advances, public acceptance or demand, legal issues, and our ability to preserve the integrity of our waters, aquaculture could hold some promise for the future in Oregon and elsewhere along the Pacific Coast.

Adapted from "Aquaculture in Oregon's Estuaries," by Kenn Oberrecht, who is also the author of Oregon Coastal Access Guide*, a co-publication of OSU Press and Oregon Sea Grant.*

Heat, serve, and enjoy!

A new line of seafood soups and sauces, developed by a Coos Bay entrepreneur with help from Oregon Sea Grant, is drawing raves from the U.S. specialty food industry.

Mike Babcock, owner of Sea Fare Pacific, learned recently that his new pouch-packed Seafood Bisque is one of 12 "Outstanding New Product" finalists in the 2013 sofi™ Awards, presented by the Specialty Food Association (SFA). Finalists in 32 award categories were selected from 2,573 entries.

The bisque is part of a new product line Babcock and his chef developed with help from Mark Whitham, the Sea Grant Extension product development specialist at Oregon State University's Food Innovation Center. Whitham had helped the young business perfect techniques for packaging fish and other seafood products in specially designed retortable pouches. Their collaboration was profiled last year in *Confluence* Volume 1, Issue 2.

The shelf-stable pouches can be processed in roughly half the time of conventional canning, resulting in seafood products with more nutrients and better flavor, according to Whitham. They also require less supermarket shelf space than cans.

Following an initial line of albacore tuna and sockeye salmon products that first shipped in October 2011, Sea Fare Pacific has continued to work with Whitham to develop additional products, including the new meal-in-a-pouch line of soups and sauces: West Coast Ciopinno, Smoked Salmon Chowder, Seafood Bisque; and three albacore curries: red, yellow, and green.

"These new products are pretty innovative," Babcock said. "The seafood protein is in the pouch—just heat, serve, and enjoy."

Bisque photo: Specialty Food Association

Dave Landkamer, sharing a "shellfish tale."

Oysters and the running man

What do farmed oysters, running, and Japanese candy have in common? They all came together for an unusual confluence near the finish line of the Newport Marathon this year, where Sea Grant Aquaculture Specialist Dave Landkamer told an unexpected shellfish tale.

The Newport Marathon, a full marathon of 42.195 kilometers (26.2 miles), has a very unique, bivalve component incorporated into the course. At miles 11 and 19 of the race, between aid stations that offer fruit and energy gels, runners can consume as many oyster shooters as they want when they shoot past the Oregon Oyster Farms on the Yaquina estuary. Rumor has it that last year, one contestant slurped more than 80 oysters during the race.

So how does Japanese candy figure into this story? In 1922, Ri-ichi Ezaki nursed his ill son back to health using glycogen extracted from oysters, and then went on to create a nutritious caramel candy fortified with oyster glycogen. He named his candy Glico—short for glycogen—and it subsequently became both the original flagship product and company name of one of the dominant confectioners in Japan.

Glycogen provides energy, and each individual Glico candy purportedly contains enough energy for the average person to run 300 meters (slightly under 1,000 feet). To promote the energy value of Glico candy, the company chose a running man as the logo for its packaging. Today and since 1935, the "Glico Runner" appears on a huge neon billboard (see accompanying photo) in downtown Osaka, where it has become a world-famous landmark.

If you had been at the Newport Marathon finish line, you could have sampled the Glico oyster candy, learned about those nutrient-dense oysters, and maybe even run 300 meters or so. Fortunately, even non-runners can still pick up fresh, nutritious oysters at one of the 20 shellfish farms along the Oregon coast.

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You can learn a lot more about the topics covered in this issue of *Confluence* by visiting seagrant.oregonstate.edu/confluence

Aquaculture...

- Information on our efforts to support sustainable aquaculture in Oregon
- Details about Oregon State University's Molluscan Broodstock Program (based at Hatfield Marine Science Center)
- A brief introduction to Oregon Sea Grant's aquaculture specialist, Dave Landkamer
- Online versions of the Oregon Sea Grant publications *Offshore Aquaculture in the Pacific Northwest* and *Development of Live Shellfish Export Capacity in Oregon*

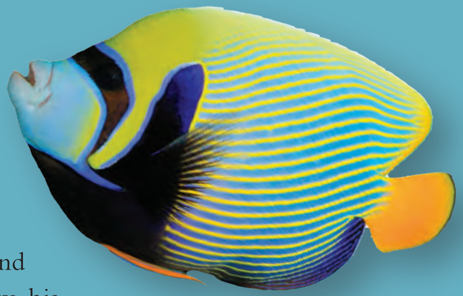
Ocean acidification...

- Learn more about George Waldbusser's Oregon Sea Grant–sponsored research into the effects of ocean acidification on oysters (and also about his work on the East Coast, in Chesapeake Bay)
- Watch Oregon Sea Grant's video, "What Is Ocean Acidification?"
- Read the *Terra* magazine article "Tipping Point: West Coast research consortium tackles ocean acidification"
- Learn about the work being done on ocean acidification by Oregon State University's Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO), a collaborative program in which Oregon Sea Grant participates

Fish and shellfish health…

- Find out more about current and past Oregon Sea Grant–sponsored research on *Vibrio tubiashii*, koi herpes virus, hypoxia, ecosystem resilience, and other issues related to fish and shellfish health

Ornamental fish…



- Visit the Oregon Sea Grant webpage for Tim Miller-Morgan to learn more about his work on behalf of ornamental fish and the ornamental fish industry, his involvement with the Aquatic Animal Health program, and his responsibilities as clinical veterinarian for all of Oregon State University's aquatic animal facilities

Seafood…

- Learn all about the OSU Seafood Lab, the OSU Food Innovation Center, and the Community Seafood Initiative
- Read Oregon Sea Grant's online seafood consumer guide, "What's Fresh and When," a handy, printable guide to Oregon's fresh seafood

Above:© iStockphoto.com/Rich Carey

Confluence (ISSN: 2165-0748) is published by Oregon Sea Grant, Oregon State University, 1600 SW Western Blvd., Suite 350, Corvallis, OR 97333. Phone: 541-737-2714. Web: http://seagrant.oregonstate.edu/

ORESU-O-13-001

This report was prepared by Oregon Sea Grant under award number NA10OAR4170059 (project number M/A-21) from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and by appropriations made by the Oregon State Legislature. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of these funders.