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June 3, 2014

Testimony of Daniel Cohen to Subcommittee on Green Jobs and the New Economy of Senate Environment and Public Works Committee

Thank you for the opportunity to address your committee as you evaluate the impact of climate change on our environment and livelihoods. These are important issues for society to grapple with. The choices we collectively have made and will make over the coming years regarding these issues will impact the quality, security, and lifestyle of our children and subsequent generations. The fishing and aquaculture industry of the US, especially the shellfish industry, are extremely susceptible to increases in ocean temperature and ocean acidification. Like “canaries” in the coal mine, our shellfish aquaculture industry has already been significantly harmed and are a harbinger of the unintended consequences of human use of fossil fuels and CO2 increases in our atmosphere and oceans, which have resulted in increases in ocean temperature and ocean acidification.

I am Daniel Cohen, President of Atlantic Capes Fisheries, Inc. I am second-generation in the fishing industry and have spent the past forty years building a vertically integrated commercial fishing enterprise. Beginning as wild fishermen and purchasing my first fishing vessel in 1978, today we operate 23 vessels, primarily on the East Coast, from the Canadian line to North Carolina. We operate offloading facilities in Maryland, New Jersey, and Massachusetts and harvest and process scallops, clams, and crabs in Massachusetts and Rhode Island.

Over the past 40 years I have spent a significant portion of my time in public roles working with fisheries managers on the state and federal level as well as working with academia to pioneer and implement collaborative research in fisheries. I am the Chairman of the NFI-Scientific Monitoring Committee, which in conjunction with the Mid-Atlantic Fisheries Management Council, raises over $1million dollars annually from the fishing industry of the Mid-Atlantic to pursue collaborative research with the National Marine Fisheries Service and academic institutions such as Rutgers University, Virginia Institute of Marine Sciences, Cornell University, and others. My company is a founding member of the first and only National Science Foundation funded science center combining the fishing industry, NOAA-NMFS, and academia – co-chaired by Southern Mississippi University and Virginia Institute of Marine Sciences.

Atlantic Capes Fisheries, Inc. is primarily a wild harvest commercial fishery whose main dollar value and volume consists of East Coast Sea Scallops, Surf Clams, Fluke, Squid, and Sea Bass.

About 15 years ago, recognizing that wild fisheries would be capped to assure the public that wild capture fisheries harvests were sustainable and renewable, we began our first efforts in shellfish aquaculture. With a rising world population (then 6 billon, now 7 billion, and projected soon to be 9 billion) wild sustainable fisheries could not and will not be sufficient to meet the public's demand for protein. Raising shellfish as a form of farming can be an environmentally friendly and efficient source of protein for the public.

Rutgers University had been developing disease resistant strains of east coast oysters in an attempt to rebuild oyster populations that had been decimated in the 1950's by two diseases. At the request of Rutgers University we began the first demonstration oyster farm in New Jersey using hatchery raised oysters and employing the French "bag and rack" method of oyster farming. Our Cape May Salt Oysters have been commercially successful and are now served in fine restaurants, including here in Washington, DC. In 2011 we expanded our shellfish aquaculture by investing in the largest operating commercial scale sea scallop farm in North America, located in Qualicum Beach on Vancouver Island, British Columbia.

Today I want to briefly introduce you to the changes occurring in our oceans which are having and will have in the future significant impacts on our economy, jobs, food supply, and quality of life. These impacts relate to:

1) Increases in ocean temperature, which most scientists attribute to climate change from greenhouse gasses warming the atmosphere;
2) Increases in ocean acidity due to the increases in carbon dioxide in the atmosphere ending up in our oceans and measured as the partial pressure of CO_2 (pCO_2); and
3) Changes in ocean currents and upwelling which scientists believe are being caused by changes in ocean temperature.

While the impacts are broad and effect the entire marine environment, I have assembled a few specific examples to provide to you a broad picture of the types of impacts and potential responses that we as commercial fishermen, shellfish farmers, and society face. The examples that I will use are:

1) Surf clam fishery on the East Coast;
2) Oyster hatcheries and farming in Oregon and Washington;
3) Scallop farming in British Columbia; and
4) Fluke fishery from North Carolina through Rhode Island.

I will conclude with a short introduction to an adaptive response to our society's energy and climate issues, which I am personally leading on the East Coast.

The surf clam fishery was historically centered off the coast of Virginia up through New Jersey. With a robust inshore New Jersey fishery, New Jersey landed more than 50% of the entire surf clams in the country. Surf clams are the primary ingredient in clam chowder and are also enjoyed as breaded clam strips. As outlined in the Wallace & Associates summary that I have included with my testimony, surf clams are an ideal candidate to observe the negative impact of bottom temperature change, since they are sedentary non-migrating animals (while fish have tails and can swim). The first real indication of a problem in the surf clam fishery was identified in a tri-annual NOAA-NMFS survey of clam populations which identified an unexplained significant die-off of surf clams off the coast of Virginia. Research funded by the clamming industry and conducted by Rutgers University and the Virginia Institute of Marine Sciences determined that the die-off was due to changes in bottom ocean temperature that made the environmental niche in the area untenable for surf clam survival. Subsequent die-offs of inshore New Jersey surf clams followed this trend. Further, temperature related changes in surf clam populations have resulted in an increase in surf clam populations in the cooler waters off the coast of Massachusetts. The impact has not only been to the animals. Surf clam processing plants have closed in Virginia, Maryland, and New Jersey with a loss of jobs, while, at the same time, new plants have opened in Massachusetts….a migration of jobs following the movement of bottom temperature and the increase of the clam resource in New England's cooler waters and the decrease in population in the Mid-Atlantic due to bottom temperature rise.

The Pacific Northwest is home to the largest hatchery based oyster industry in the US. This hatchery based industry grows Pacific Oysters to augment wild harvests. As outlined in a white paper that I have included with my testimony is the work of George Waldbusser, Professor at Oregon State University. Professor Waldbusser findings indicate that the hatchery industries of Oregon and Washington State lost at least $110 million dollars due to ocean acidification. The oyster industry must continue to be negatively impacted by rising levels of ocean acidity because juvenile shellfish are impeded in establishing their shells in a more acidic environment. The hatcheries in the Pacific Northwest have adapted by "buffering" their hatchery and nursery waters, the equivalent to using "Tums" to buffer an acidic stomach. Although buffering can be done in a controlled hatchery to a limited extent, we can't buffer the entire ocean.

In 2013, British Columbia scallop farmers growing hatchery reared sea scallops experienced a 90% mortality of three year classes during grow-out in the ocean. In full disclosure this includes a $10 million loss experienced by my company in our British Columbia scallop farm. High levels of pCO2 (ocean acidity) were measured in the ocean waters at the same time. While the actual cause of the mortality has not be determined with 100% accuracy by the scientists, the hypothesis is that ocean acidity weakened the animals thereby making them more susceptible to endemic and underlying disease. I have included in my written testimony an October 2013 Power-point presentation in which the Pacific Northwest and British Columbia shellfish industry have banded together with the Indian Native Bands (who have invested in shellfish aquaculture) to seek Canadian government, US Government, and / or NGO funding to undertake a multi-year genomic program to develop heartier and more resistant broodstock that will be adapted for survival in a more acidic ocean environment. To date that funding has not been secured and the future of this nascent industry is in question.

My last example is the East Coast Fluke fishery, as highlighted in a technical article to be released publicly today by the Daily Climate, written by Marianne Lavelle, and attached as part of my written testimony. As outlined in the article, and documented by NOAA and NMFS studies, the center of the bio-mass of summer flounder, an important commercial and recreational fishery, has been slowly migrating north as bottom temperatures have been slowly but continually warming. While the fluke stocks are healthy and fully rebuilt, due to sustainable management by the Mid-Atlantic Fishery Management Council, the movement in their geographic distribution has increased conflict between commercial and recreational fishermen as well as created conflict in the state by state allocation of the fishery. Diesel fuel, a non-renewable resource consumed by vessels which must steam further north to catch their fish, is being wasted to deliver the fish to southern ports. The change in spatial distribution is causing societal conflict over access and allocation of this valuable and important resource. Again, this is a harbinger of things to come in other fisheries and resources, unless we can somehow stop the current changes in use of fossil fuels and the creation of greenhouse gases.

I want to conclude by outlining one adaptive change the fishing industry has undertaken to help address these issues. On the East Coast I am one of the founders of a company formed by East Coast fishing industry leaders to propose and build offshore windfarms. While opposed to built structures in the ocean these fishing industry leaders banded together to be agents of change rather than victims of change. Seeing firsthand the impact of climate change on their businesses, and being concerned with solving energy issues for future generations without reliance on fossil fuels, Fishermen's Energy began in 2008 to propose to build a demonstration offshore windfarm off the coast of Atlantic City. On May 7th of this year the US Department of Energy announced that the team lead by Fishermen's Energy was awarded a $47 million Grant to help build a $200million windfarm off the coast of Atlantic City. Fishermen's Energy hopes to build this first project in 2016.

As I have outlined in my verbal and attached written testimony, the changes in ocean temperature and ocean acidity are real. Their impacts are real. Without a concerted collaborative effort between the fishery / aquaculture industry, academia, and government our marine food supply is threatened. How will we feed 9 billion people? Only with a well-funded and well thought out adaptive response, species by species, environmental niche by environmental niche, can we assure success. We have significant challenges ahead. Will our industry, government, and NGO communities rise to this collective societal challenge? Our children and future generations are dependent upon how well we collectively respond to these challenges.

