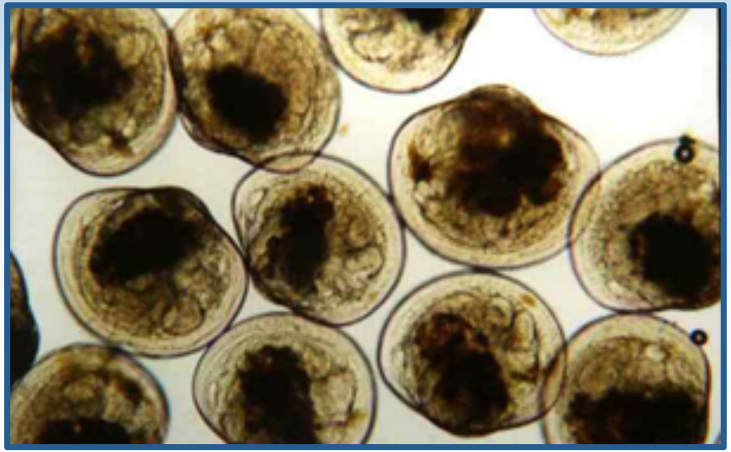
Ecosystems

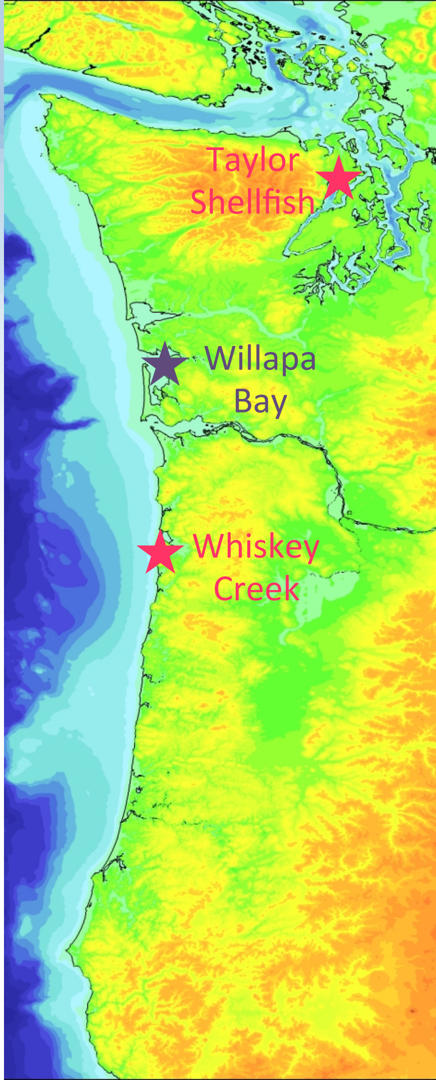
Ocean Acidification Program – Simone Alin
Richard Feely, Adrienne Sutton,
Chris Sabine, Jeremy Mathis

Pacific Northwest hatchery failures

Relevance



Photos: Taylor Shellfish



"Between 2005 and 2009, disastrous production failures at Pacific Northwest oyster hatcheries signaled a shift in ocean chemistry that has profound implications for Washington's marine environment."

Washington Blue Ribbon Panel on Ocean Acidification 2012

Ocean Acidification (OA) Chemistry 101

CO_2

$$CO_2 + H_2O \rightarrow H_2CO_3$$

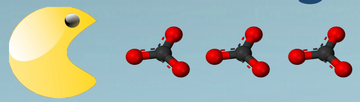
carbon dioxide — water — carbonic acid

$$H_2CO_3 \downarrow$$

hydrogen ion / pH → $H^+ + HCO_3^-$ — bicarbonate ion

$$\downarrow$$

$H^+ + CO_3^{2-}$ ← carbonate ion / saturation state (Ω)



