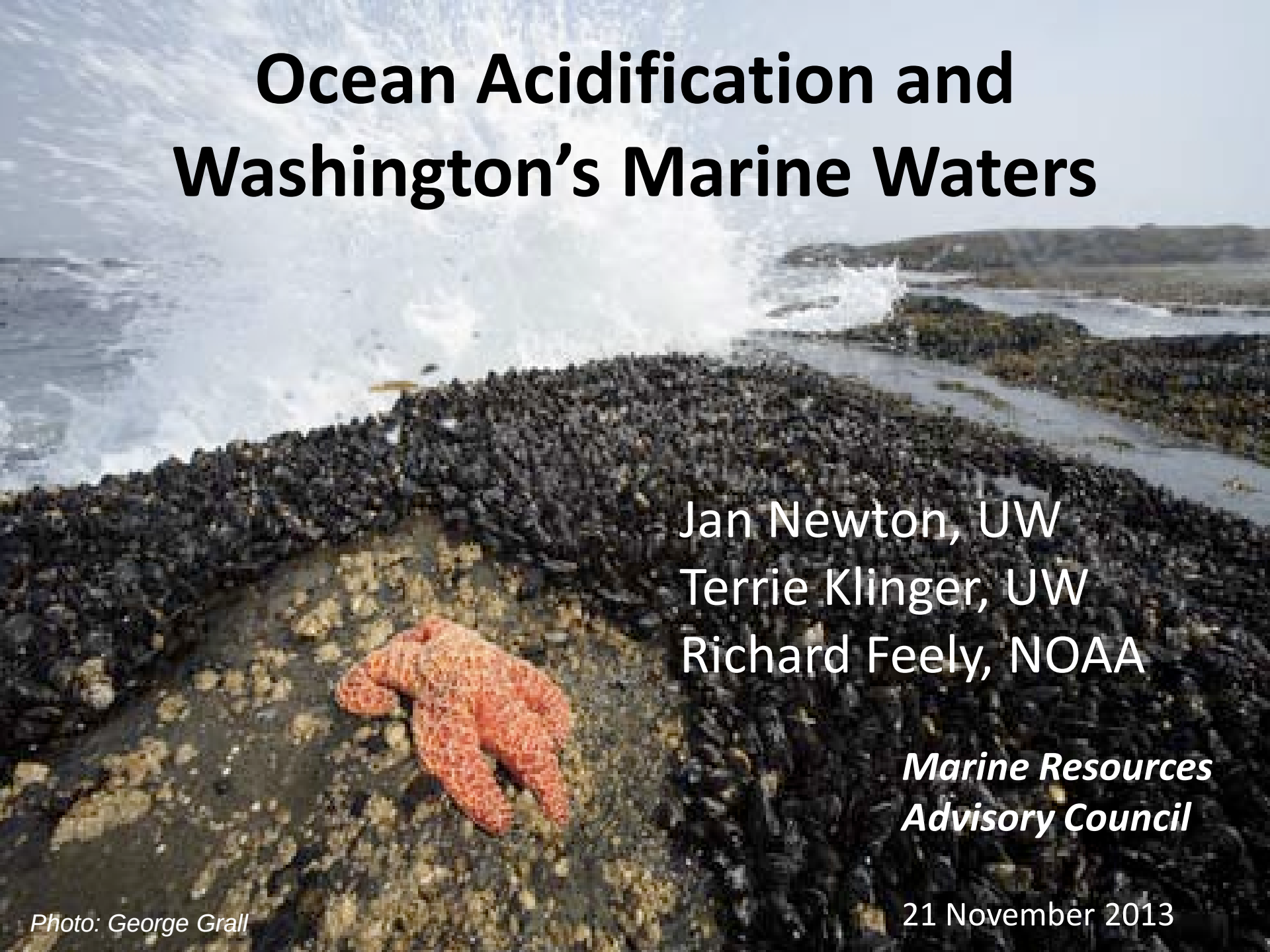
Ocean Acidification and Washington's Marine Waters



Jan Newton, UW
Terrie Klinger, UW
Richard Feely, NOAA

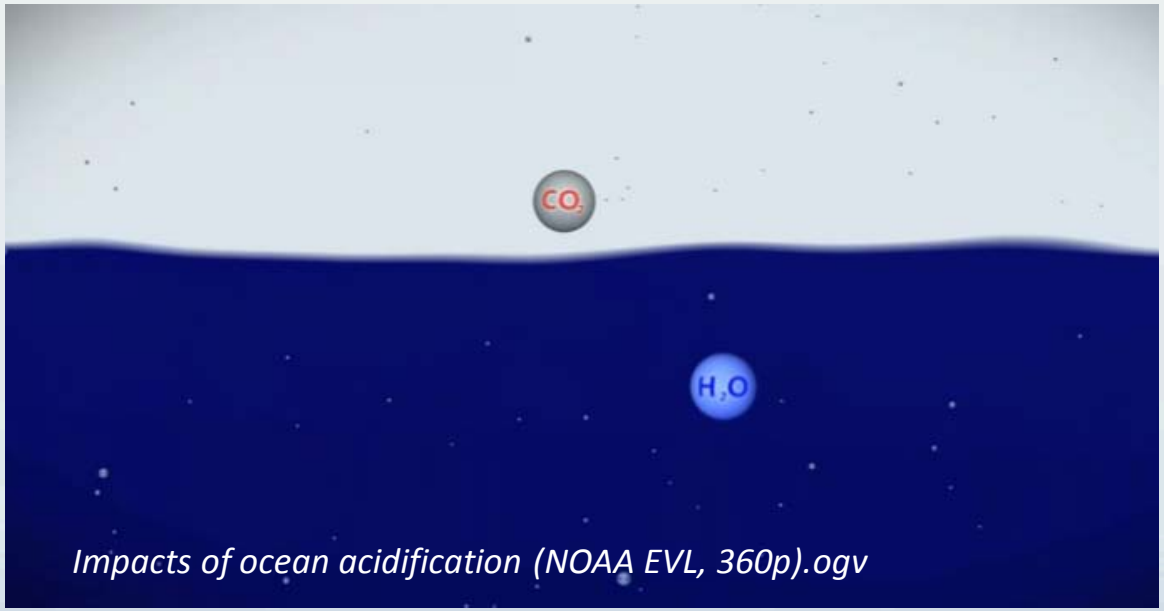
Marine Resources Advisory Council

21 November 2013

Photo: George Grall

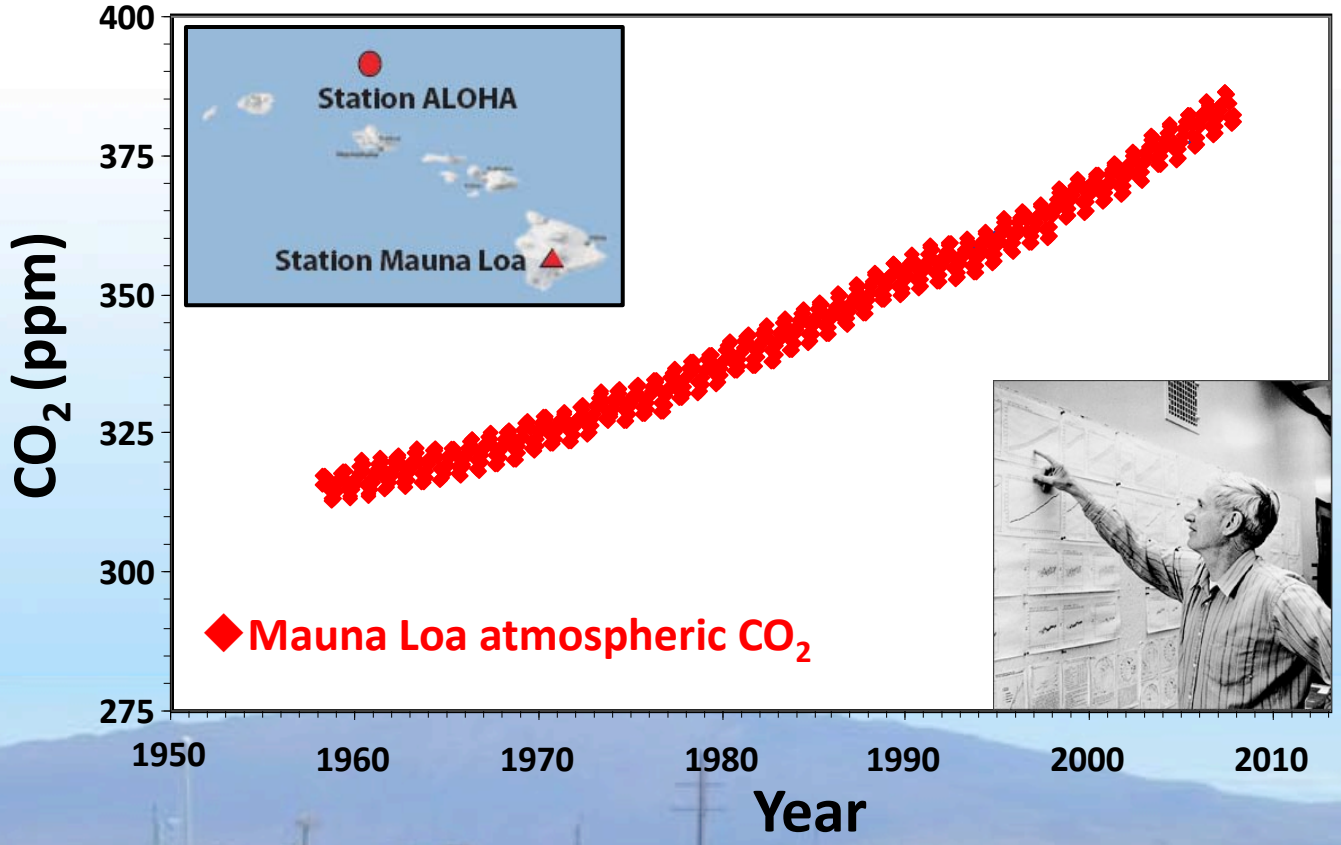
Ocean Acidification

1. Atmospheric CO_2 has increased from human activity
2. The oceans absorb CO_2
3. The increased CO_2 causes ocean acidification (OA)
4. OA reduces growth and survivorship in some organisms