Thank you,
Daniel Cohen

WALLACE &
ASSOCIATES

May 28, 2014

Mr. Daniel Cohen, President
Atlantic Capes Fisheries
Cape May, New Jersey

Re: Effects of warming ocean temperature of Atlantic Surf Clams in the North Atlantic

Dear Mr. Cohen,

Ocean temperatures on the East Coast of the United States from North Carolina to the Canadian border have increased by about 1°-2° C over the last 20 years according National Marine Fisheries Service's, Northeast Fishery Science Center, document titled, "Description of the 2008 Oceanographic Conditions on the Northeast U.S. Continental Shelf" (Reference Number; Document 09-12).

Surf clams are bivalves that are naturally occurring in the marine waters of the continental shelf off shore of the northeast United States in large numbers. They are commercially valuable and are one of the highest populated marine species of the northeast region. Surf clams live approximately 25 years and are found in temperate waters from the coastal shore to about 120 feet of water depth in the ocean.

The surf clam landings from all areas in 2013 were about 2.6 million bushels with an ex vessel landed value of more than 40 million dollars and total value of the, value added products. of more than 450 million dollars, and providing an estimated 1900 jobs.

Surf clams are water temperature sensitive in all life stages. From the time they are free swimming larvae to where they settle and grow to adults. Because they are bivalves they do not move more than a few hundred feet in their life time. Therefore, they are good barometers for understanding changes in the ocean environment, particularly water temperature.

As the water temperature increases on the continental shelf, this causes the surf clam population to migrate slowly to deeper colder water and move further north. In Virginia a large beds of surf clams died because of warmer water and the reduction of plankton, their food source.

Other beds of surf clams died off as far away as the inshore beds in northern New Jersey, with warm water being the primary factor according to a group of studies by Eric Powell from Rutgers University and Roger Mann from Virginia Institute of Marine Sciences which were directly funded by the surf clam industry.

There is evidence that the surf clam population is being effected in all life stages by warmer ocean temperatures. The young are having a difficult time developing to young adults in the Mid-Atlantic because of the lack of food and warmer water temperatures. It appears that they are being stunted in growth because there food source is limited by the change in the environment. Older adults are not growing to the size that their ancestors 25 years ago and their body weight is also less...

Why are these observations important to the surf clam population? Water temperature is having a profound effect in the physiology of the population and is also affecting the plankton population which is the food source for the surf clam population. There is scientific evidence there may be an effect on the very young adults to create shell material necessary to make the transition from a free swimming larvae to a sedentary animal because of the changes in the pH or ocean acidification. The acidity of the ocean is increasing because of the greater amount of carbon dioxide (CO2) in the atmosphere.

The surf clam fishery historically has operated in the Mid-Atlantic region. Now the fishery and the industry that supports it is moving northward. This is because as the water temperature increases, the surf clam population at the southern end of their range has drastically been reduced because of warmer water temperature and a lack of food supply. This has effected both the off-shore surf clam stocks and populations in the inshore waters of New Jersey and New York. The surf clam population inshore New Jersey has being adversely effected by the population collapse with the preponderance of evidence that the problem is temperature related. In New York State the surf clam population is not as stressed as in New Jersey but there are signs that the animals are under pressure demonstrated by slower growth and lighter body weight. This demonstrates that the population of surf clams are moving further offshore to deeper cooler water and further to the north.

The clam processing industry that removes the clam meat from the shell is also moving north where much of the surf clam landings are now takes place. Today a significant portion of surf clams are being harvested and processed in New England unlike ten years ago when all of the surf clam shucking plants were in Virginia, Maryland, Delaware and New Jersey.

There are changes in the surf clam population because these animals cannot move but their larvae will settle and grow in only an environment conducive areas to their life cycle requirements. The next generation of clams move from one area to another reacting to changes in the marine environment which is a slow but observable process over time. The more rapidly the environmental regime changes, the more it effects the environment required for the bivalve population to survive. The surf clam food source of plankton essential for their survival is marked by the change in temperature too. As the water temperature changes these species are found in areas that they did not occupy before and the older ones as they die are not being replaced where they traditionally were found.

I hope you find this information helpful.

Sincerely,

David H. Wallace

David H. Wallace

OREGON STATE UNIVERSITY
College of Earth, Ocean, & Atmospheric Sciences

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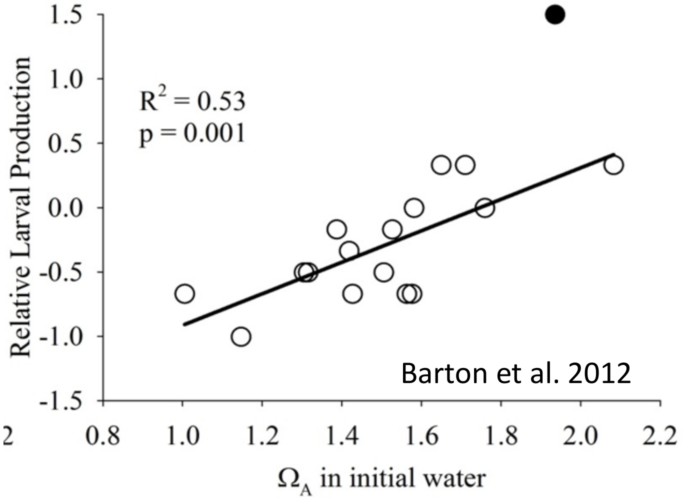
Background and Status of Ocean Acidification Impacts on Pacific Northwest Shellfish, with a particular focus on Oysters

The Pacific Northwest, and Washington State in particular, is one of the largest producers of oysters in the US. Oregon is the largest supplier of oyster seed to independent growers throughout the US West Coast. The annual economic impact (gate value) of the US West Coast Shellfish industry is estimated at approximately $270 million, and directly employees 3200 people in coastal areas where other employment opportunities are limited. This industry and these jobs are critical to the economic well-being of these coastal communities, and oysters make up the bulk of the shellfish production in the Pacific Northwest. The oyster seed crisis, as it has been called in the Pacific Northwest, resulted in a 22% decline in oyster annual production from 2005 to 2009, and a 13% annual decline in gross sales. The industry, prior to the seed crisis used to produce nearly 95 million pounds of oysters per year, this was reduced to less than 75 million pounds annually, by 2009. The economic impact over the seed crisis period has been estimated at $110 million in gate value, and this does not include economic multipliers or costs included to adapt to changing water chemistry

Starting in about 2005-2006, Whiskey Creek Shellfish Hatchery (Netarts Bay, OR) and Taylor Shellfish Hatchery (Dabob Bay, WA) began having significant production failures of Pacific Oyster seed. Both hatcheries are owned and operated by multi-generational shellfish growers, and both reported they had never previously encountered persistent failures of this scale and scope. The initial concern was a pathogen called *Vibrio tubiashii* that infects larvae in hatchery settings, and samples from the hatcheries indicated that the pathogen was present. At the Whiskey Creek Hatchery, a comprehensive water filtration system was installed in 2007; in 2008 failures continued but no *Vibrio* was found in the hatchery or in the incoming waters. Production failures in 2008 included month-long failures of larvae that generally occurred in the mid to late summer.

At the end of 2008, personnel began to link the failures to the upwelling of deep oceanic water, which led to the possibility that seawater with high levels of dissolved CO_2 (pCO_2) was to blame. In 2009, Oregon State University scientists began working with the Whiskey Creek Hatchery on the issue and were able to confirm that in fact elevated pCO_2 (low pH) seawater was the culprit. In fact, what was found was quite striking; exposure to elevated pCO_2 water during the first 48 hours of larval life could predict just over half of the variability in how much oyster seed the hatchery produced. And the waters did not have to be “corrosive” or even that high in pCO_2 for these effects to manifest.



The figure left shows the relationship between larval production and a measure of corrosiveness to the calcium carbonate mineral that larvae use to make their shell. Importantly, these are not experiments, this is real production and chemistry data from the hatchery. Values of saturation state below 1 are considered corrosive; however, even at values above 1, there are still sub-lethal losses of larvae. Each point on the graph represents one cohort of larvae in 2009, and a "relative production" value of 1 indicates that the cohort ended up with roughly the same biomass they started with. In other words, it would be akin to planting a cornfield, and having the same mass of corn at harvest that you started with as seed.

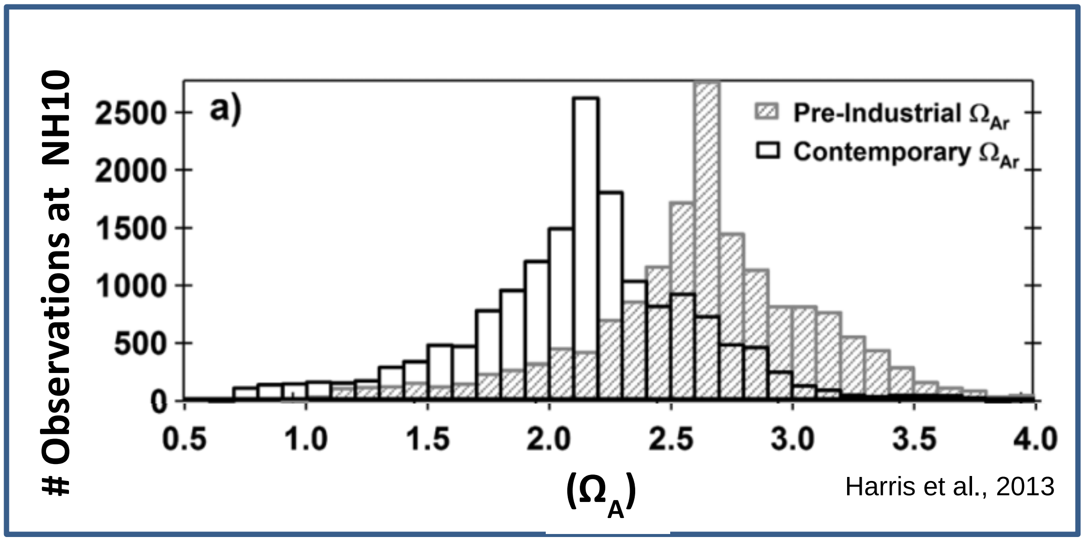
Through the installation of a real-time pCO_2 monitor, hatchery personnel noted they could take advantage of the daily inhale and exhale of Netarts Bay; by filling their culture tanks in the afternoon (after the seagrasses and phytoplankton in the bay have sucked up pCO_2), instead of morning, they were able to avoid the worst of the high pCO_2 water. This monitoring equipment prevented Whiskey Creek Hatchery, a hatchery that had historically supported roughly 70% of independent oyster growers on the US West Coast, from going out of business. The Washington Blue Ribbon Panel on Ocean Acidification estimated the total loss to the industry in gate value of $110 million.