How CO_2 in seawater affects marine life

Changes in chemistry

$CO_{2(aq)}$ ↑

HCO_3^- ↑

CO_3^{2-} ↓

pH ↓

Biological effects

Increase in photosynthesis

Decrease in calcification

Changes in physiology

Global

Temp ↑

Oxygen ↓

Regional

Overfishing

Pollution

Oil spills

Socioeconomic implications of ocean acidification

In Washington State alone:

- The shellfish aquaculture industry is worth $270 million per year and employs more than 3,200 people.
- Recreational shellfish harvesting contributes another $30 million per year to the state.
- The seafood industry generates 42,000 jobs and contributes $1.7 billion to gross state product.
- Shellfish are an important natural resource and of cultural importance to Washington's tribal communities.

Washington Blue Ribbon Panel on Ocean Acidification 2012

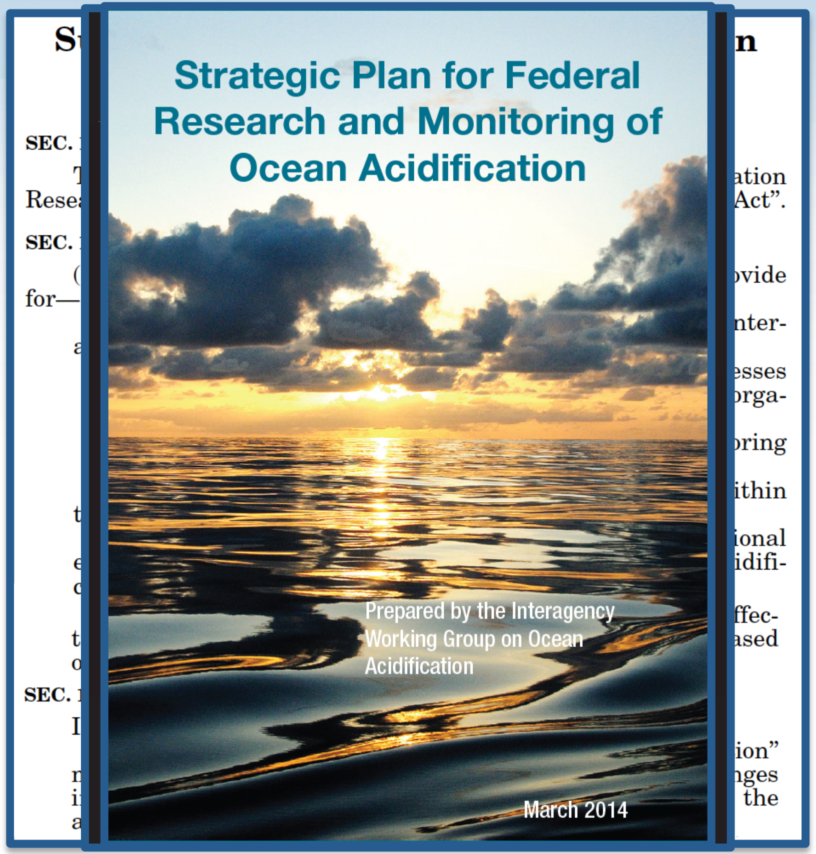
A brief history since 2008

2009 – FOARAM Act passed by Congress

2010 – NOAA OA Research Plan, PMEL heavy contributor

2010 – NOAA Ocean Acidification Program officially starts, first NOAA OA funding to PMEL

2014 – Interagency Working Group on OA releases Strategic Plan



Relevance to NOAA Goals

NOAA Ocean Acidification Program Themes

NOAA Next Generation Strategic Plan

Climate Adaptation and Mitigation

- Improved scientific understanding
- Assessments identify impacts, inform decisions
- Climate-literate public