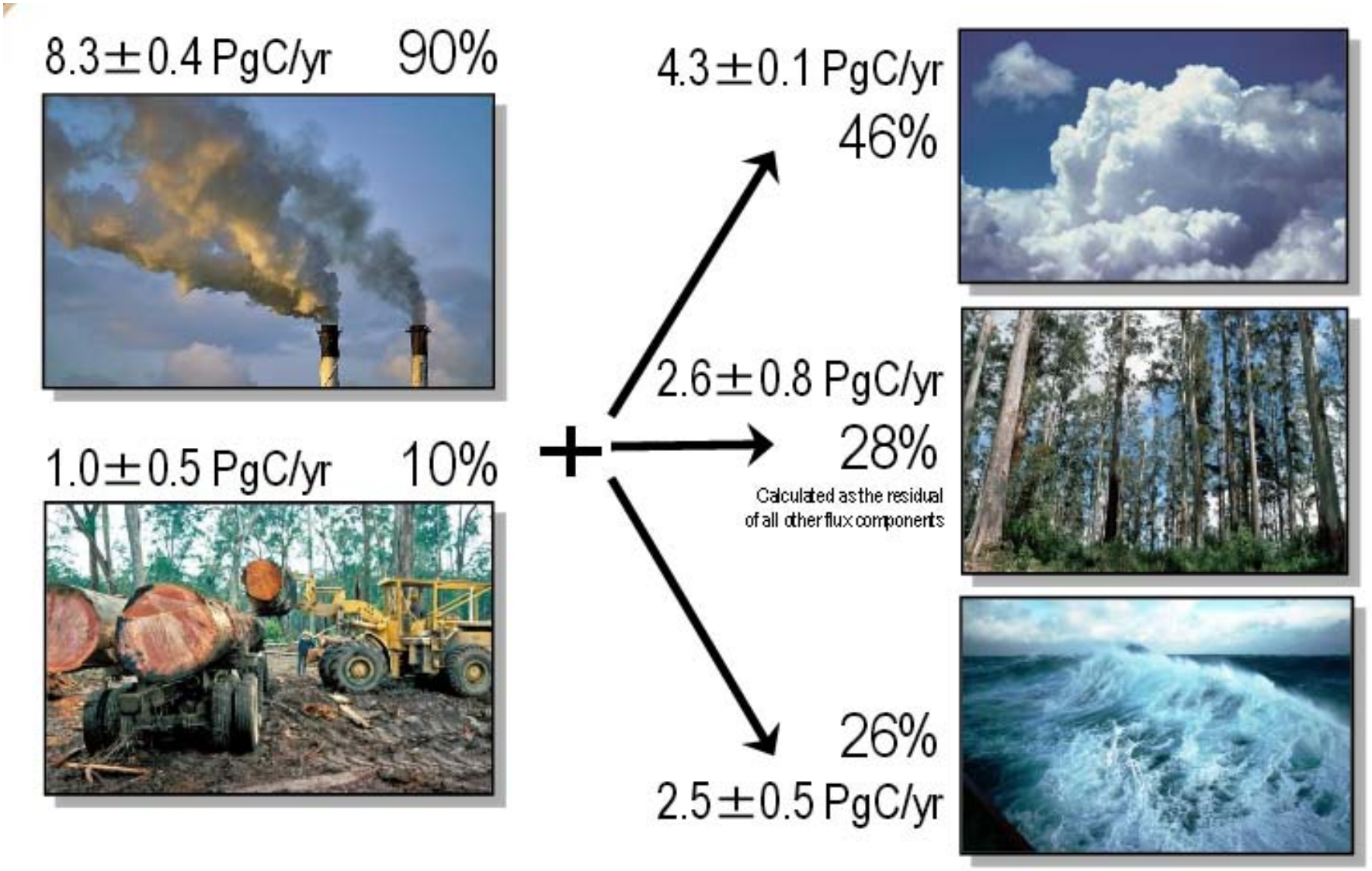
Impacts of ocean acidification (NOAA EVL, 360p).ogv

CO_2 in the atmosphere is increasing



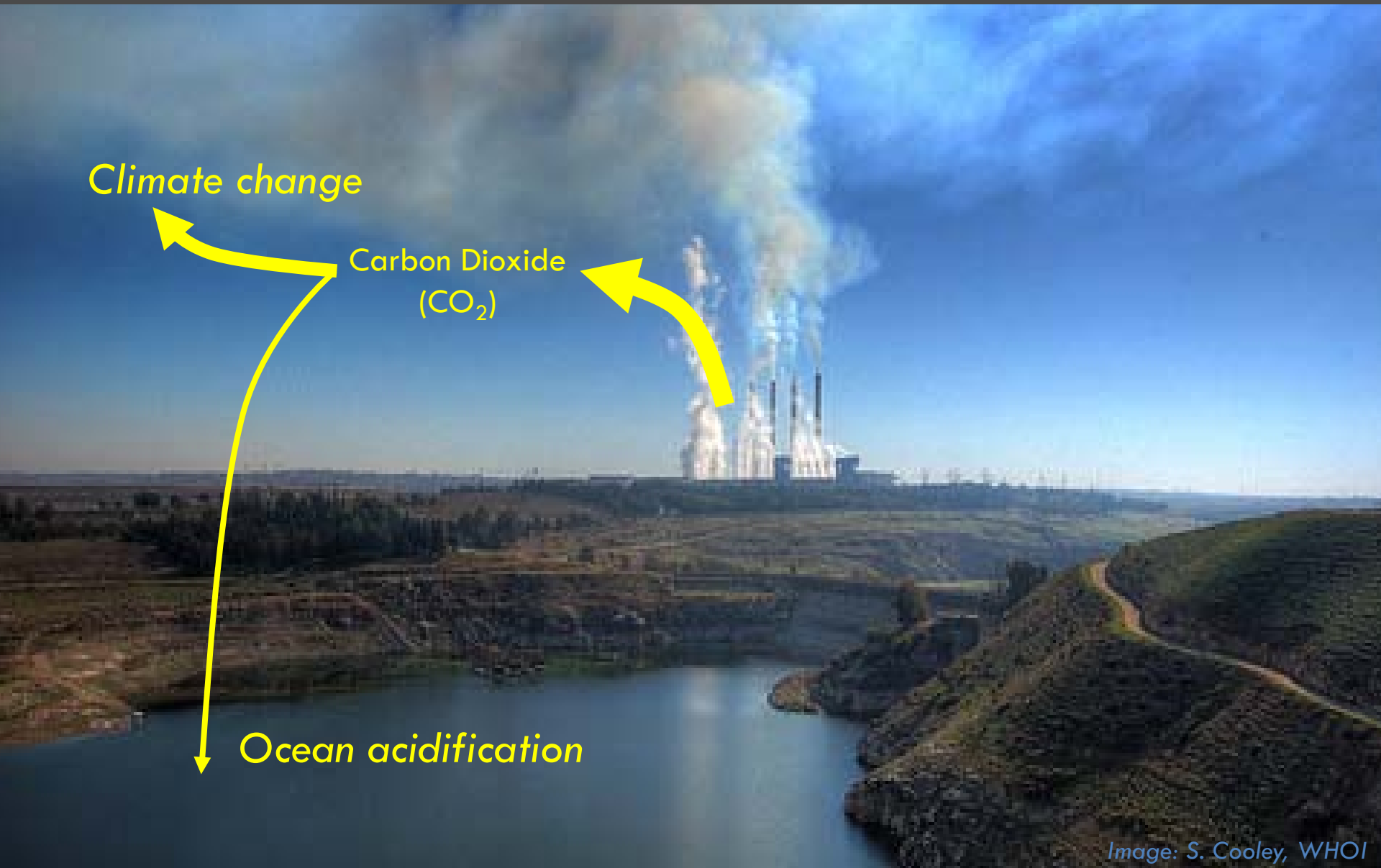
Data source: NOAA Station Mauna Loa

Oceans are an important sink for the CO_2

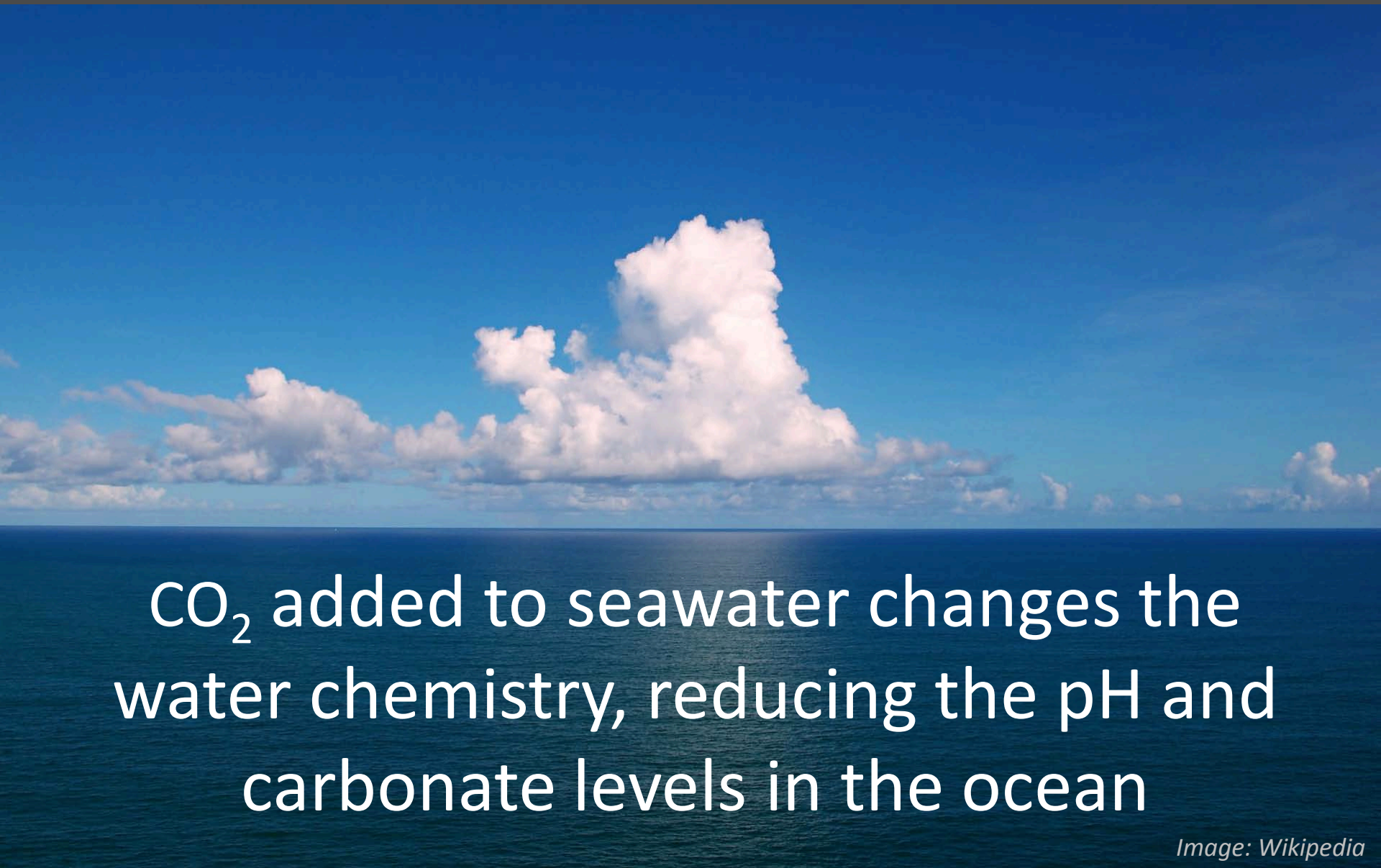


Source: Le Quéré et al. 2012; Global Carbon Project 2012

Increased CO_2 has two effects



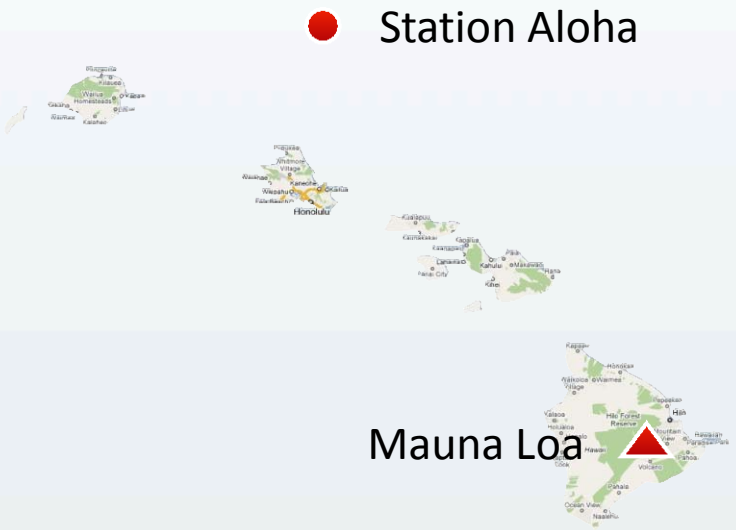
How does CO_2 cause ocean acidification?

