Margaret A. Pilaro
Executive Director, Pacific Coast Shellfish Growers Association
Written Testimony
Congressional Committee of Science, Space and Technology
"Sea Change: Impacts of Climate Change on our Oceans and Coasts"
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Oysters have been grown commercially on the West Coast since the mid-to-late 1800s, thriving in the brackish water found in the shallow, cool estuaries along the Pacific Coast. By the 1890s, oystermen were pulling 200,000 bushels a year out of the Puget Sound. But the boom was followed by bust, as over-harvesting and declining water quality decimated the native population of *Ostrea lurida*, or Olympia oysters. In the 1920s, as a way of saving their industry, the West Coast oyster growers began importing *Crassostrea gigas*, or Pacific oysters, from Japan. The Pacific oysters thrived, and oyster farmers began growing the species in large numbers. The shellfish industry continued to grow – beyond Washington, into Oregon, California, Alaska and Hawaii and in coastal areas around the US. It also grew beyond oysters to include clams, mussels, scallops, and geoduck.

Shellfish aquaculture provides economic opportunities for rural and coastal communities through harvests of healthy seafood products. Farming mussels, clams, oysters, and geoduck provides invaluable ecosystem services in coastal waters by improving water quality, removing excess nutrients, providing critical habitat for juvenile fish and invertebrates, and sequestering nitrogen. The most recent Census of Agriculture identified over 1700 shellfish farms - 240 along the West Coast and 1500 on the East Coast - producing nearly $300 million in annual sales and employing 1000's of people in mainly rural economically depressed counties.

But unlike the native Olympia oyster, the Pacific oyster was never able to reproduce quite as successfully in the wild—so in the 1970s, the shellfish industry began installing hatcheries along the Pacific Coast, in order to supply oyster farmers with the seed needed to sustain their businesses. In 1978, the Whiskey Creek Shellfish Hatchery set up shop next to Netarts Bay, five miles southwest of Tillamook, Oregon. A family-run business, it eventually grew to supply Pacific oyster larvae to 70 percent of the West Coast's oyster farms stretching from Canada to South America.

In 2007 two of the three largest shellfish hatcheries along the west coast, including Whiskey Creek Shellfish Hatchery, witnessed 70-85% mortality of oyster larvae. Hatchery employees immediately sought to determine the reason for these unimaginable results. They turned to bacteria or disease then learned of a research out of the University of Washington which linked changes in climate on coastal marine organisms. It became clear the carbonate concentration, compound essential for shell growth, was severely out of balance. High levels of $C0_2$ in water are correlated with developmental abnormalities, reduced fertilization success, slowed growth, and the precipitation of weaker thinner shells.

Shellfish farmers witness, first hand, the changing environmental conditions and weather patterns. They also encounter the related impacts to shellfish farming. All of these threats to the industry create hardship for shellfish farmers; added expense in equipment, additional testing,

uncertainty of harvest, and consumer confidence. The increase in frequency and duration of storms impacts the amount of time farmers can safely work on the water and increases challenges with maintaining gear. The increase of shellfish-related disease is also linked to changing climate, specifically rising temperatures. As the temperatures of coastal waters rise, harmful algal blooms (HABs) are more likely to occur. These blooms produce marine biotoxins that are poisons. Shellfish ingest the biotoxins, which remain in their systems, causing illness in humans who consume the infected shellfish. As shellfish adjusts to different conditions, it becomes stressed and more susceptible to naturally occurring bacteria, such as Vibrio, and shellfish-related disease such as MSX, Dermo, and Pacific Oyster Mortality Syndrome (POMS).

Shellfish growers are also starting to examine how increases of shellfish predation and increasing populations of organisms that prey on shellfish are to climate; and how shellfish may respond to growing at different depths and substrates if sea-level rise estimates are realized.

Today's shellfish farmer has incorporated review of real-time oceanographic data collected by NOAA's Integrated Ocean Observing System (IOOS) at its dozens of monitoring buoys and stations along the coast of the US. In addition to tides, farmers now base activities and farm management on salinity, temperature, and carbonate chemistry of the water.