Subsequent work on monitoring and adaptation has allowed the hatcheries to rebound, and restore a major production of their annual loss. Two of the three large commercial hatcheries in the US PNW are now taking the "Tums" approach, in which they are buffering all of the water coming into the hatchery. This coupled with a shift to a much earlier production season, has provided resiliency on the short-term to the oyster industry. One side effect of this buffering has been improved production of other shellfish, previously believed to be robust to OA. In the Taylor's hatchery, since the installation of their buffering system they have seen much improved survival of geoduck seed, as their shells are thicker and more able to withstand the outplanting than previously. Although they had not previously seen massive mortality, this is a classic example of a shifting baseline, where conditions change slowly enough that human perception generally does not notice the change.

The effects of ocean acidification are happening today, and can be seen in the following electron micrograph of Pacific oyster larvae raised in water at the Taylor's Hatchery (end of document). It has now been documented that under elevated pCO_2, larvae are unable to properly make their shells; they have a limited amount of energy to do so until they complete their first shell (and can begin feeding). In fact, for many of the failures that have occurred, larvae do actually appear for about a week, then they stop swimming, as they have run out of energy and cannot recover. Think neonatal nutrition. This is expensive for hatcheries, given that the larvae are essentially marked in the first 48 hours, then the actual response manifests seven days later. In that time the hatcheries are feeding cultured food to the larvae and heating seawater to support their growth.

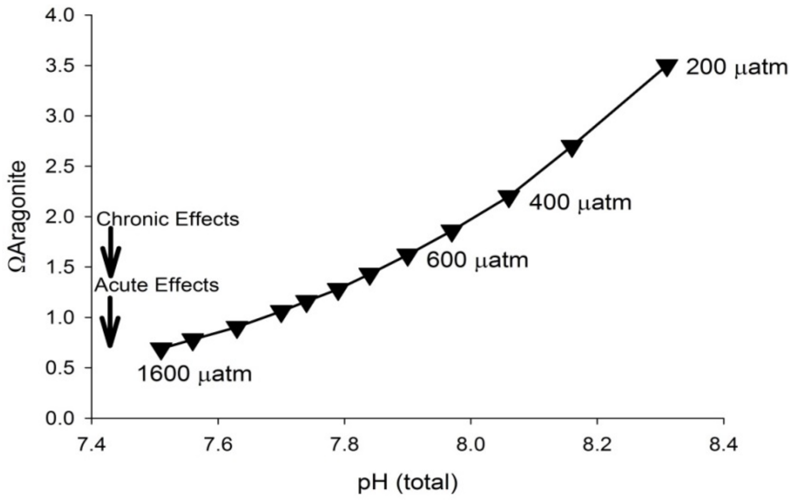
The question should arise of how come all of a sudden, in this region, did high pCO_2 impact oyster larvae? The Pacific Northwest has naturally elevated pCO_2 to begin with due to the upwelling of old, deep oceanic water. The best estimates indicate that this water last contacted the atmosphere 30-50 years ago, setting the current baseline CO_2 levels. Each year, as source water sinks, that baseline increases a little bit more, pushing conditions closer to important thresholds for oyster larvae and other sensitive species including other bivalves and pteropods (important food for salmon). In fact, estimates of the near-shore chemistry with the anthropogenic fossil fuel CO_2 removed indicate there has been a nearly 0.5 decrease in saturation state (that important measure of how easy it is to make shell material).

The graph below shows the distribution of observations just off shore Newport, OR, and what it would have been before the addition of fossil fuel. Importantly, the average conditions are quickly approaching the thresholds we now know are important for bivalve larvae, and Pacific Oysters in particular. A survey of the literature indicates that chronic, sub-lethal effects on bivalve larvae appear to begin when this measure of how easy it is to make shell material hits about 2.0. At about 1.5 we begin to see acute impacts on bivalve larvae.



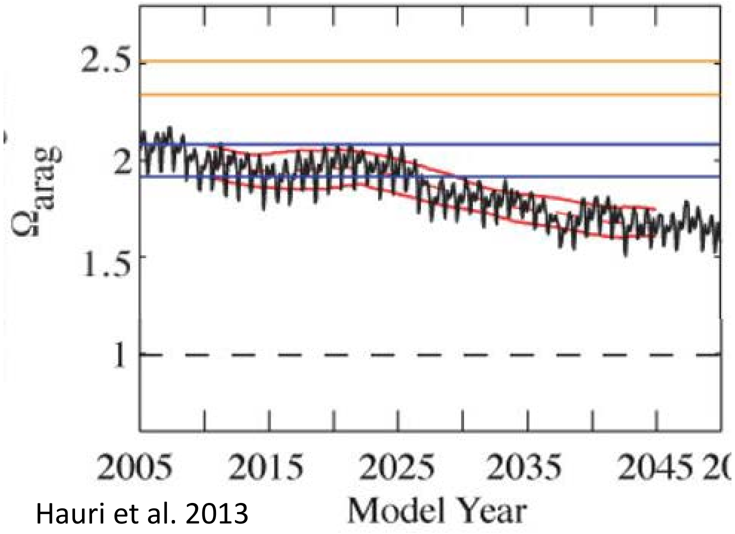
Harris et al., 2013

It is very important to note that these changes in saturation state do not translate into large changes in pH. The figure below is from a manuscript in preparation by Waldbusser *et al*. This shows the change in saturation state and pH relative to CO_2 for oceanic water typical of upwelling along the Oregon coast. The important point is that not much additional CO_2 results in decreases in saturation state that are critical to bivalve larvae, while pH hasn't changed in nearly as significant a way. The best current models suggest these levels will be outside of the present range in conditions within 20 years in the highly productive California Current Ecosystem. See below.



So where are we now? Shellfish hatcheries are being equipped with monitoring equipment, but need continued technical support staff to help ensure proper instrument operation. Buffering of water and timing of oyster seed production has shored up the seed production side, but significant questions remain regarding the timing of seed planting and fate of seed. Several growers have noted increasing mortality of seed planted mid to late summer. In fact, one major grower no longer plants seed after June in Willapa Bay, WA, as the seed almost always die. Although this corresponds to the major upwelling period in the PNW, we are just starting to get sensors in the water in these locations.

Many growers are planting oyster seed much earlier in the year, months before upwelling begins; however, food for oysters is also much more limited this time of year. We do not yet know if this is an issue, or if oysters can simply catch up when food becomes more available. If this is a problem, then there is a shrinking window of time when conditions will support planting of seed.



Hauri et al. 2013

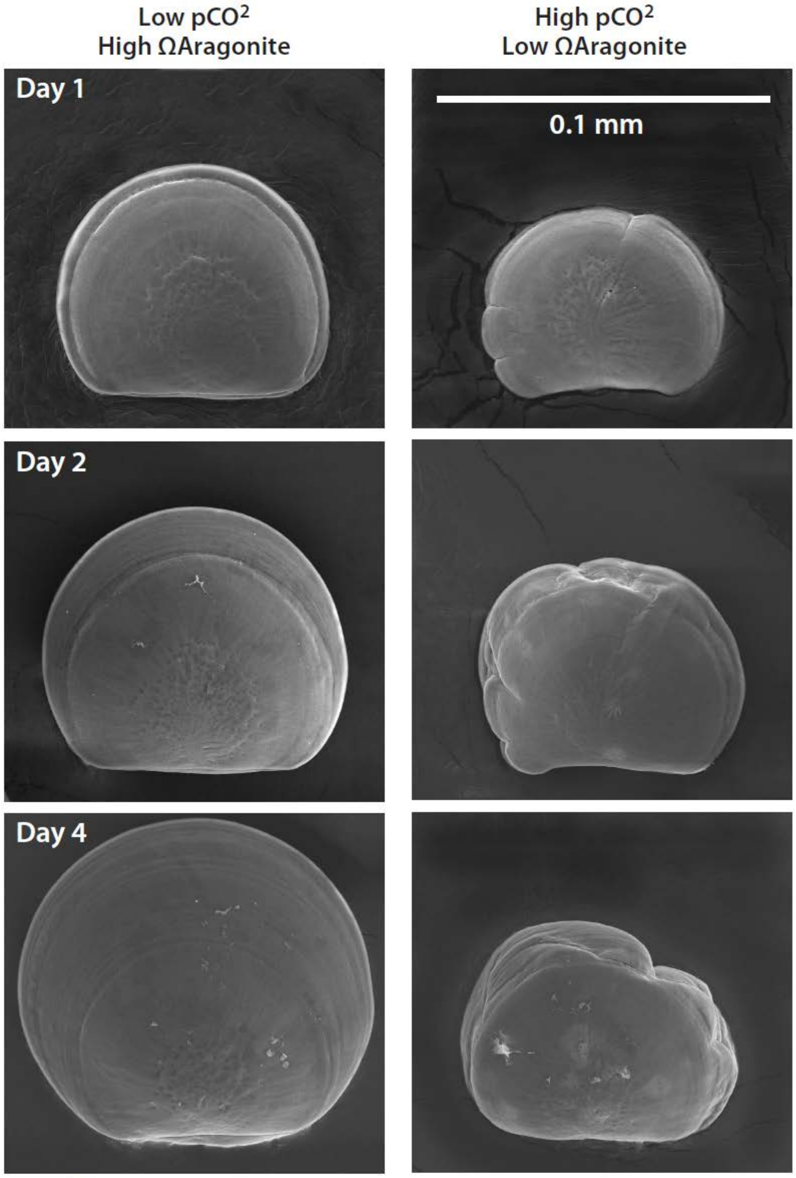
In summary, ocean acidification is happening now; the ocean has become 30% more acidic in the span of only a few years. There are significant economic impacts of ocean acidification on the shellfish industry, and although there is some capacity to adapt and alter chemistry in hatcheries, seawater chemistry cannot be effectively altered across entire water bodies at the moment. There is not much more capacity for waters in the Pacific Northwest to absorb much more CO_2 without leading to increasingly persistent problems for commercially and ecologically important species. Although in some locations it may be possible to take regional actions to stem off some more immediate impacts, such as habitat restoration, without a global carbon policy that significantly reduces CO_2 emissions, conditions will continue to deteriorate in the world's oceans and threaten food production and livelihood.