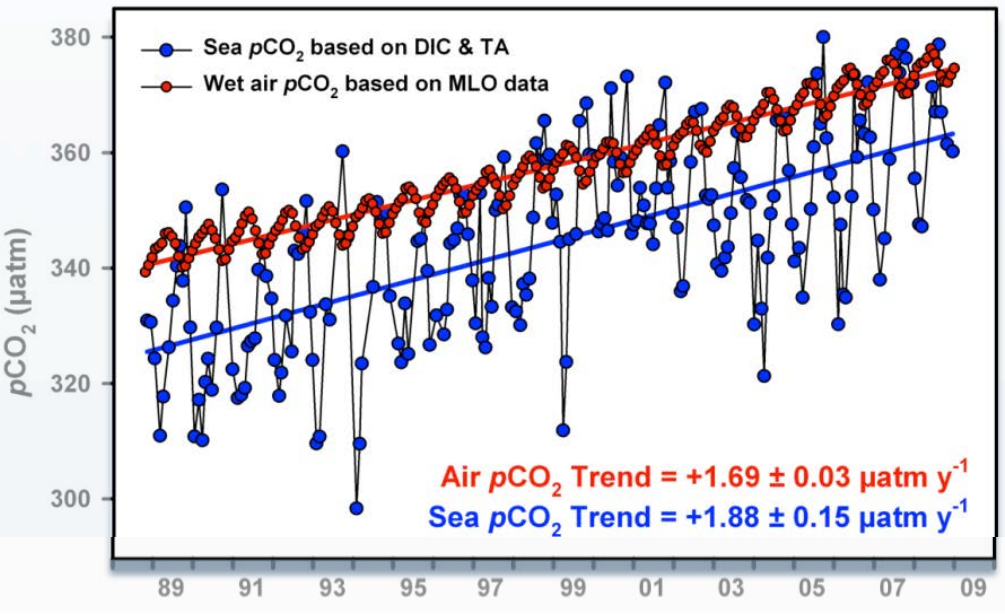


CO_2 added to seawater changes the water chemistry, reducing the pH and carbonate levels in the ocean

Image: Wikipedia

Ocean chemistry changes as atmospheric CO_2 rises



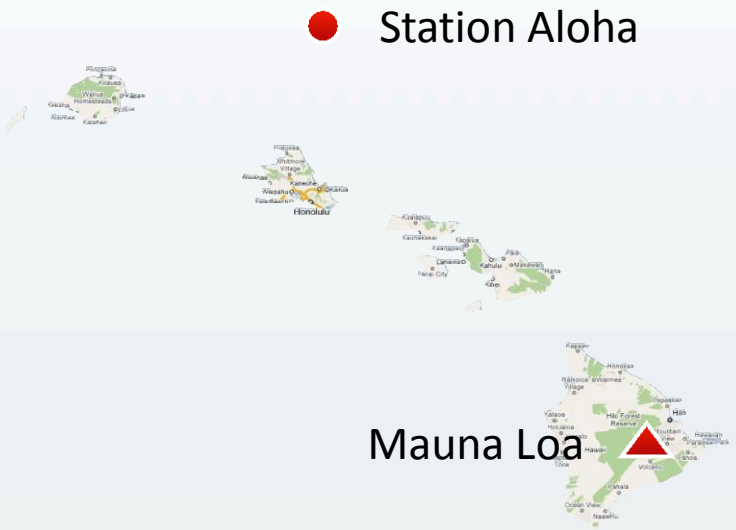


Surface water pCO_2 is increasing at about the same rate as atmosphere

We also see a decrease in pH

Source: Doney, Science 2010
Dore et al., PNAS 2009

Ocean chemistry changes as atmospheric CO_2 rises



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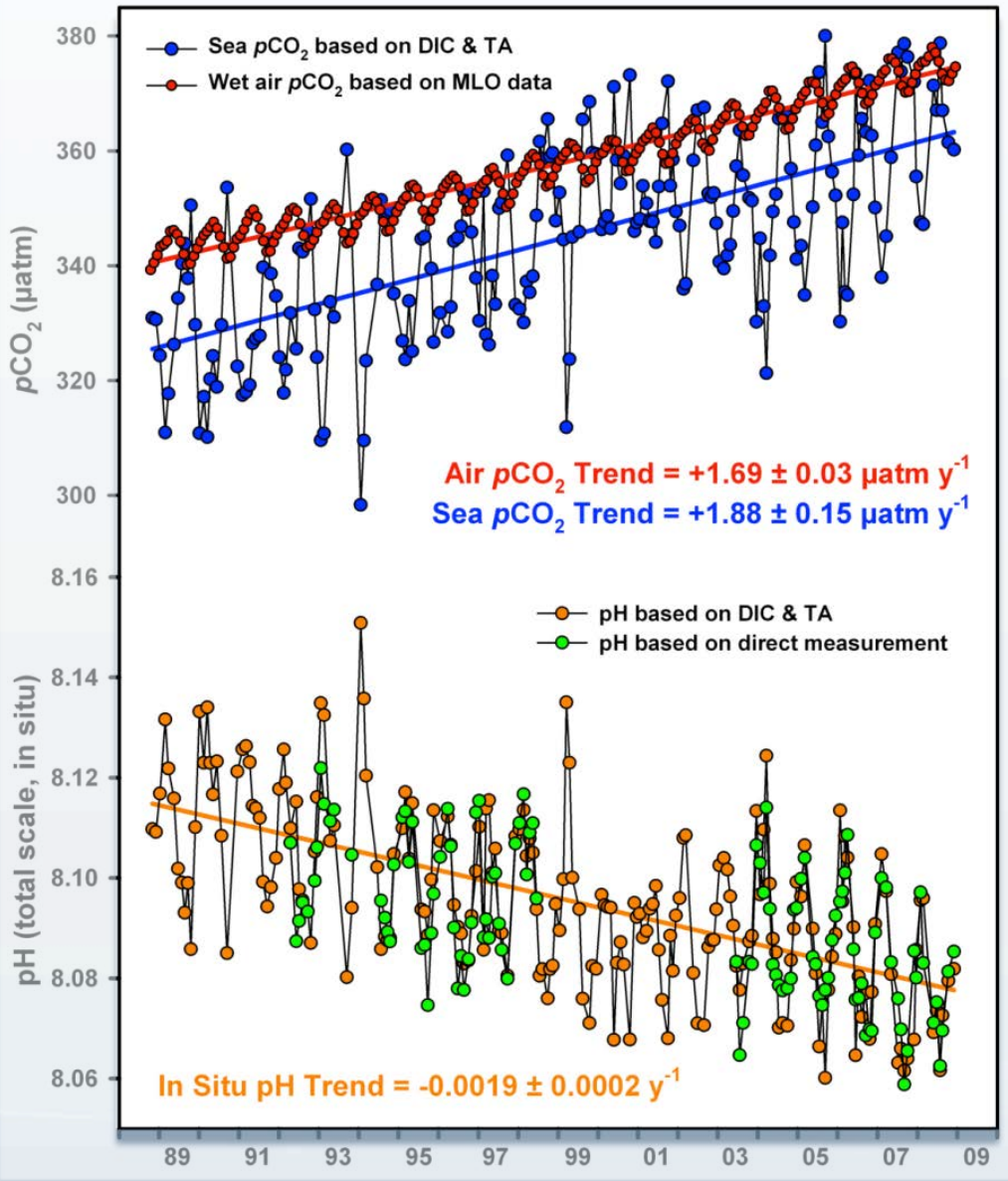
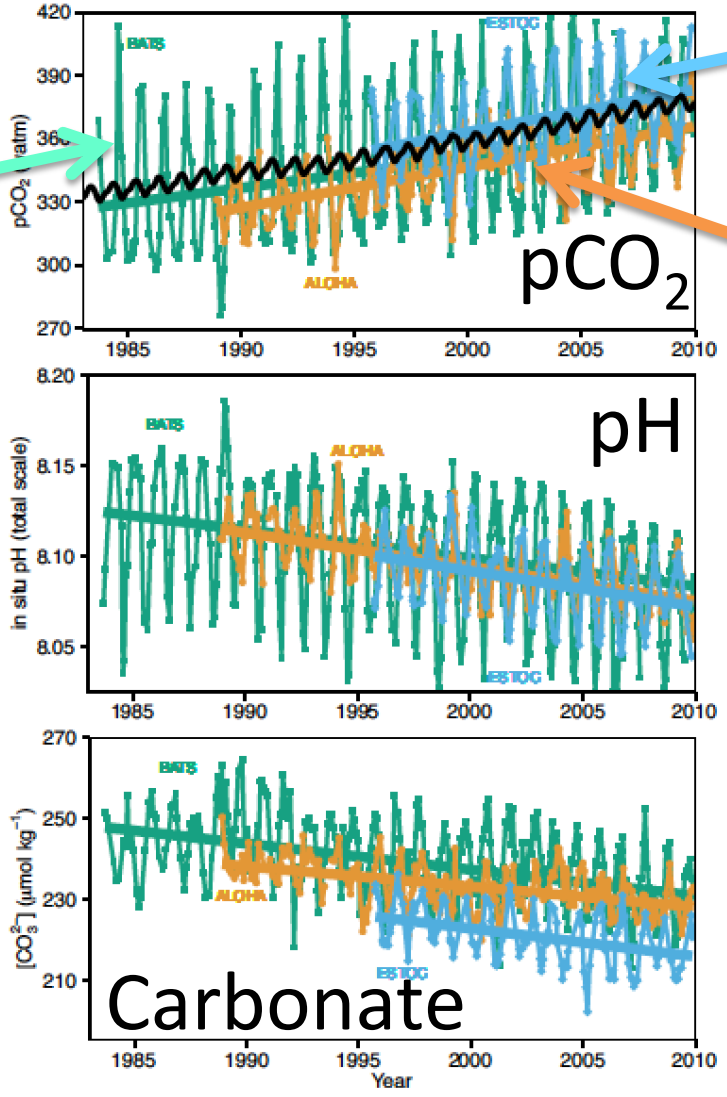


The trend is consistent across ocean basins

Bermuda

Canary Is.

Hawaii



Source: IPCC 2013

Why does a small pH change matter?

pH is on a logarithmic scale so that a pH change of 1 unit means a 10-fold change in acidity

In other words, small changes in pH units mean much larger changes in acidity!

Image: NOAA PMEL

Why does a small pH change matter?

acidification = movement in acidic direction

Image: NOAA PMEL

Why does a change in carbonate matter?

$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$

calcium carbonate — calcium carbonate

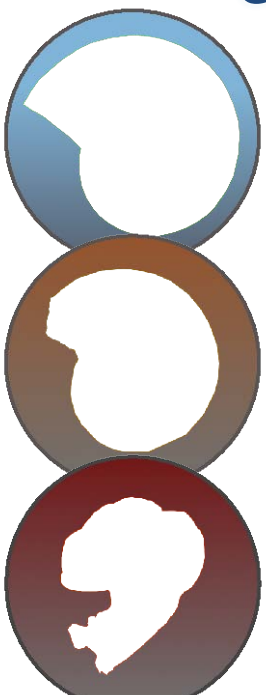
$\Omega > 1$ $CaCO_3$ precipitates

$\Omega = 1$ equilibrium

$\Omega < 1$ $CaCO_3$ dissolves

It affects shell mineral availability:

Calcium carbonate saturation state (Ω) indicates how easy it is for organisms to build shells



$\Omega > 1$ shell-building favored

$\Omega = 1$ equilibrium or threshold

$\Omega < 1$ corrosive conditions

Image: NOAA PMEL

What do we know about ocean acidification?

- Approximately 26-28% of the CO_2 generated by human activities since the mid-1700s has been absorbed by the oceans.
- Ocean acidity has increased 30% since the start of the industrial age.
- Ocean acidity is projected to increase 100-150% percent by 2100.
- Current rate of acidification is nearly 10x faster than any period over the past 50 million years.

Washington waters are particularly vulnerable to ocean acidification

Ocean acidification is appearing in Washington decades *sooner* than anticipated.