The industry is also hoping to address climate-related impacts through genetics. Shellfish farming is a relatively new enterprise and it is based on stocks that have not been subject to intensive, long-term genetic improvements, like we have for wheat and cattle. With the assistance of genetics research programs at Virginia Institute of Marine Sciences, University of Rhode Island, University of Washington, and Oregon State University, the industry is hopeful to that genetics can play a critical, long-term, solution to developing disease-resistant lines.

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info@readthedirt.org

Oysters and Ocean Acidification

by: Pacific Coast Shellfish Growers Association: Margaret Barrette Posted on: January 06, 2012

By Margaret Pilaro Barrette, Executive Director for the Pacific Coast Shellfish Growers Association

Editor's Note: The Executive Director for the Pacific Coast Shellfish Growers Association takes us through her realization of the harm Ocean Acidification is doing to the oceans, shellfish populations, and a way of life for shellfish growers. Yet another reason to check our unfettered consumption of fossil fuels.

I am not a physical scientist. It's not that I don't "get" science, or that my palms get clammy when I hear about the scientific processes. I'm one of those people who when faced with something very scientific, is more interested in the "So what's that mean?" or "How's that going to impact people?" rather than the "Hey, how'd that happen?" I guess that makes me more of a social scientist.

About 18 months ago, I left my position at the WA Department of Natural Resources and began working as the Executive Director for the Pacific Coast Shellfish Growers Association (PCSGA). This organization has been around for over 80 years and is made up of shellfish farmers who produce oysters, mussels, clams and geoduck in Washington, Oregon, Alaska, California and Hawaii.

Within my first few weeks on the job, I attended the Association's annual conference –the first day of which was entirely dedicated to the topic of "Ocean Acidification". I was struck by all the long faces. I needed to learn more.

The learning process took me knee-deep into science. When water absorbs CO2 from the atmosphere, the CO2 is converted to carbonic acid. I learned that the water along the Pacific Coast is layered. The top layer is made up of "newer water", which comes from fresh water inputs like rivers and runoff. "Older water" is deeper in the water column and because of its age has absorbed more CO2 and carbonic acid making it acidic or corrosive, with a lower pH. During certain weather events, such as a north west wind, the older water "up-wells" or rises towards the surface, bringing with it higher concentrations of CO2 and acidic water.

At one time the oceans were thought to be essential in helping us deal with the rise of carbon dioxide in the atmosphere – capable of storing large amounts of CO2. Now we realize that the ocean's ability to store CO2 is impacting those that live within it. In the case of oysters, corrosive water makes the shells of oyster larvae dissolve faster than they can form. Oyster larvae need that early shell development in order to grow into a baby oyster "seed" and live a healthy life.

The folks at Whiskey Creek Shellfish Hatchery in Netarts Bay, Oregon first drew attention to this issue in 2007. At first they thought it was due to bacteria. Finding nothing, they turned to the pH levels of the water.

We now know that acidic water, with a low pH, is responsible for a significant decline in oyster larvae production at west coast shellfish hatcheries. It's also likely responsible for the lack of natural oyster recruitment in the Willapa Bay region, as spawning events have not naturally occurred there in the past six years. This change in the water is clearly responsible for all the long faces and defeated spirits I witnessed at my first shellfish growers conference.

The oyster industry contributes over $270 million to Washington's economy and supports 3,200 jobs. When places such as Willapa Bay don't experience naturally occurring oyster spawning events for six years, those working in the industry as well as all who enjoy eating shellfish, lose. Shellfish is a high-quality protein that is sustainably produced under the most comprehensive environmental laws in the world, such as the Clean Water Act, the Endangered Species Act. The

demand for Washington-produced shellfish far exceeds the supply and as we've seen with other American-produced products, foreign competition from China and New Zealand are standing by ready to fill the need. Importing foreign shellfish ignores the issue of Ocean Acidification, reduces jobs in rural communities, and introduces seafood into our markets that is produced without high standards for environmental sustainability or human health.