For more information:
http://coenv.washington.edu/research/major-initiatives/ocean-acidification/ocean-acidification-in-the-pacific-northwest/

Videos on the problem (WA and OR)-

http://www.youtube.com/watch?v=5IJl-INsVYE

http://www.youtube.com/watch?v=qPhgyB8o_U4



Taylor Shellfish Farms

Oregon State University OSU College of Earth, Ocean, and Atmospheric Sciences

nfcc

SHELLFISH IN DISTRESS

The Collaborative Research Effort is Needed to Secure Survival of the Shellfish Industry in British Columbia

Island Scallops

OCEAN GROWN
OCEAN SMART
CANADIAN · FRESH · GUARANTEED

Shellfish Farming in British Columbia

The Problem: Ocean Acidification

- The shellfish industry is in crisis due to unprecedented changes in the ocean environment: OCEAN ACIDIFICATION
- Both wild and hatchery-produced shellfish have already been negatively impacted
- At risk are over decades of research and development and millions of dollars of investment by, BC Shellfish growers, governments, First Nations, and Foundations

Shellfish Farming in British Columbia

The Solution: A Collaborative Approach

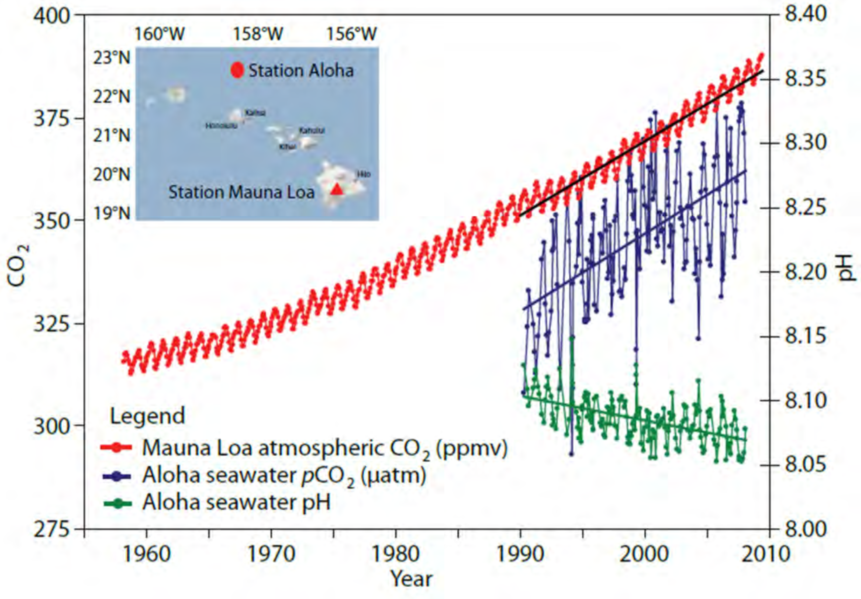
- Shellfish that can thrive in an increasingly acidic ocean must be selected to secure the future viability of the industry
- Solving the problem requires a coordinated effort, combining the resources and expertise of:
  - BC Shellfish Growers
  - First Nations
  - Government (e.g. Fisheries and Oceans Canada) and academic scientists
  - Funding sources

Shellfish Farming

The Challenge Facing the Shellfish Industry in BC

Ocean Acidification

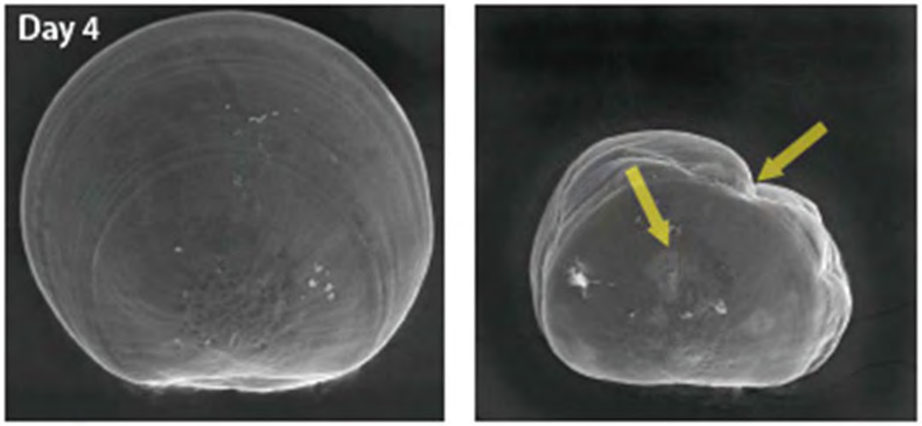
- Greatest threat to survival of the BC shellfish industry today
- Caused by increasing levels of CO_2 in the ocean
- Affects the ability of calcified organisms to form shell
- Shellfish larvae and juveniles are particularly susceptible



Increase in atmospheric and oceanic CO_2 in Hawaii over recent years. (Source: NOAA)

Shellfish Farming

Mitigation of Ocean Acidification



Scanning electron micrograph of (left) healthy four-day old shellfish larva and (right) larva grown in seawater with high levels of CO_2. (Source: Oregon State University and Taylor Shellfish Farms)

AT THE HATCHERY:

- Ocean acidification caused significant mortality of oyster and scallop larvae in 2009 and 2010 at ISL
- The problem was successfully mitigated in 2011 and 2012 by buffering the seawater. NaOH, NaCO

Scallop Farming

Mitigation of Ocean Acidification

AT THE FARMS:

- In 2013, 90% mortality was experienced in all three year classes (2010, 2011, 2012)
- This was attributed to a weakening of the animals by ocean acidification
- The ocean cannot be buffered, so scallops able to thrive in an increasingly acidic environment must be selected
- Alternate scallop species that may be more tolerant must also be investigated

The local Giant Rock Scallop may be an alternate culture species in BC. (Source: SIMoN / MBNMS)

Ocean Acidification

CO_2 (atm)

88% of carbon in the ocean exists in the carbonate ion (at pH8.2)

$$CO_2\,(aq) + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons \boxed{HCO_3^-} + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

$$CO_3^{2-} + Ca^{2+} \rightleftharpoons \boxed{CaCO_3}$$

Marine calcifiers fix dissolved ions into solid calcium carbonate - these structures dissolve if the concentration of dissolved ions is too low