...regional factors can exacerbate acidification caused by global CO_2 emissions:

Coastal upwelling of CO_2-rich waters

Runoff of nutrients and organic carbon from land-based activities

Decay of organic matter in subsurface waters

Photo: Russ McMillan

Seasonal upwelling brings high CO_2, low pH water to surface

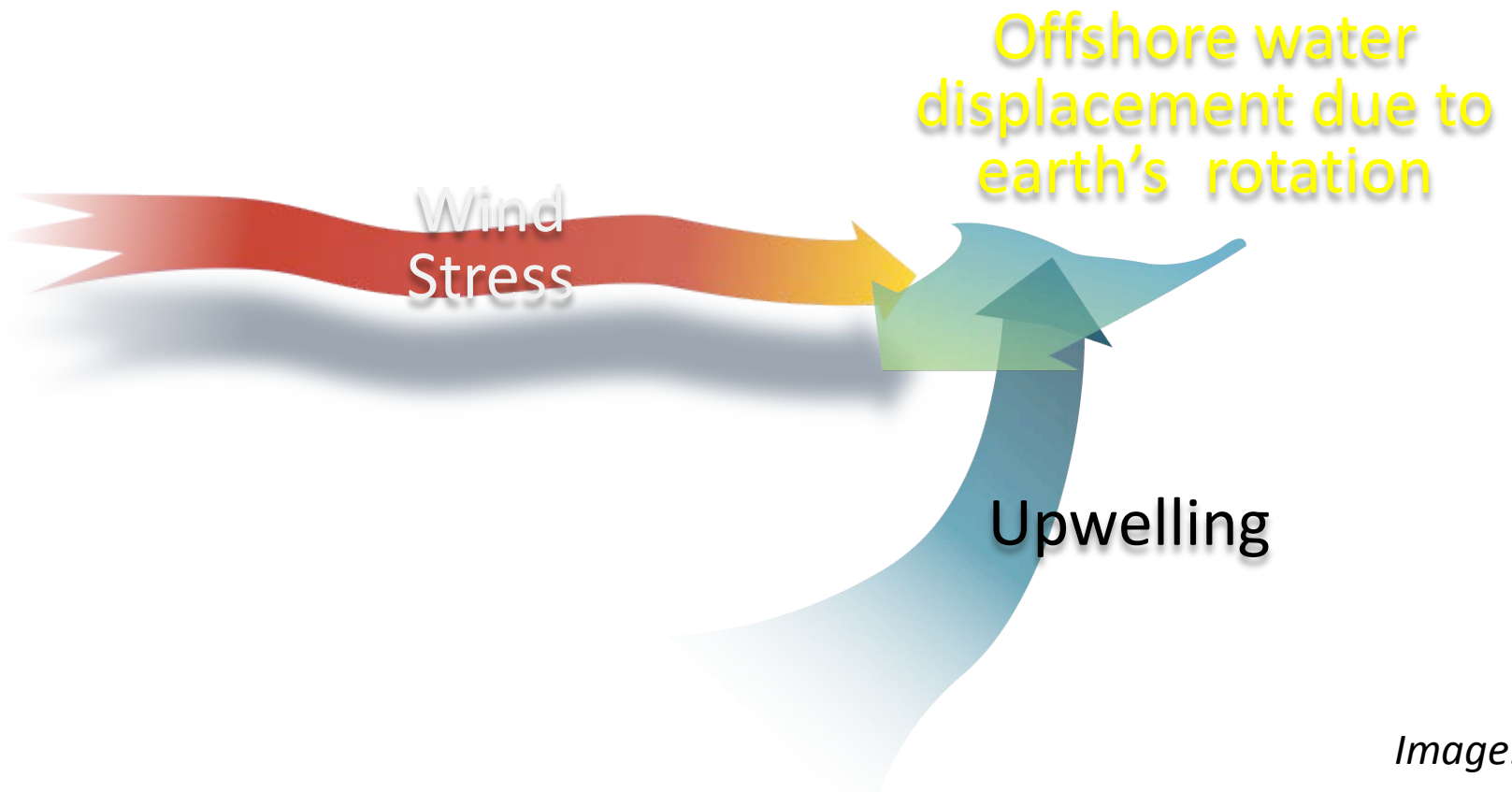


Image: NOAA PMEL

Processes that fuel increased respiration yield higher CO_2 and lower pH

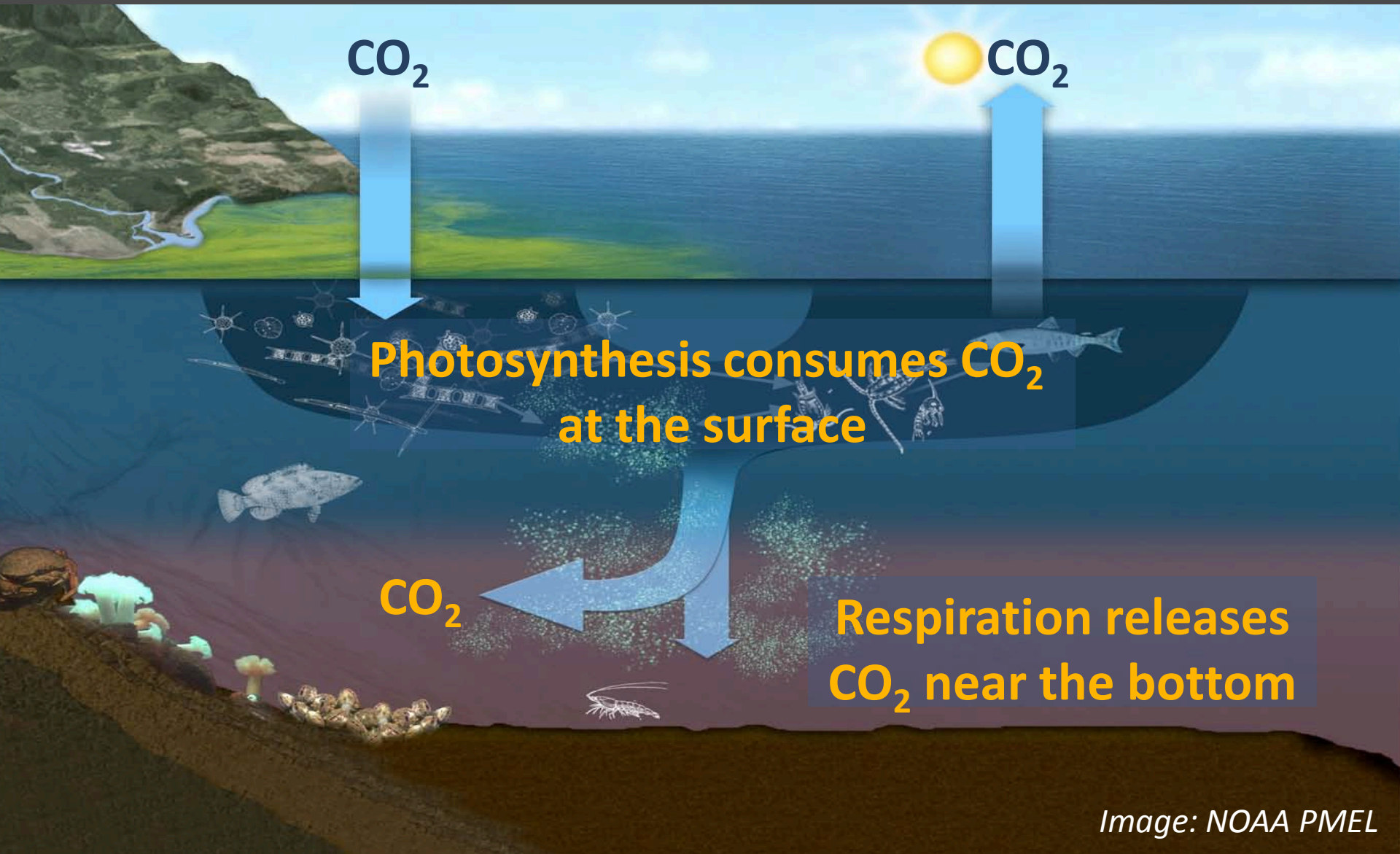
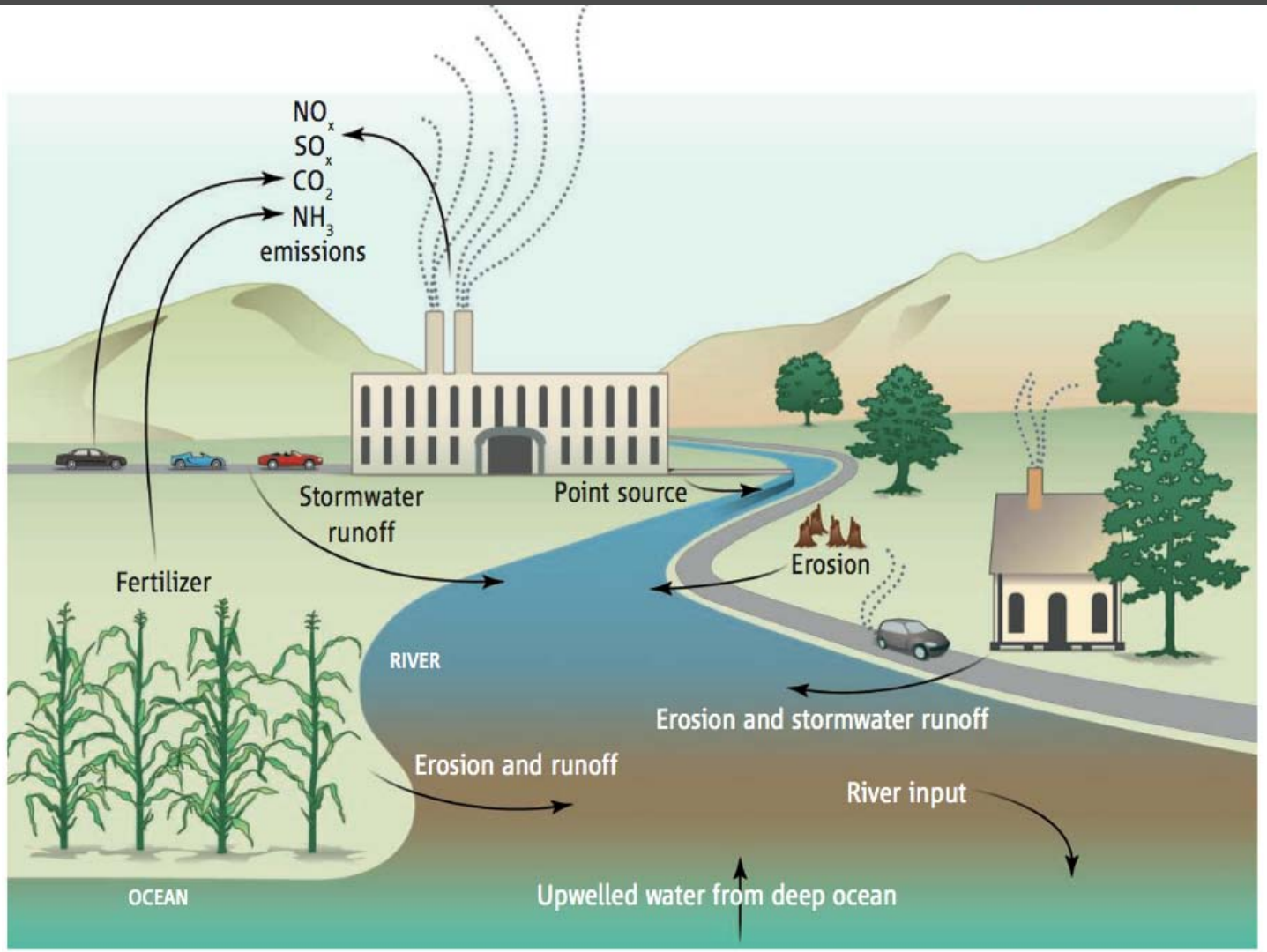


Image: NOAA PMEL

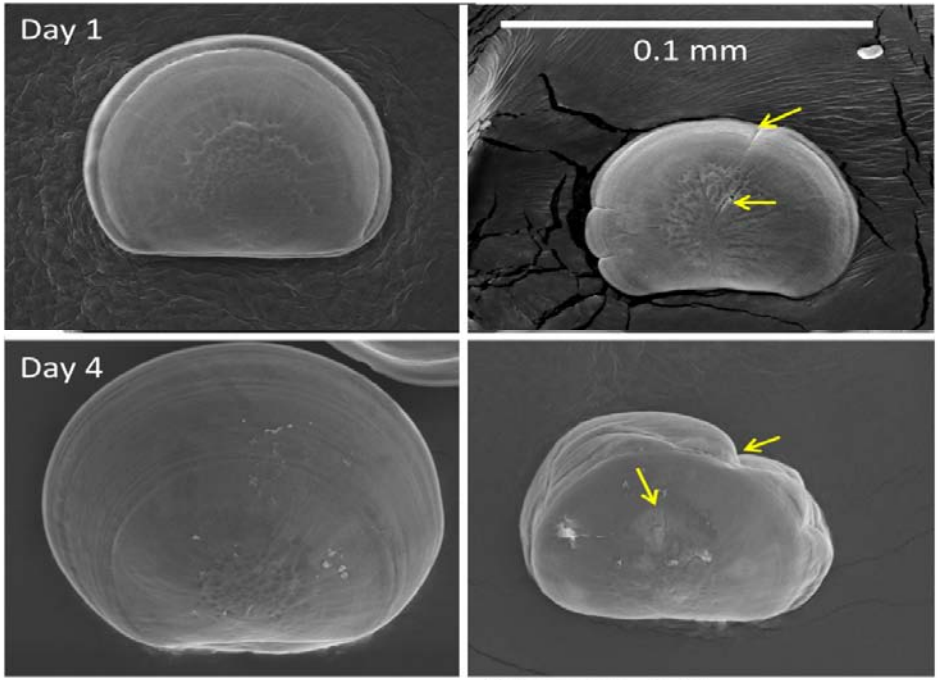
Are local stressors contributing too?