Acidic water (with low pH) kills Phytoplankton, a staple in the marine food chain and a major component of juvenile salmons' diet. Other marine organisms such as crabs, corals, and shellfish depend upon carbonate to build skeletons and protective shells. As the amount of available carbonate in marine waters declines with acidity, the health of these species is compromised. We're also learning that certain types of harmful algae blooms thrive in acidic waters. During such a bloom, the algae release toxins that can kill fish, mammals, and birds and can cause human illness. Impacts to marine species also translate to impacts to the overall health of the marine environment. Bottom line – Ocean Acidification is bad news for everyone.

Researchers and shellfish hatchery operators on both the east and west coast are trying to understand and adapt to the changing conditions. Thanks to funding obtained by the Pacific Coast Shellfish Growers Association, monitoring stations exist at the Whiskey Creek Hatchery as well as in Bellingham, Dabob Bay, Gray's Harbor and Willapa Bay. Among other things, these sites monitor for pH, temperature, salinity, and bacteria levels. By knowing the composition of the chemistry of the water, hatchery operators and shellfish farmers can adjust their schedules to work around times of low pH.

Unfortunately, Ocean Acidification can't be addressed through a single piece of legislation. In fact if we were to stop emitting carbon into the atmosphere today, we'd still experience acidic ocean water for decades. But we can bring attention to the issue and demonstrate the related impacts. Last spring, PCSGA hosted a Congressional Briefing on the issue of Ocean Acidification. We were joined by our colleagues from Maine to express need for continued research funding and support of federal programs that conduct marine monitoring.

Turns out you don't need to be a lab coat scientist to understand the basics of Ocean Acidification. You also don't need to be a social scientist nor a shellfish consumer to appreciate why it's bad. Chances are if you appreciate sustainably produced food, species diversity, and the many other values the marine environment provides, you probably want to pay attention to Ocean Acidification.

For more information visit NOAA's webpage and search "ocean acidification" or visit the following links:

http://www.oar.noaa.gov/oceans/ocean-acidification/index.html

http://www.pmel.noaa.gov/co2/story/Ocean+Acidification

Also, to learn more about how University of Washington is playing a role go to:

http://depts.washington.edu/coenv/news-blog/2011/11/23/featured-video-oyster-standoff-with-ocean-acidification-uw-360/

P.S. from the Editor:

For more on Ocean Acidification and its impact on the Great NW see the Sightline Institute's report on Northwest Ocean Acidification.

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2 Responses to "Oysters and Ocean Acidification"

- G'day Margaret Simplified the story of Ocean Acidification very nicely. I take issue to your implied comments on New Zealand's shellfish produced without high standards for environmental sustainability or human health. I'm an Aussie so its unusual I'd be sticking up for the Kiwis, but their environmental systems of production, and human health are world class, and having just finished visiting the US, Canada and Europe looking at shellfish production, I'd make the comment that this issue of Ocean Acidification and environmental influences on shellfish production is one that "we" as a global industry should be standing shoulder to shoulder on. The PCSGA does a great job uniting your growers together, and informing the public about the issues. Keep up the good work. Regards Ian Duthie
  by: **Ian Duthie**on: *Tuesday 6th of November 2012*
- ScienceDaily (May 12, 2008) — For members of the multimillion-dollar West Coast shellfish industry, their world is the oyster. Unfortunately, the oyster industry's ability to meet rising demands is hampered by two species of burrowing shrimp. So Agricultural Research Service (ARS) scientists are collaborating with colleagues from Washington State University and Oregon State University to develop sustainable shrimp-control strategies. Ghost shrimp and mud shrimp inhabit the tideflats in estuaries where West Coast oysters are raised. The shrimp burrow into the estuaries, making the intertidal mud soft and unstable. As a result, oysters and other shellfish can sink beneath the silty surface and suffocate. Brett Dumbauld, an ARS ecologist stationed in Newport, Ore., and his colleagues are uncovering information about the shrimps' habitats, life history and natural predators—information that can be used to help develop new methods to protect oysters from pests. ... http://www.sciencedaily.com/releases/2008/05/080509112525.htm
  by: **Dan**on: *Wednesday 28th of November 2012*

Impacts of Ocean Acidification on United States West Coast Shellfish Aquaculture and Adaptation Responses

Bill Dewey, April 2017

Oyster growers from Alaska to California on the west coast of the U.S.A. have struggled in recent years to find seed and oysters to keep their businesses viable. Scientists from the National Oceanographic and Atmospheric Administration (NOAA) and various Universities have linked the oyster seed losses to ocean acidification. Shellfish growers' understanding of what has caused these oyster seed shortages and their response to the issue have evolved in recent years through sea water monitoring and collaborative research.