Image Courtesy: NOAA

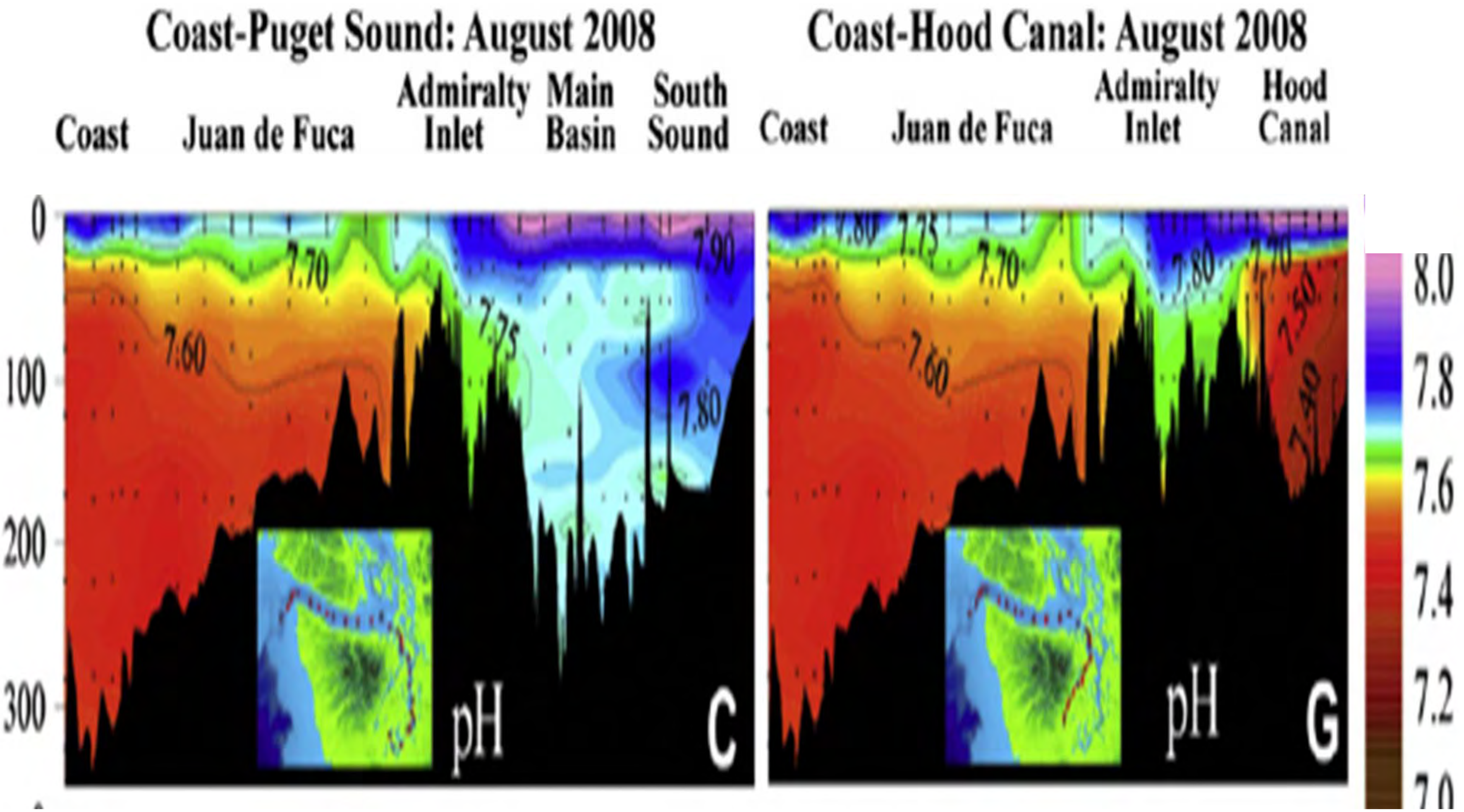
A SWIMMING PTEROPOD, LIMACINA HELICINA

www.woodbridge.tased.edu.au

www.na.oceana.org

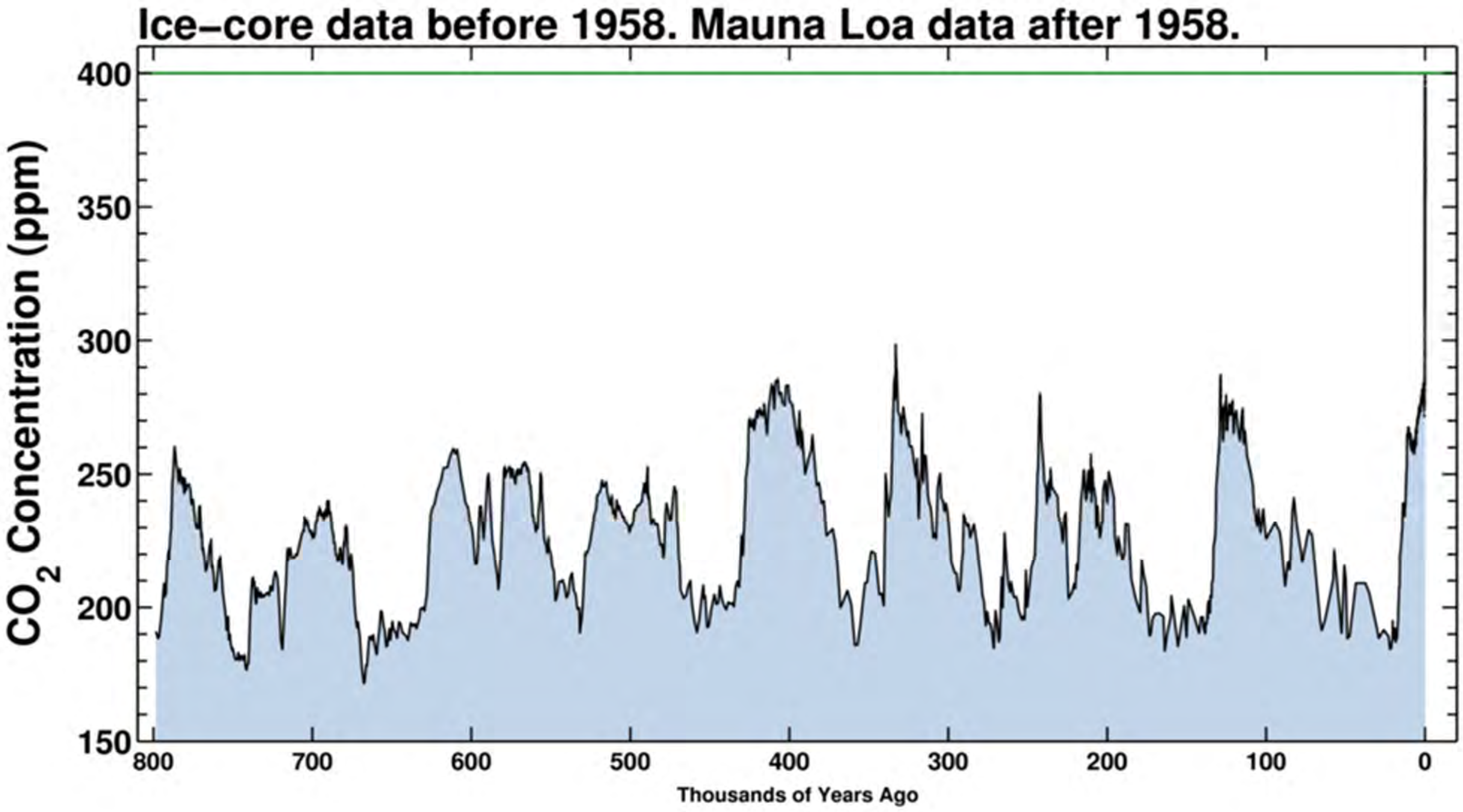
Jeremy Young
Natural History Museum, London

Ocean Acidification



Feely et al 2010 Est Coast Shelf Sci 88:442-449

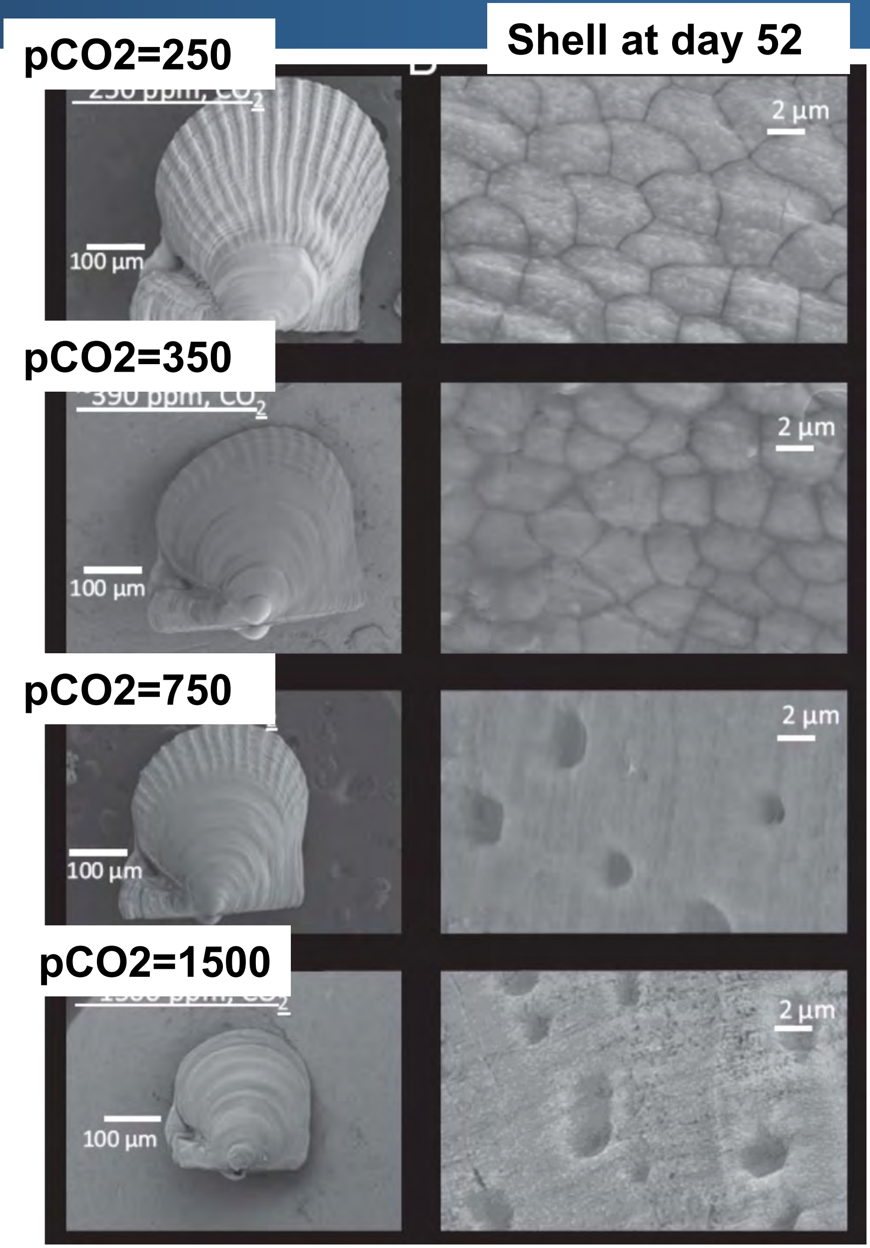
800,000 years of atmospheric CO2



Shellfish Response to Acidification: bay scallop example

- **Decreased fertilization rates**
- **Decreased hatching success**
- **Decreased larval growth**
- **Impacts on acid-base metabolic physiology**
- **Shell deformities**
- **Problems with deposition of calcium carbonate and weakening of shell**