Kelly et al. (2011) Science

Six things we know about ocean acidification in Pacific Northwest coastal waters

1. **Rising atmospheric CO_2 changes ocean chemistry and negatively impacts shelled organisms.**
2. **Pacific Northwest shellfish are sensitive to reduced calcium carbonate-saturation state within the current range of conditions.**



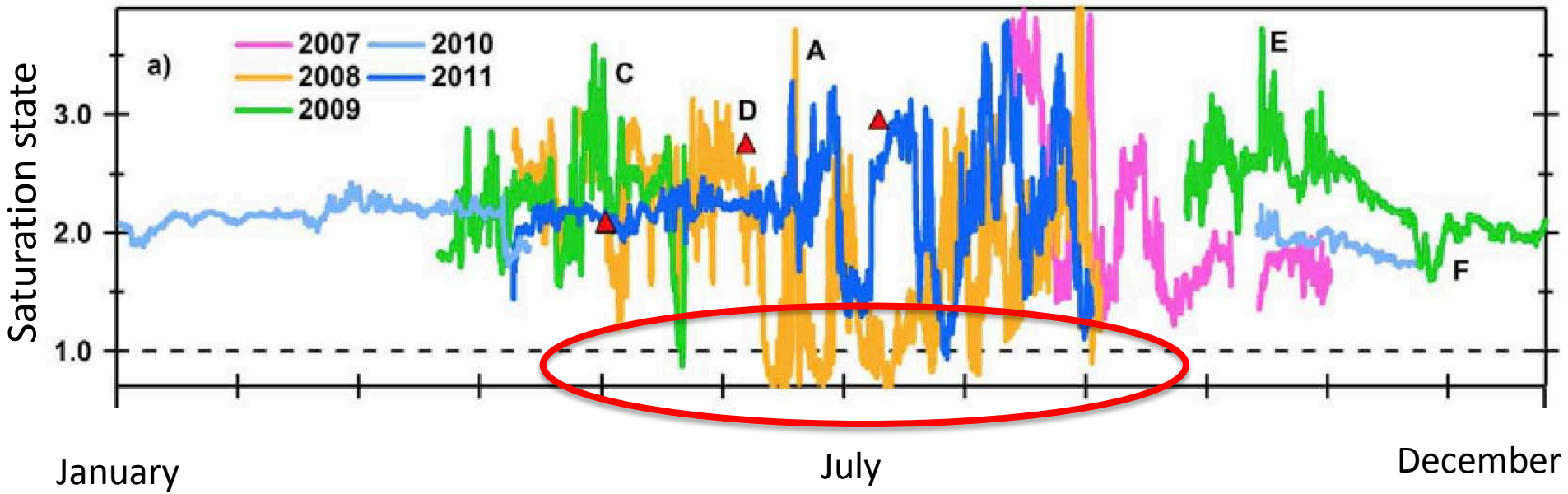
Pacific oyster larvae spawned in favorable (left) and unfavorable (right) seawater conditions

Figure source: E. Brunner and G. Waldbusser, Oregon State University

Six things we know about ocean acidification in Pacific Northwest coastal waters

3. **Natural and anthropogenic contributions are additive.**
4. **Anthropogenic contributions to ocean acidification are detectable and have increased the frequency, intensity, and duration of harmful conditions.**

Shell mineral availability off Newport, Oregon



"Makes a bad day worse…"

Harris et al. 2013

Six things we know about ocean acidification in Pacific Northwest coastal waters

5. Small changes in the environment can cause large responses among living organisms.

6. Local species are affected.

Mussel larvae exposed to high CO_2 are more easily crushed *Gaylord et al 2011*

Photo: B. Gaylord

Photo: PISCO

Implications for Marine Food Webs & Ecosystem Services

Many biological processes are sensitive to changes associated with OA.

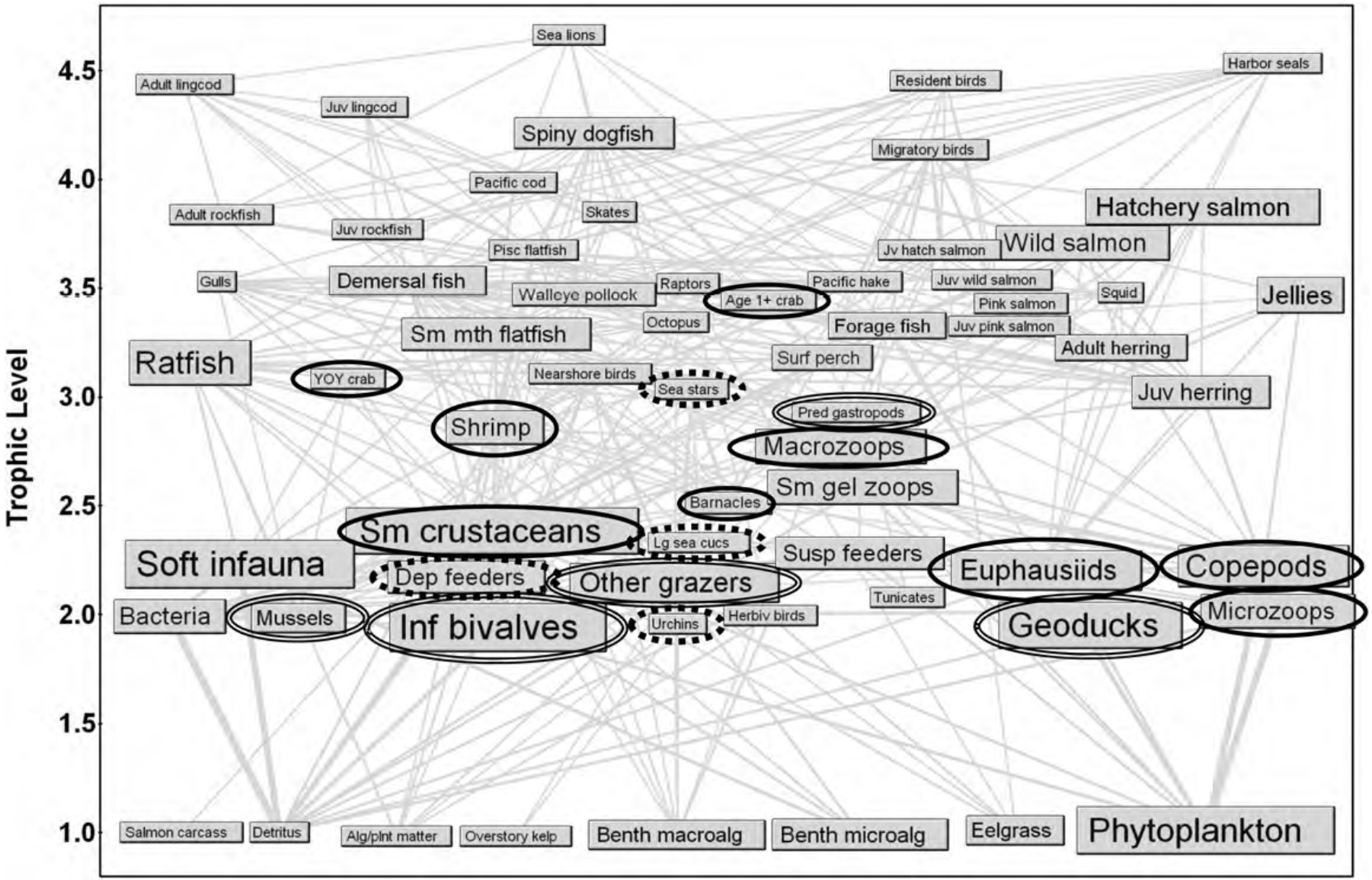
These include:

- Increased mortality among pteropods (a type of plankton)
- Impacts on the nervous system of some fish
- Potential increase in toxicity of harmful algal blooms
- Potential loss of water quality benefits provided by shellfish, which filter nutrients out of marine waters