From 2007 to 2009 U.S.A. West Coast shellfish growers experienced a severe oyster seed shortage. Oyster larvae production at two of the four major seed producing hatcheries declined by approximately 75% during this period. In addition to the drop in hatchery production there was no significant natural recruitment of larval oysters in Willapa Bay from 2006 through 2012. Willapa Bay is one of the largest oyster producing estuaries in the country and many oyster growers there rely on natural recruitment of Pacific oysters to seed their beds. These seed production failures had a real and profound effect on shellfish production.

In 2012, Washington State's Governor appointed an Ocean Acidification Blue Ribbon Panel to develop a response for the state. This diverse group of shellfish growers, business representatives, politicians, scientists and environmental nongovernmental organizations arrived at 42 recommendations for the state, which the Governor memorialized in an Executive Order for implementation. This response garnered international recognition as one of the first to address ocean acidification. In December 2015, through an effort of the Pacific Coast Collaborative the International Alliance to Combat Ocean Acidification (OA Alliance) was launched. The OA Alliance is providing collaboration and tools for countries and affiliates to combat changing ocean conditions.

Due to these initiatives, the West Coast oyster seed situation has improved. The outstanding response from policy makers and an unprecedented collaboration between University, agency and industry scientists has advanced knowledge of the problem dramatically in a very short period of time. Created by the Washington State Legislature in 2013, the Marine Resources Advisory Council is overseeing implementation of the Blue Ribbon Panel's recommendations. Also created by the Legislature in 2013, the Washington Ocean Acidification Center at the University of Washington is studying the effects of ocean acidification on the state's marine resources. Today, U.S.A. West Coast shellfish hatcheries have sophisticated monitoring equipment deciphering seawater chemistry as it is drawn from the ocean and automated systems treat the water to make it more conducive to oyster larvae survival.

In addition to the monitoring systems in the hatcheries equipment has been added to several buoys that are part of NOAA's Integrated Ocean Observation System (IOOS). This allows shellfish growers and scientists to understand changes in the ocean's carbonate chemistry around the hatcheries and farms. Five of the IOOS regions in the Pacific Ocean have linked to provide one data portal (IOOS Pacific Region OA data Portal - www.ipacoa.org) that serves data from all five regions. This data portal streams live real-time data from various government, academic and Native American facilities and buoys including five major West Coast shellfish hatcheries. Beyond the outstanding monitoring collaboration in the United States the Global Ocean Acidification Observing Network (GOA-ON, http://www.goa-on.org/) is working to gather and exchange ocean acidification data internationally.

Submitted as part of written testimony for Margaret Pilaro, February 27, 2019

As a result of these responses the production has improved, at least temporarily for shellfish growers. Hatchery production has largely recovered and ocean conditions have resulted in some limited natural oyster seed recruitment in Willapa Bay since 2012. While oyster seed supplies have improved, they are still not adequate to meet all growers' needs.

What do West Coast shellfish growers know about ocean acidification that they didn't a few years ago?

Initial efforts to determine the causes of oyster larvae losses focused on the naturally occurring bacteria *Vibrio coralliilyticus* (initially misidentified at *V. tubiashi*). As it turns out these bacteria thrive in the water conditions created by upwelling off the West Coast. Filtration systems were designed and installed to eliminate the bacteria only to find the oyster larvae were still dying. In 2008 NOAA ocean acidification experts informed shellfish growers that the likely cause of the oyster larvae deaths was changing seawater chemistry resulting from the ocean absorbing anthropogenic carbon dioxide.