(Kurihara et al 2008 MEPS 373:275-284; Fabry et al 2008 ICES 65: 414-432)



Talmage *et al* 2010 PNAS 107: 17246-17251

Functional Genomics ACRDP project for oysters and scallops

Environment One

i.e. atm. pCO2 (~350μatm)

- **Organism responds to environment**
- **gene expression (RNA production) changes**
- **Some genes are up-regulated (produce more mRNA) and others are down-regulated**

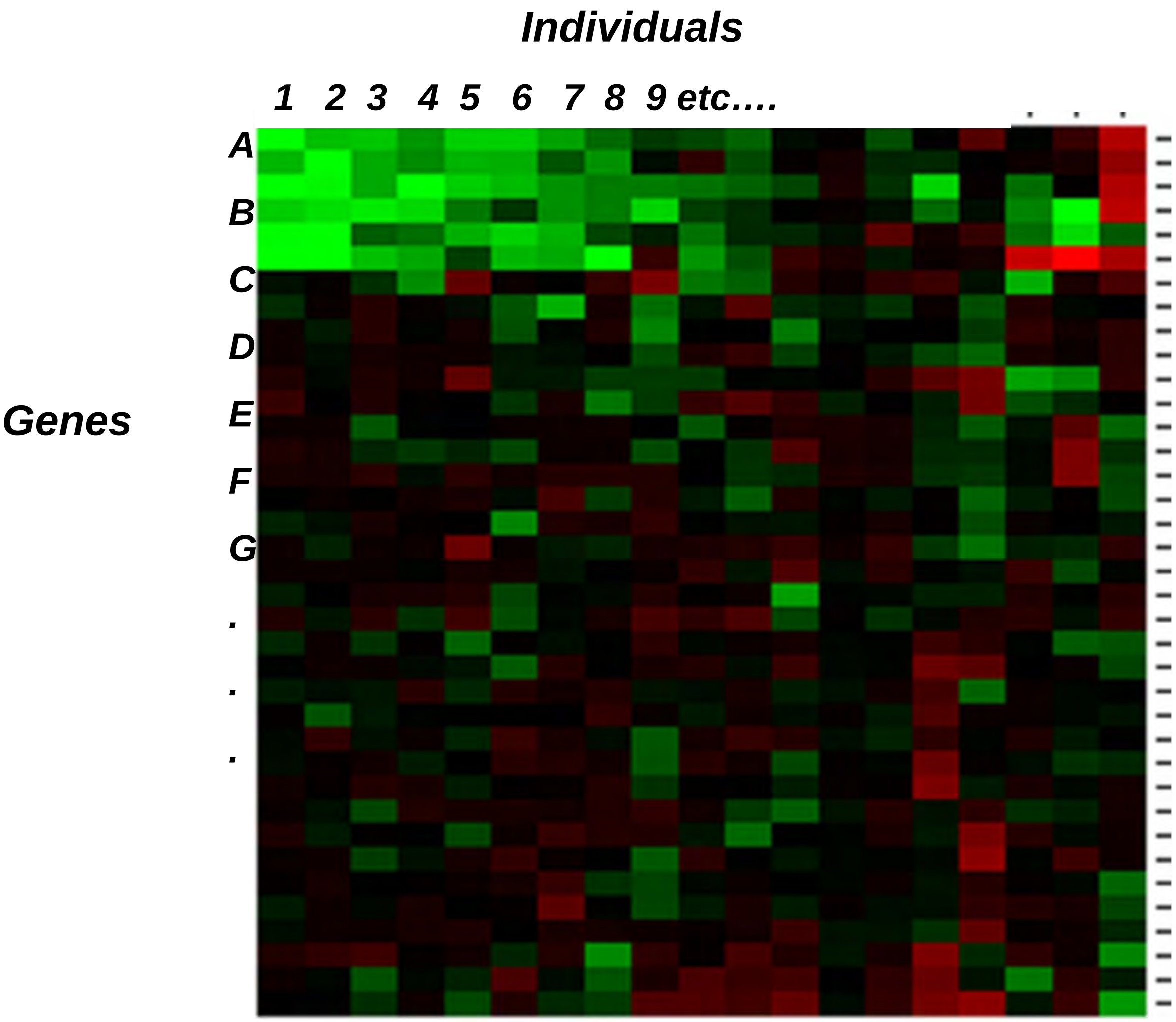
Environment Two

i.e. high pCO2 (~550μatm)

- **Organism responds to environment with different response than environment 1**
- **gene expression (RNA production) changes**
- **Some genes are up-regulated (produce more mRNA) and others are down-regulated**

- **RNA isolated from organisms**
- **Visualized on a microarray slide**
- **Compare organisms from environment 1 to those from environment 2 and identify differences in gene expression**
- **Determine which physiological pathways differentially expressed genes are part of**

Functional Genomics: microarray



Scallop Microarray

- Based on ESTs from *Patinopecten yessoensis* and *C. gigas*
- 24505 unique expressed sequence tag probes
  - 91 probes for pathogenic marine bacteria
  - 24414 probes for scallop sequences
  - 33% of scallop probes are annotated (putative gene function known)
  - Annotated genes include those for the following pathways (among others):
    - Protein metabolism
    - Immune function
    - Growth and development
    - Cell signalling
    - Reproduction

Functional Genomics: biomarkers

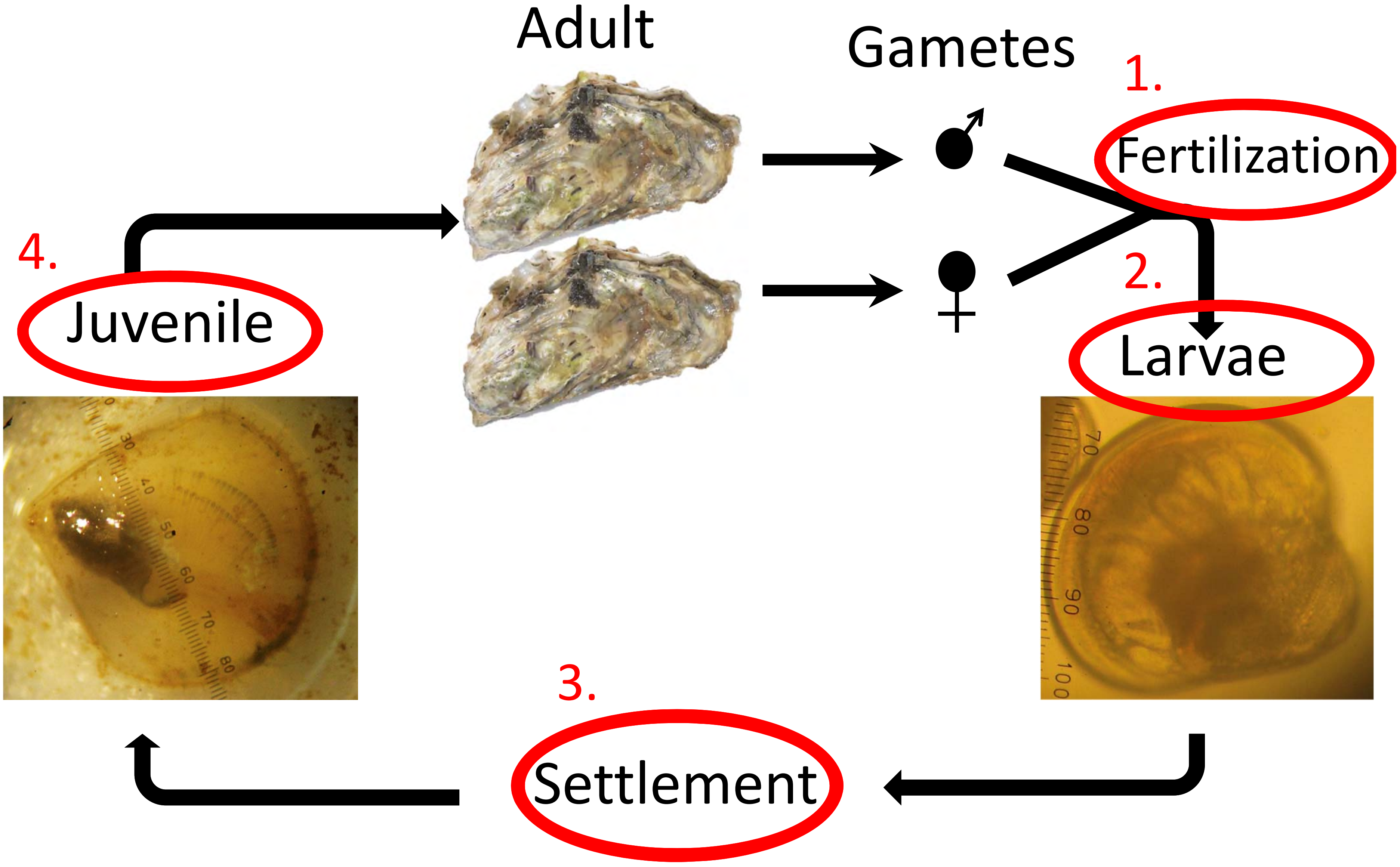
Goal:

to discover genes which, when up- or down-regulated, indicate whether scallops and oysters are being negatively impacted by ocean acidification

Applications:

- **more efficient selective breeding and ability to target desired traits such as tolerance to high pCO2**
- **early (sub-clinical) indicators of poor health**
- **measurable markers for determining if environmental manipulations are having the desired affect**