Pteropod

Photo: Russ Hopcroft

Productivity of local food webs could change



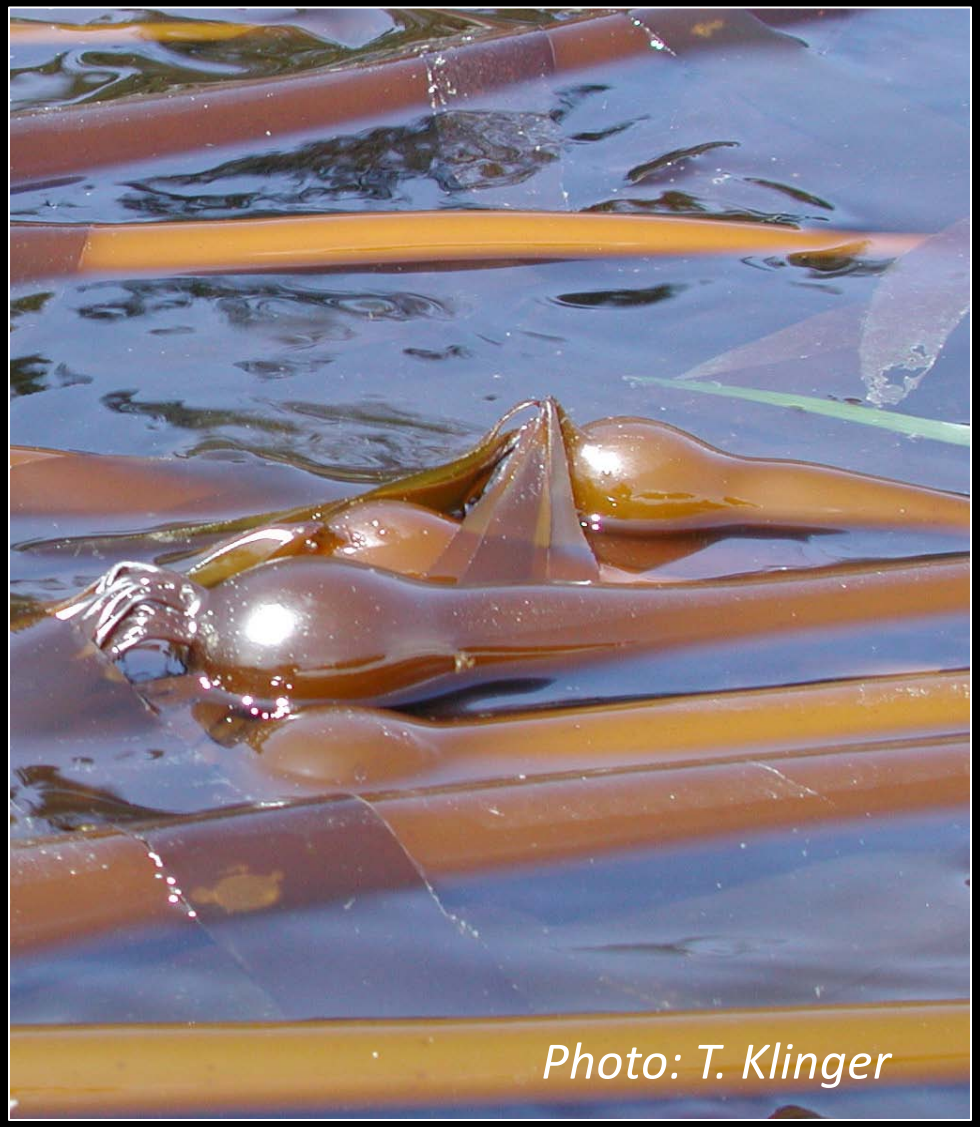
Busch et al., 2013

Implications for Marine Food Webs & Ecosystem Services

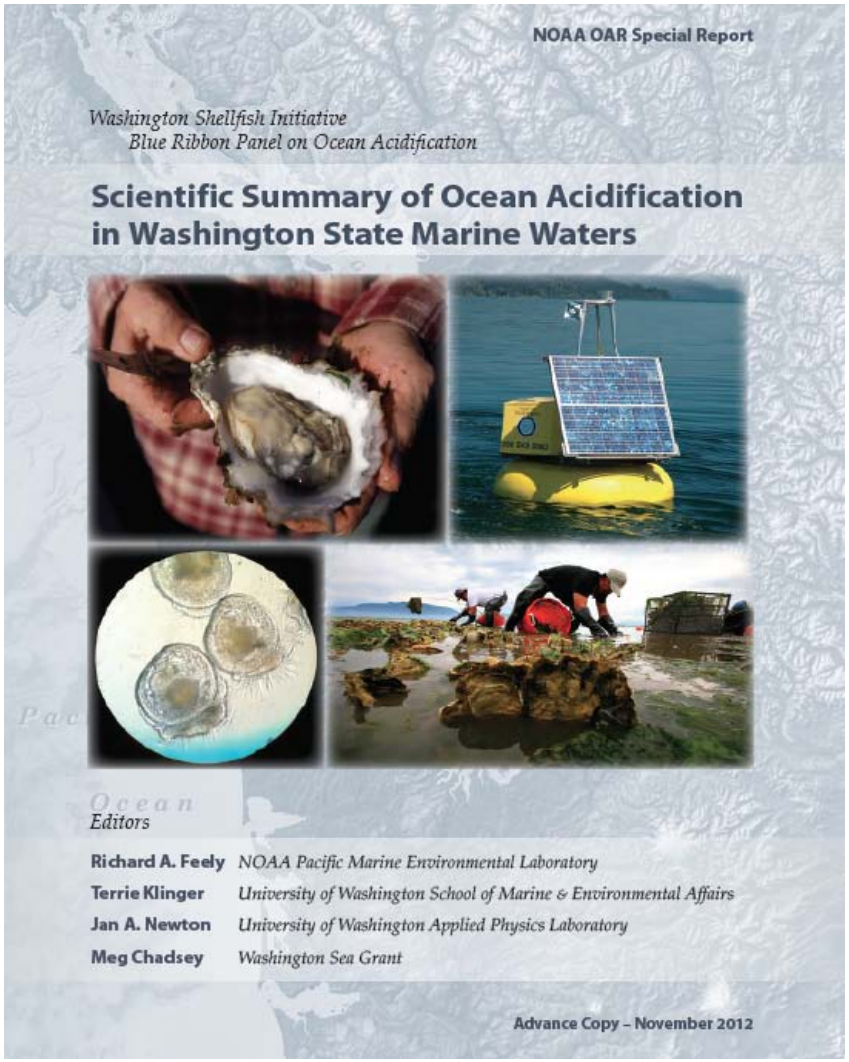
Some responses could help us meet the challenge locally.

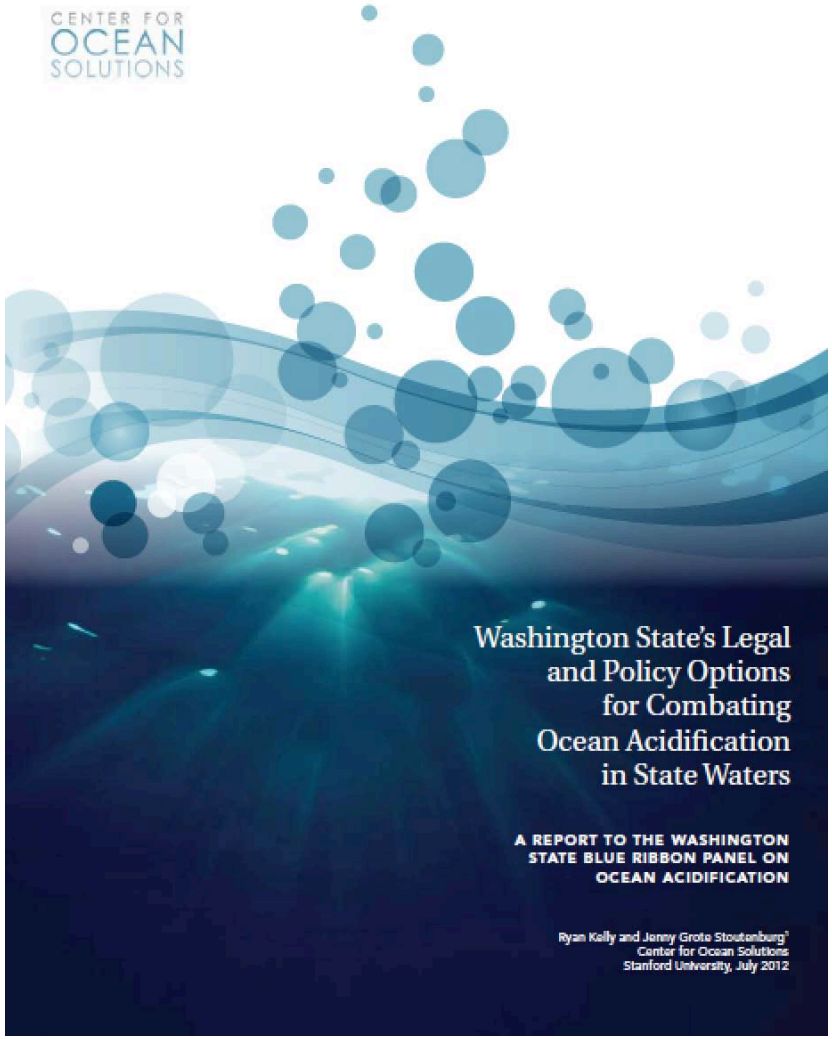
These include:

- Seagrasses and kelps could partially mitigate local effects
- Some species may be able to adapt



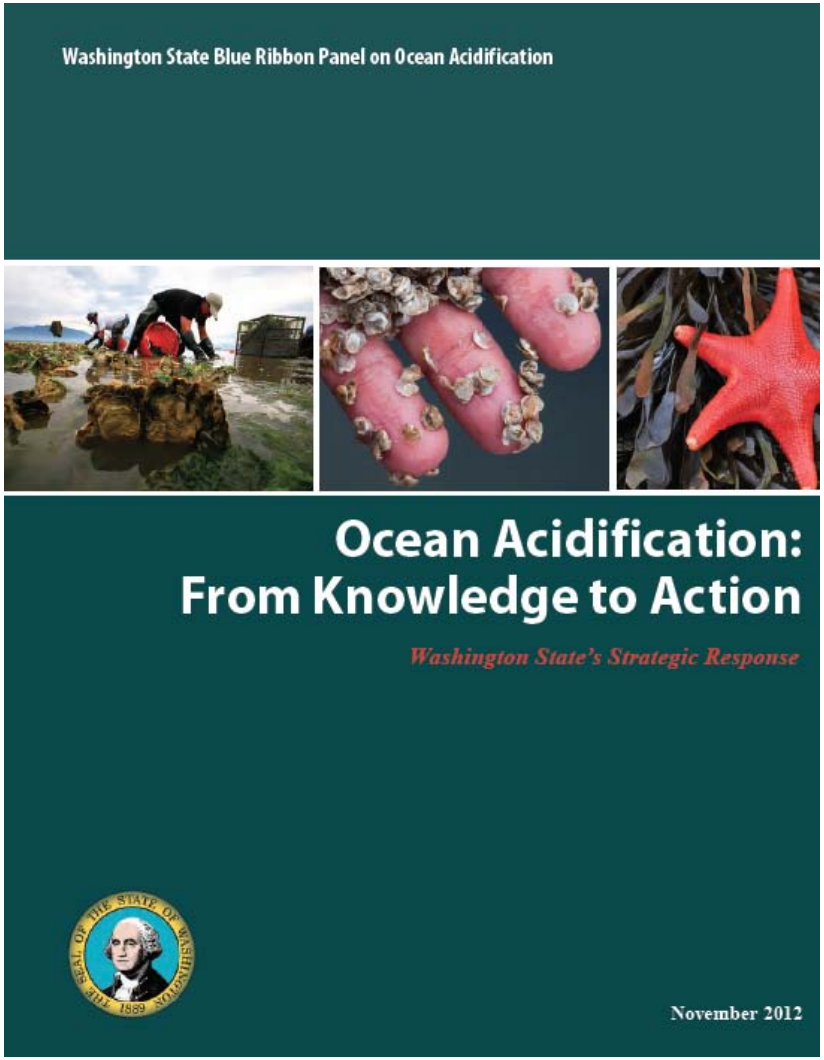
Washington State Process: Science and Policy Outputs





http://www.ecy.wa.gov/water/marine/oceanacidification.html

Washington State Process: Synthesis and Recommendations



http://www.ecy.wa.gov/water/marine/oceanacidification.html

Legislative Actions

Established the Marine Resource Advisory Council

Established the Washington Ocean Acidification Center at the University of Washington

Directed Center to implement five actions from Blue Ribbon Panel recommendations

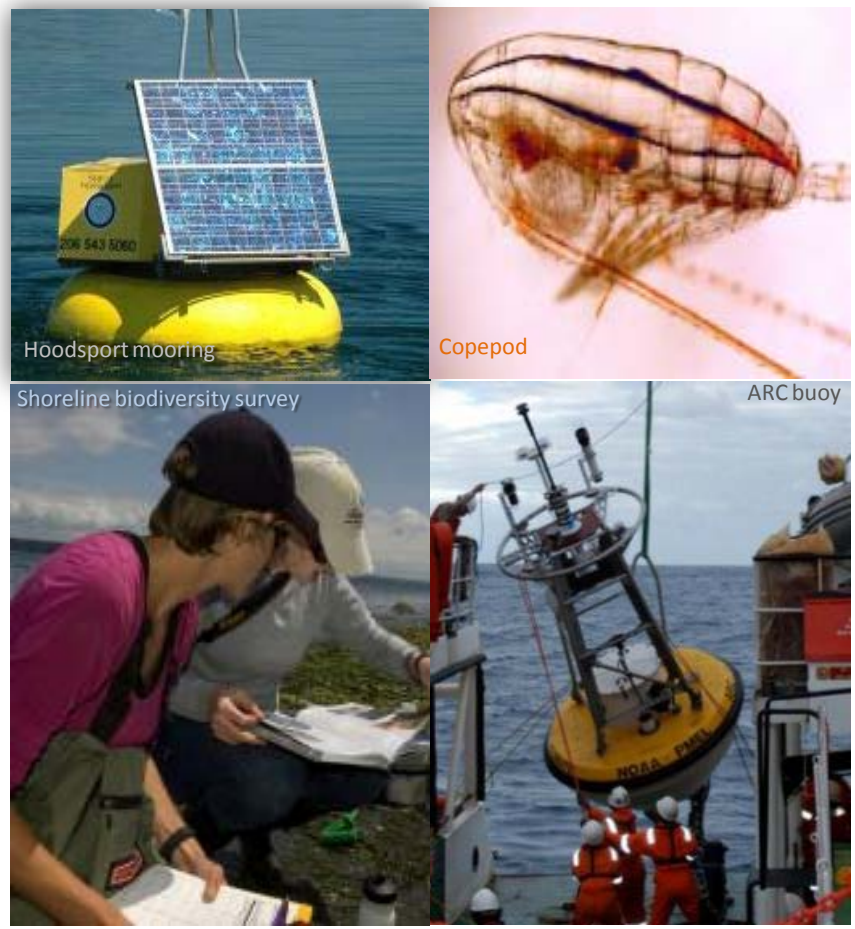
Photo: Dan Bennett

Focus on Research and Monitoring

Panel

Recommendation:

Increase research and monitoring of acidification in state waters



Photos (clockwise from upper left): Wendi Ruef; Michael J. Bok; NOAA Pacific Marine Environmental Laboratory; Northwest Indian Fisheries Commission

Washington Ocean Acidification Center

The Center is charged by the legislature to execute five priority actions from the Blue Ribbon Panel:

- continue water quality monitoring at the six existing shellfish hatcheries
- expand and sustain ocean acidification monitoring network
- make short-term forecasts of corrosive conditions
- conduct laboratory studies on Washington's species and ecosystems
- develop commercial-scale water treatment methods or hatchery designs

Washington Ocean Acidification Center

The Center will:

- **Coordinate scientific efforts** to promote scientific collaboration and leverage resources.
- **Bring a regional focus** to research and serve as a hub for OA science
- **Connect decision-relevant** OA science with managers and policy-makers.
- **Promote outreach and education**.
- **Engage broadly with others.**

Washington State is a leader

UW TODAY

Ocean acidification center another example of state leading the nation

Washington's governor and state legislators in the last session created a hub at the University of Washington to coordinate research and monitoring of ocean acidification and its effects on local sea life such as oysters, clams and fish.

Read more »

Barbara Kinney

But WA is not alone

- WA is joined by the nation's lead federal agency on ocean acidification, NOAA, that will contribute to our Center's efforts.
- WA will be engaging with EPA through the Center's participation on the West Coast Panel on Ocean Acidification and Hypoxia.
- WA will benefit from NOAA investments through US IOOS, regionally as NANOOS, that will enhance the Center's abilities.

'Like putting headlights on a car'

Pacific oysters gain from IOOS® data

Promoting Economic Vitality

About six years ago, production at some Pacific Northwest oyster hatcheries began declining at an alarming rate, posing severe economic impact and challenging a way of life held by shellfish growers for more than 130 years.

By 2008, the oyster harvest at Whiskey Creek, a major Oregon supplier to the majority of West Coast oyster farmers, plummeted 80 percent. At about the same time, corrosive, acidified seawater was hitting the shores of the Pacific.

Something had to be done. Oyster production accounts for more than $84 million of the West Coast shellfish industry, which supports more than 3,000 jobs.

"When you see oyster shells dissolving in water, there's a compelling need to know why," says Bill Dewey of Taylor Shellfish Farms in Washington state.

Thanks to a $500,000 federal investment in monitoring coastal seawater strengthened by data and observational information from the U.S. **Integrated Ocean Observing System** (IOOS®) and the **NOAA Ocean Acidification Program**, oyster hatcheries on the verge of collapse just a few years ago are again major contributors to the $111 million West Coast shellfish industry.

IOOS is a NOAA-led interagency and regional effort aimed at "knowing" — that

IOOS partners in the Northwest Association of Networked Ocean Observing Systems (NANOOS) deployed this buoy in 2010 as part of a three-piece observing array to assess issues in the Northwest, including **ocean acidification**, **hypoxia and harmful algal blooms**, and **climate change**. The coastal buoy will aid computer models that predict ocean and atmospheric conditions. Known as "Chá bă," the buoy is named for the Native American word (pronounced "chay buh") for "whale tail."

(Photo courtesy of Dr. John Payne, Pacific Ocean Shelf

"Putting an IOOS buoy in the water is like putting headlights on a car. It lets us see changing water conditions in real time," says Mark Wiegardt, co-owner of Whiskey Creek Shellfish Hatchery.

OA response must be at many scales

- **Regional:**
  - NOAA OAP & PMEL works with NANOOS to site sensors, serve data, provide outreach
  - NANOOS integrates federal, tribal, state, industry, tribes, academia to work collectively
- **National:**
  - NOAA OAP and US IOOS work together on OA observing capacity
  - Inter-agency Federal Working Group on OA
- **Global:**
  - NOAA OAP and US IOOS have lead effort to establish Global OA Observing Network, based on 29 nation consensus plan
  - International GOA-ON Steering Committee to guide

Global Ocean Acidification Observing Network (GOA-ON) Monitoring Physics, Chemistry and Biology of the Global Oceans

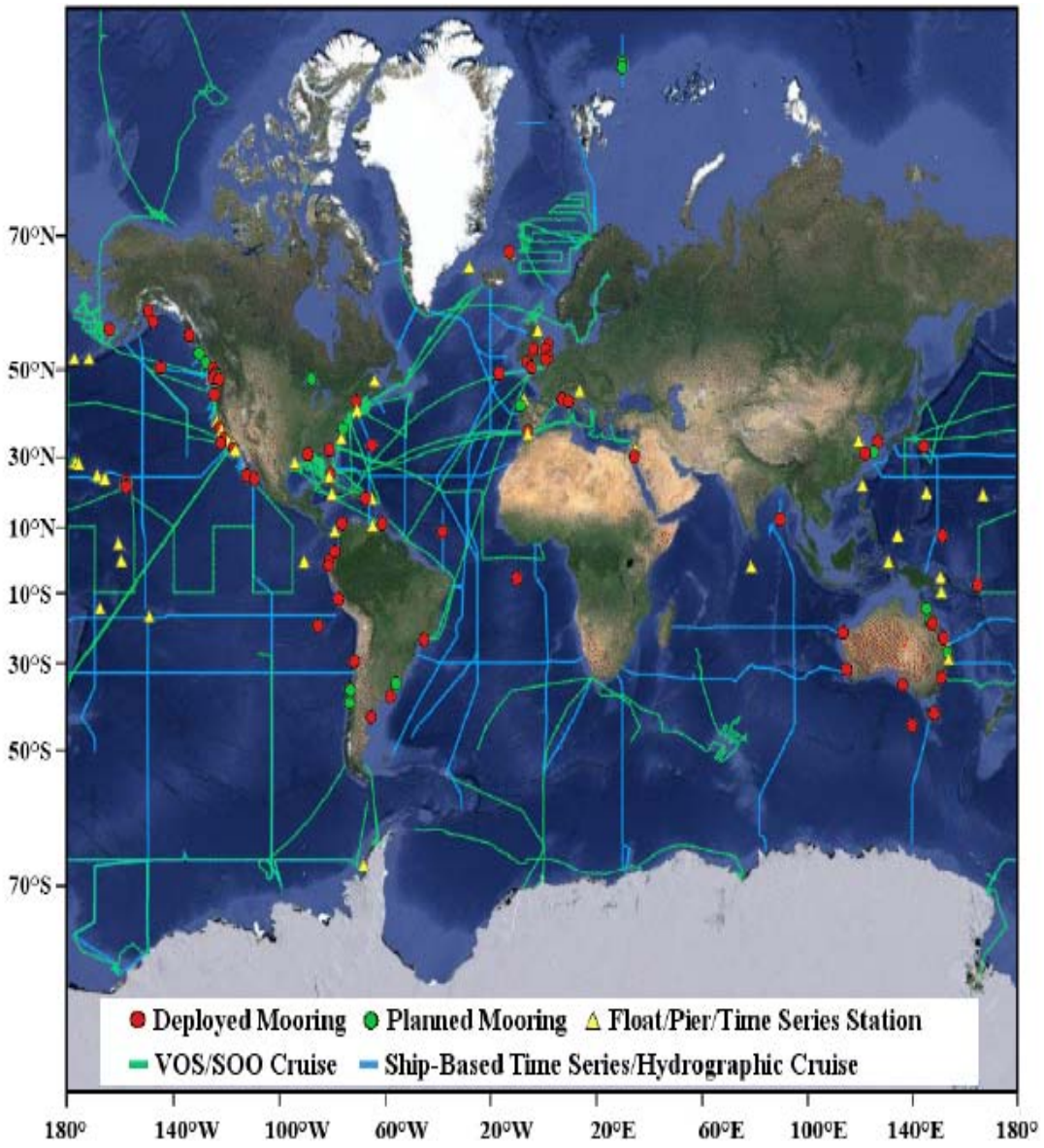
Global Ocean Acidification Observing Network

29 countries are involved

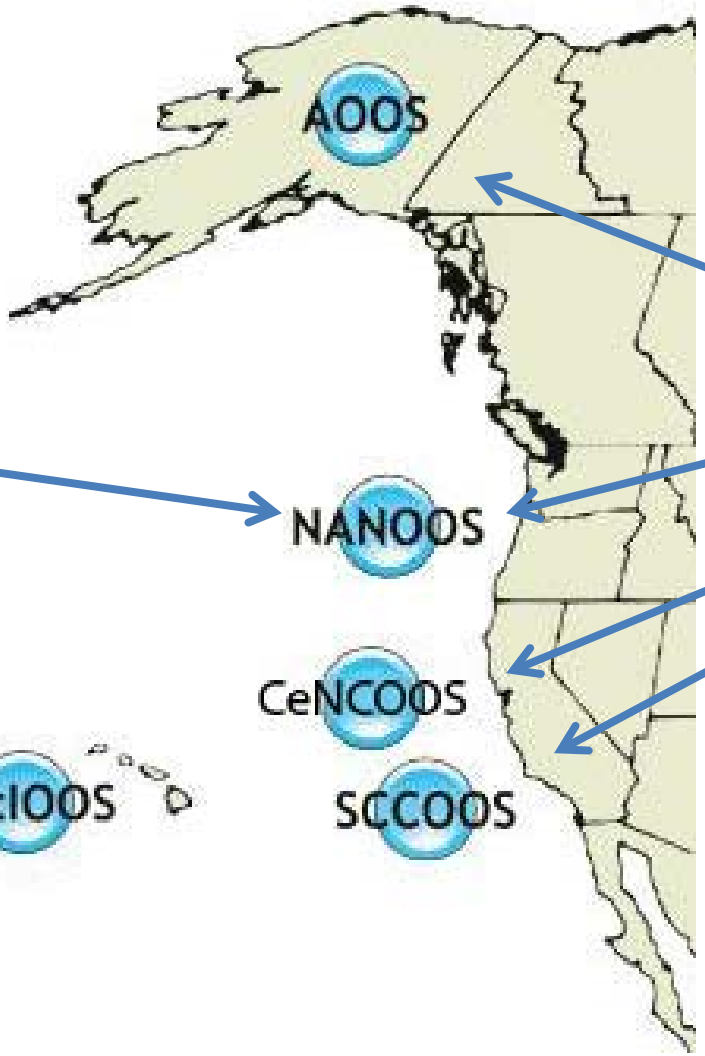
Goal 1: Provide an understanding of global ocean acidification conditions