The ocean absorbs approximately 30% of all anthropogenic carbon dioxide emitted into the atmosphere. This results in the formation of carbonic acid which reduces the ocean pH making it more acidic. Since the industry became aware that ocean acidification may be the cause of the hatchery issues operators with the help of university scientists have identified the availability of carbonate ions as most critical. They are the building blocks for the oyster shells and carbon ion availability diminishes as the ocean acidifies.

The carbon dioxide from 250 years of burning fossil fuels has made the ocean surface waters 30% more acidic and reduced the availability of carbonate ions by 16%. By the end of this century scientists predict the acidity of the ocean surface waters will have increased by 100-150% and reduced carbonate ion availability by 50%. A more troubling message for shellfish growers from the experts studying ocean acidification is that the water currently upwelling off the U.S.A. West Coast is 30-50 years old. So even if carbon dioxide emissions were curtailed today the waters along Washington State's coast will continue to get more acidic for decades to come because of the residual effects of carbon dioxide already absorbed by the Pacific Ocean.

Shellfish growers have now come to understand through monitoring and research that natural factors associated with summer upwelling off the U.S.A. West Coast can result in ocean chemistry conditions detrimental to the development and growth of oyster larvae. Research suggests these conditions occurred about 11% of the time prior to the industrial revolution. Corrosive events for oyster larvae are now happening an estimated 33% of the time and are more severe when they occur.

Taylor Shellfish Farms has a second hatchery in the State of Hawaii where they haven't experienced the same ocean acidification related problems. As an additional adaption response to larval failures in their Washington State hatchery the company has expanded production capacity at the hatchery in Hawaii. In 2012 another Washington State shellfish farming business, Goose Point Oyster Company started up a hatchery in Hawaii in also in response to the West Coast oyster seed shortage.

Currently West Coast shellfish growers seem to have found a temporary solution to the impacts of ocean acidification by treating hatchery water to restore larval production. Juvenile and adult oysters on farms in the estuaries have not yet been visibly impacted. Growers expect under worsening ocean conditions that shellfish in the nurseries and on beds will eventually be impacted as well. Unlike in the hatcheries there is no way to control the seawater chemistry over thousands of acres of beds in the ocean. To address this vulnerability the University of Washington and Oregon State University are working with shellfish growers to determine if selective breeding may yield oysters that can tolerate reduced levels of carbonate ions. Research is also underway to see if culturing seaweed together with shellfish or culturing

shellfish in or around seagrass beds be may provide refuge for the shellfish in an increasingly acidic ocean by naturally reducing carbon dioxide concentrations and increasing carbonate ion availability.

All these actions demonstrate ways in which the shellfish industry is adapting to changing seawater chemistry.

What can be done to improve the environment for the shellfish industry?

As mentioned above, the response from policy makers and scientists to date has been proactive and effective. Washington State's Governor and Legislature continue to fund the Marine Resources Advisory Council and the University of Washington's Ocean Acidification Center.

The science on ocean acidification is rapidly evolving and having a coordinated review and response by the Marine Resources Advisory Committee is critical. Efforts to expand this coordination throughout the West Coast are underway and similar efforts are being undertaken on the east coast of the United States. Continued monitoring and the development of predictive models is also key for managing the adaptation response.

It is important to remember the impacts of ocean acidification extend well beyond shellfish. They are just one of many calcifying organisms in the ocean likely being effected by changing ocean chemistry. In addition, scientists are finding other detrimental impacts beyond calcification. The governance, coordination and adaptation responses for the west coast shellfish industry[1] can be applied to other aquaculture ventures and fisheries that face similar climate change impacts.

Bill Dewey is Director of Public Affairs for Taylor Shellfish Farms. Based in Shelton, Washington USA, Taylor is the largest producer of farmed shellfish in the United States. Mr Dewey also owns and operates his own clam farm in Washington. He served on governor Gregoire's Ocean Acidification Blue Ribbon Panel and serves today on Governor Inslee's Marine Resources Advisory Council which advises Washington State's ocean acidification response.

[1] To learn more about Washington State's response to ocean acidification go to: http://www.ecy.wa.gov/water/marine/oceanacidification.html. To learn more about what individuals can do in response to ocean acidification go to: http://wsg.washington.edu/our-northwest/ocean-acidification/