How does increased $p\mathrm{CO}_2$ affect…



Adult

Gametes

♂

♀

1. Fertilization

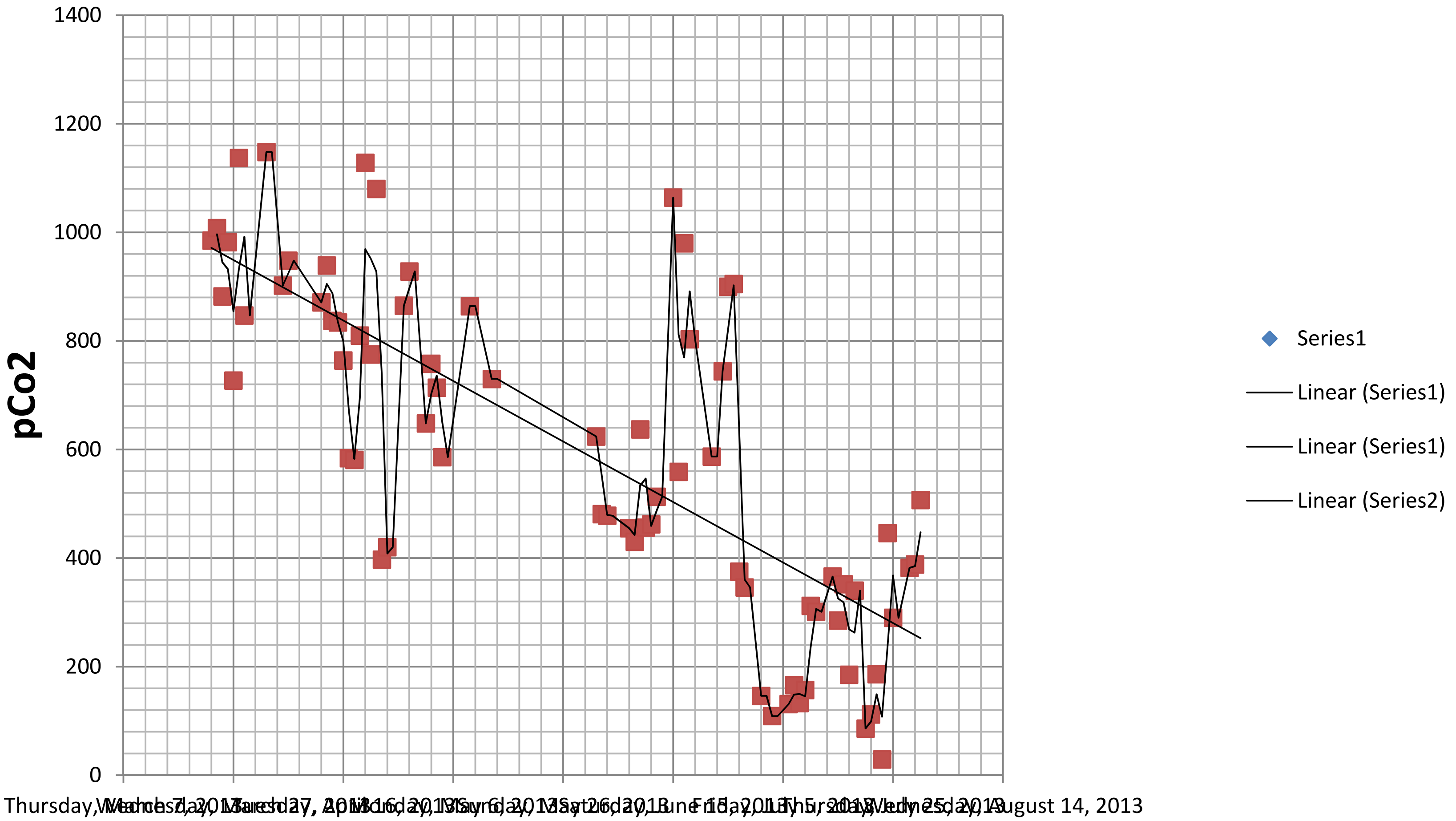
2. Larvae

3. Settlement

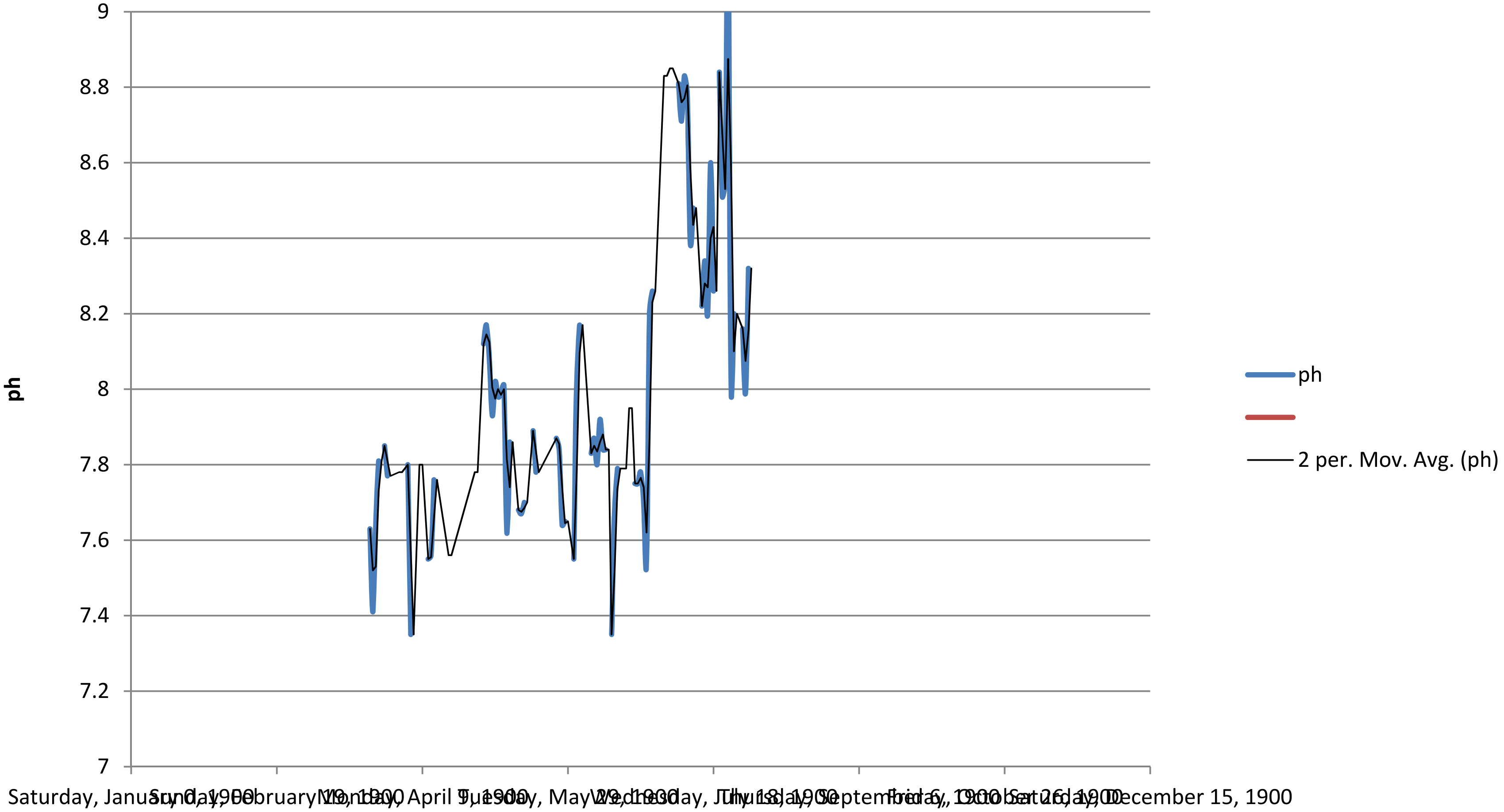
4. Juvenile

Flask experiment

Partial pressure of CO2 in seawater at Qualicum Beach



Ph of seawater in Qualicum Beach



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Summer flounder stirs north-south climate change battle.

An uncivil war is brewing over "fluke," one of the most popular fish of U.S. East Coast, as its habitat drifts north in warming waters.

By Marianne Lavelle

The Daily Climate

http://www.dailyclimate.org

The summer flounder – one of the most sought-after catches on the U.S. East Coast – is stirring up a climate change battle as it glides through the sand and grasses at the bottom of a warming North Atlantic.

Also known as "fluke," the flat, toothy fish is remarkable for its ability to change color to adapt to its surroundings, rendering it almost invisible to predators and prey.

Some scientists say in recent years the species has begun adapting in another way. As the Atlantic Ocean has warmed, they say, the fish have headed north.

The center of summer flounder population, recorded as far south as Virginia around 1970, is now off the New Jersey coast. Its migration has set the stage for battle between northern and southern East Coast states on how to share the business of harvesting this tasty, lean fish—valued at $30 million per year commercially and untold millions more for the recreational fishing industry.

Battle lines have been drawn over a fish that has staged a remarkable come-back from overfishing, but has returned to a dramatically changed environment in the sea and on land. On one side are southern states, most importantly, North Carolina, with a commercial fishing fleet that has been pummeled in recent years by competition from cheap foreign seafood imports. It is eager to hold onto its summer flounder quota, based on its historic leading role in East Coast fluke fishing, even if that now means motoring closer to New Jersey to find the fish. On the other side are northern states, particularly New York, where recreational sports fishing has become an important business and economic engine that is chafing under what it views as outdated quotas.