Goal 2: Provide an understanding of ecosystem response to ocean acidification

Goal 3: Provide data necessary to optimize modeling for ocean acidification



NOAA technology investments



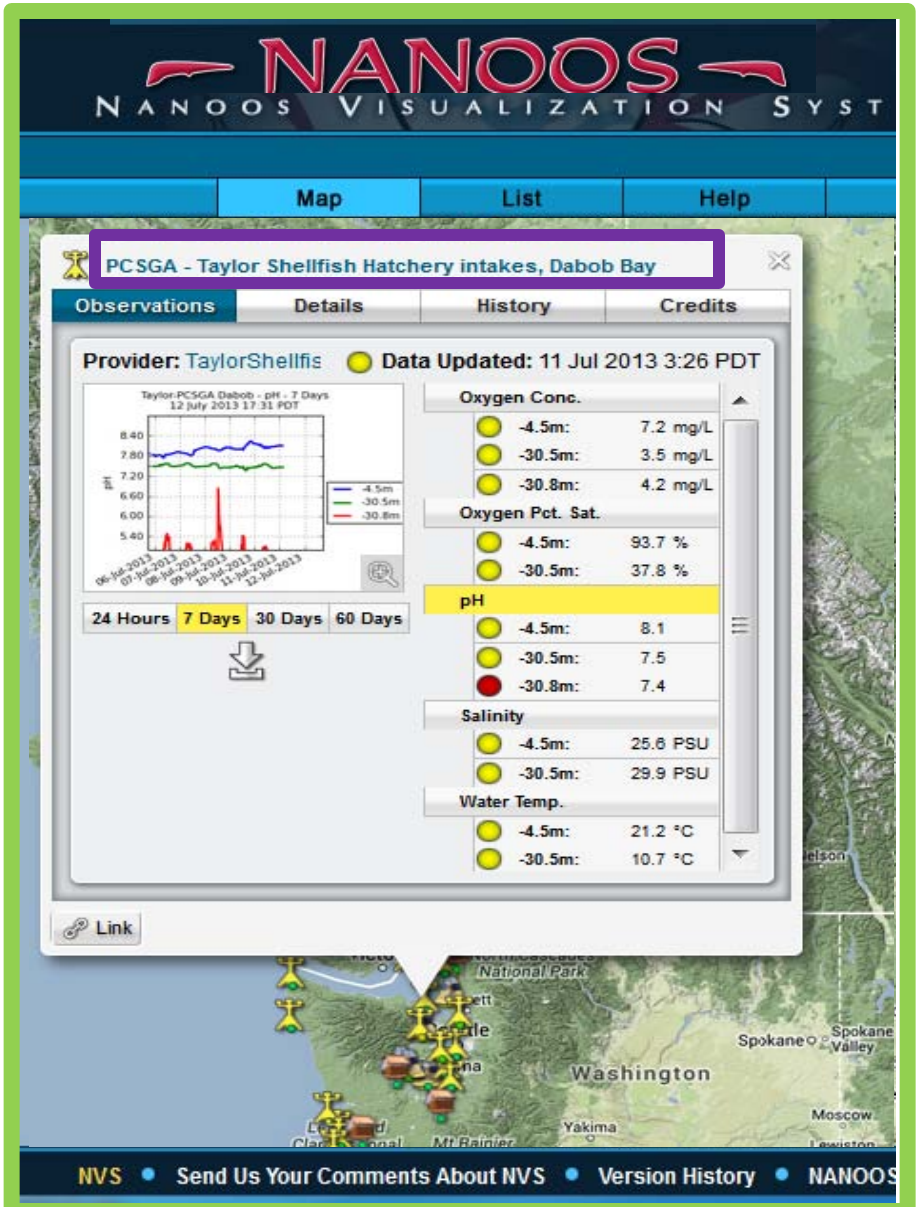
Field testing pH at depth and on profiling estuarine buoys

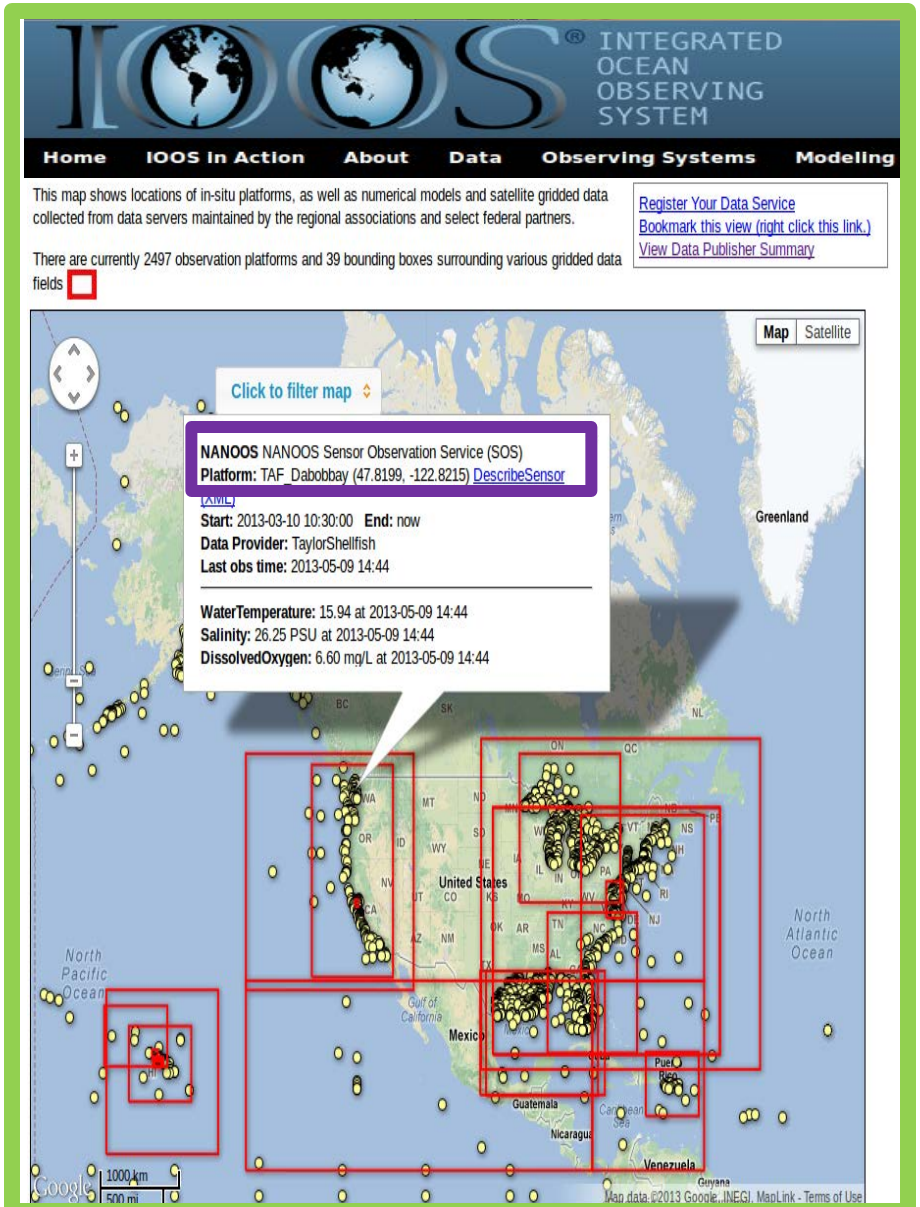
Shellfish hatchery monitoring with expert consultants and joint data delivery

Field testing DIC sensor

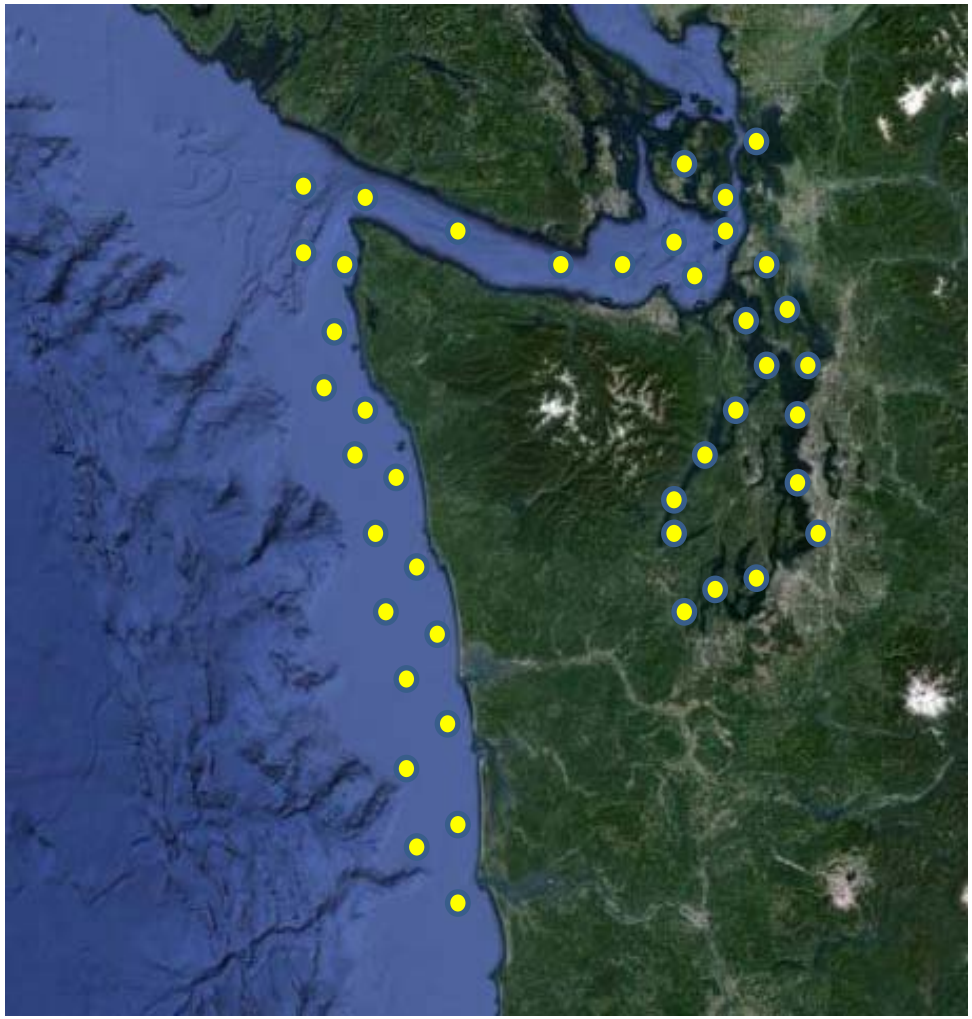
IOOS data investments

OA data accessible via regional portals AND discoverable nationally via IOOS



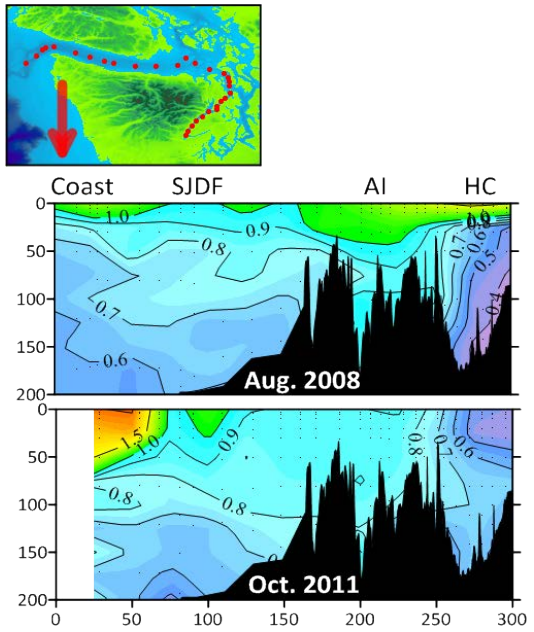


NOAA & WA OA Center shared shiptime investment



NOAA PMEL & UW-NANOOS

- Past shared cruises yielded important insights to condition
- Currently engaging in joint cruise planning, inclusive of other science partners



Alin et al., in prep.; Feely et al., 2010



Ocean Acidification: From Knowledge to Action

Washington State's Strategic Response

- OA is a global problem with local effects.
- This issue demands a local and coordinated response.
- The Center works on all scales, local to global, to bring knowledge on ocean acidification to Washington