Sen. Charles Schumer, D-N.Y., has pledged to bring "fluke fairness" to Long Island by introducing legislation to do away with the long-standing state-by-state summer flounder management quotas that he says short-change New York's fishermen. But North Carolina is not likely to surrender its quota quietly.

"This is an opportunistic reason for using climate change or whatever the heck reason they want to use—the northern states would like to get some of our quota," said Jerry Schill, president of the North Carolina Fisheries Association. He maintains it would be an unfair way to repay Tar Heel State commercial fishers for sacrifices they've made that have helped rebuild the summer flounder stock so that it's robust enough to head into cooler waters.

The regional authorities that manage East Coast fishing under U.S. law made tweaks in their summer flounder plans this year in an attempt to address concerns about inequity and allow more flexibility for recreational anglers. But unhappiness persists, and work is underway on a longer-term solution.

A team of scientists from four mid-Atlantic universities, working with the fishery managers and with funding from the U.S. National Oceanic and Atmospheric Administration (NOAA) Sea Grant program, this spring launched a project aimed at better understanding what is happening with the summer flounder, *Paralichthys dentatus*. The researchers hope that their close examination of this one species will serve as a prototype approach for addressing similar conflicts and quandaries over fisheries that are bound to arise as climate change's impact becomes more evident.

A study published earlier this month by NOAA researchers suggests that more fluke are now found north primarily because fishing pressure has been reduced, not because of climate change. But co-author Jon Hare, NOAA's Northeast Fisheries Science Center in Narragansett, Rhode Island, says the team plans to publish follow-up research showing warming is, in fact, causing a northward shift for two other northeastern species that have been grouped together with summer flounder in the same federal management: scup and black sea bass.

"Much of our management assumes that conditions in the future will be the same as they have been in the past," said Hare. "Now have observational data to show the conditions have been changing through time, so assumptions about the future are being brought into question."

Previous research has shown that changes in local temperatures can explain recent geographical shifts of more than 300 different fish species: They've migrated toward the north or south poles, and even east or west into deeper waters, depending on their original locations. "We do think that climate is playing an important role for a wide range of species," said Malin Pinsky, a Rutgers University ecologist who led that research and who now is leading the NOAA Sea Grant study on summer flounder's changes.

Subhead

While scientists try to sort how much of fluke's northward shift is climate-change related and how much is not, pressure is building on authorities charged with divvying up the fishery among East Coast states.

"Fish have very strong thermal preferences, and they also have tails," said Richard Robins, chairman of the Mid-Atlantic Fishery Management Council, one of eight regional fishery management councils tasked with meeting demand while preventing overfishing in U.S. waters. "They don't wait to be convinced."

The council, which by law recommends species management plans that are then approved and enforced by the U.S. Department of Commerce's National Marine Fisheries Service, has had to cope with northward shifts by several species, including the Atlantic mackerel, he said.

But perhaps no fish is causing as much consternation as the summer flounder, which is not only highly prized by commercial fishing operations. It is among the top ten most popular fish caught in U.S. waters by recreational anglers, who relish pursuit of "flatties," or "doormats," as the largest fluke are sometimes called. Summer flounder are known for grabbing bait aggressively with well-developed teeth. "They offer a particular challenge to the angler bold enough to use light tackle," notes one web site on northeastern fishing.

Fluke were so heavily overfished in the 1980s that commercial landings plummeted from 38 million pounds to a low of 9 million pounds by 1990. The haul by recreational fishers dropped from around 30 million pounds to about 3 million pounds.

Only after the contentious and much-litigated process of putting quotas, size, and catch limits into place in the early 1990s did the species recover. By 2010, NOAA declared the summer flounder stock rebuilt. Total annual harvest recently has been about 20 million pounds of fluke per year, split 60-40 percent between commercial and recreational fishers.

Subhead

With flaky, white meat, easily broiled, poached, or fried, summer flounder is considered by many to be a sustainable seafood choice, since it is caught wild by U.S. fishers in the carefully managed program. And it is popular for East Coast diners looking for fresh catch, a stand-out local choice at a time when 91 percent of seafood on U.S. plates is imported, mostly from farming operations in Asia.

“In many ways, it has been a success story,” says Pinsky.

But as fluke stocks have rebuilt, the North Atlantic has been warming, at 0.41° F (0.23°C) per decade from 1982 to 2006, or close to twice the global average for marine ecosystems, according to one widely cited study. And the bottom trawl surveys conducted by the U.S. NMFS since the 1960s show that the center of the summer flounder population has moved northward at roughly 19 miles (30 kilometers) per decade for the past 40 years.

That poses a problem, because the commercial summer flounder quotas are based on where fish were brought into port—“landings,” in industry parlance—as they stood during the 1980s. As a result, in the commercial fishery, nearly 28 percent of the quota is allocated to North Carolina, followed by Virginia, with 21 percent, and New Jersey, with 16 percent. New York’s share is just under 8 percent.

The fact that fewer summer flounder are found off just off North Carolina’s coast hasn’t been a major impediment for that state’s commercial boats, which have been willing to travel long distances for catch. “North Carolina boats have always been very, very mobile,” says Schill, who knows stories of N.C. boats in the 1950s going as far as Alabama to find shrimp. “They do what they have to do to put bread on the table.”

So North Carolina vessels travel north, if necessary, to catch summer flounder, then motor home so the fish are landed in state, counting against its high quota.

But for recreational anglers, who typically cast bait close to their home state ports, summer flounder’s northward migration is starkly evident. Under the rules in place last year, New York anglers could only bring in fish at least 19 inches in length, with a possession limit of four fish. Even so, New Yorkers landed more than 500,000 fluke in 2013, about 13 percent over the target regulators set for the state. Meanwhile, North Carolina’s rules were far looser; recreational fishers could reel in fluke as small as 15 inches, with a possession limit of six fish. Nevertheless, N.C. recreational summer flounder landings totaled just 45,240 fish, some 67 percent below the state’s target. New Jersey anglers, meanwhile, caught 1.2 million fish, about 22 percent over target, especially rankling to boats in neighboring Long Island waters.

At the end of last summer, New York Governor Andrew Cuomo threatened to sue federal authorities to overturn the summer flounder management rules, which he said “stifle the New York fishing industry.” His office estimated that New York’s fishing industry is losing about $6 million per year in revenue because its allocation falls below that of neighboring states.

“All of this is set against the backdrop of demographic change in the Northeast, and a huge boom in recreational fishing,” points out Chris Kennedy, environmental economics professor at Virginia’s George Mason University, one of the team of researchers working on the NOAA Sea Grant project on summer flounder. The change that is happening in the water is only one part of the equation that the team is tackling, he said. They are trying to understand the changes occurring on land as well, in both commercial and recreational fishing communities.

For both New York and New Jersey’s fishing industries, still recovering from 2012 superstorm Sandy damage, it has been painful to forego the readily available fluke just offshore. “Due to economic losses sustained due to Hurricane Sandy, many marinas and tackle stores in the northeast were relying on the summer flounder fishery to finance rebuilding and repair costs,” noted the Mid-Atlantic Fishery Management Council’s fishery performance report completed at the end of last summer.

Subhead

New York's recreational summer flounder restrictions were eased somewhat this season, and are now in line with those in both New Jersey and Connecticut. But the Mid-Atlantic Council, and its partner agency, the Atlantic States Marine Fisheries Commission, which regulates fishing with three miles of shore, are reopening their summer flounder management plans, with the hope of arriving at a longer-term solution.

"We're going to revisit what is the appropriate management response to the emerging idea that the fluke biomass have shifted north and east," explains council member Jeff Kaelin.

Kaelin, who heads up government affairs for Lund's Fisheries, a commercial operation based in Cape May, N.J., says that the unintended consequences of the current system are readily apparent to his own company's operations. Although most of the vessels Lund's owns or works with call Cape May home port, some have North Carolina permits. They may catch summer flounder right off the Jersey shore, but need to head south "and burn hundreds of gallons of fuel to land 100 boxes of fluke against their [North Carolina] quota," says Kaelin. "That's with fuel at $3 to $4 a gallon, and very contrary to the issues of climate change and carbon footprint."

Kaelin says that with the help of electronic monitoring and reporting, it might be possible to address the problem with greater flexibility—allowing commercial boats to bring fish into port in New Jersey, but tally their catch against North Carolina's quota. That idea will not sit well, however, with the N.C. coastal fish processing industry, which is relying on fresh catch. "As an industry organization, we want the biggest bang for the buck for our state," says Schill.

He maintains the problem is that authorities have not figured out how to manage a species that has rebuilt as strongly as the summer flounder. Schill says he hopes the fishing community across the Middle Atlantic can reach agreement on fluke without regulatory intervention.

Kennedy says that few relish the prospect of reallocation of the fluke quota, even if the fish has swum far from its historic habitat. "Whenever you change the allocation, it's never good for everyone," he says. "There are always winners and losers."

Even more daunting is the prospect of what will happen in the years ahead, when projections call for the North Atlantic to warm even more dramatically. Summer flounder's northward journey may not yet be at an end.

It's not surprising that the system set up long ago to manage the fishery, involving two separate regional stakeholder councils and seven states with differing interests, has difficulty addressing the fluke's geographic shift, says Kennedy. "It illustrates well the difficulties facing local authorities and stakeholder groups, representing a spectrum of priorities, when attempting to respond to large-scale environmental change."

</tail>Marianne Lavelle is a science reporter for the Daily Climate, a nonprofit news service covering energy, the environment and climate change. Follow her on Twitter @mlavelles (http://twitter.com/mlavelles).

On the web:

U.S. NOAA animation of shifting summer flounder distribution:

http://www.nefsc.noaa.gov/ecosys/climate_change/movie5-17.html