Healthy Oceans

- Improved understanding of ecosystems
- Sustainable fisheries, safe seafood

Resilient Coastal Communities & Economies

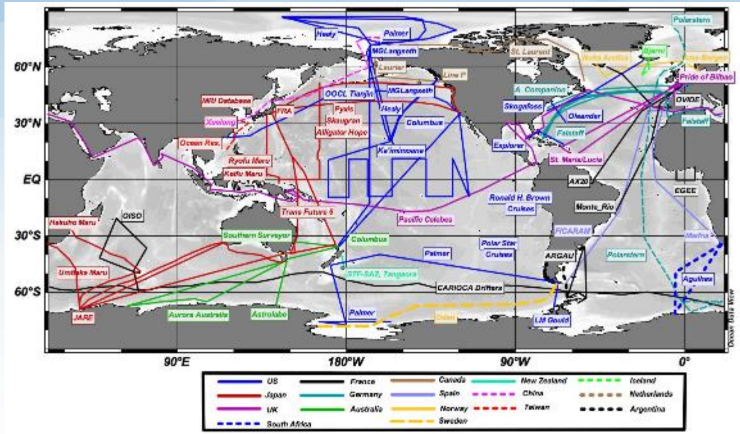
- Resilient coastal communities
- Improved coastal water quality

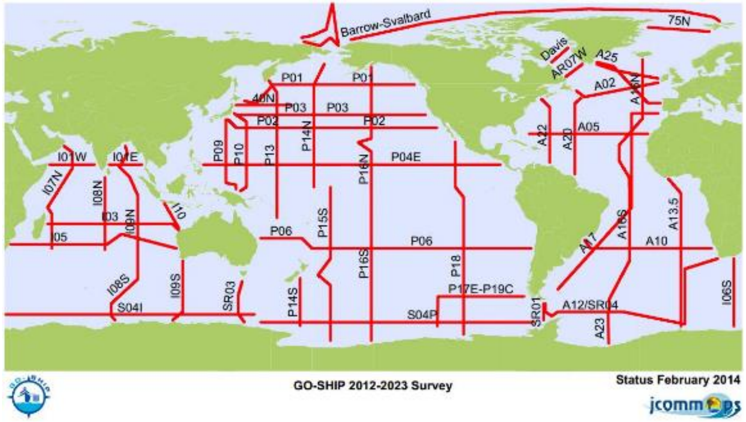
Key questions

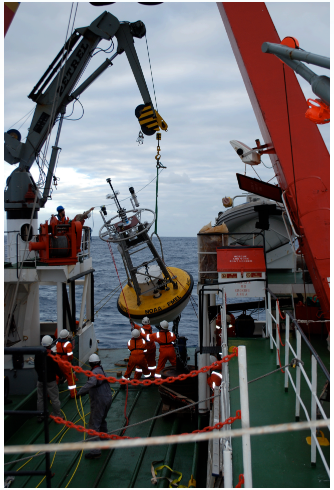
- ***How rapidly is ocean carbon chemistry changing?***
- ***What will the effects be on marine ecosystems and the human communities that depend on them?***

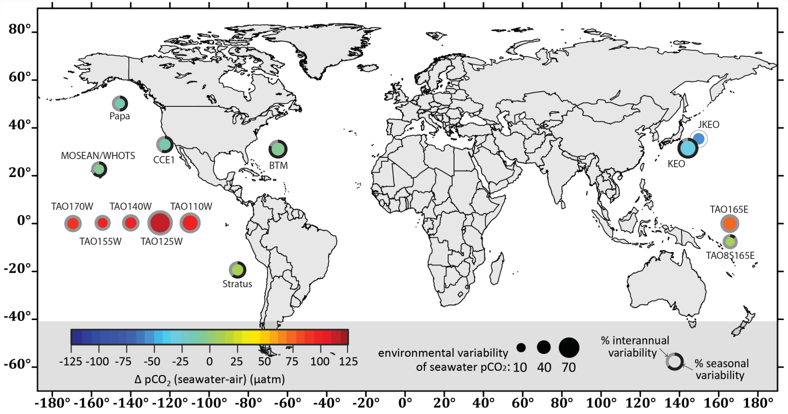
Open-ocean observations

SURFACE OCEAN CO_2 ATLAS



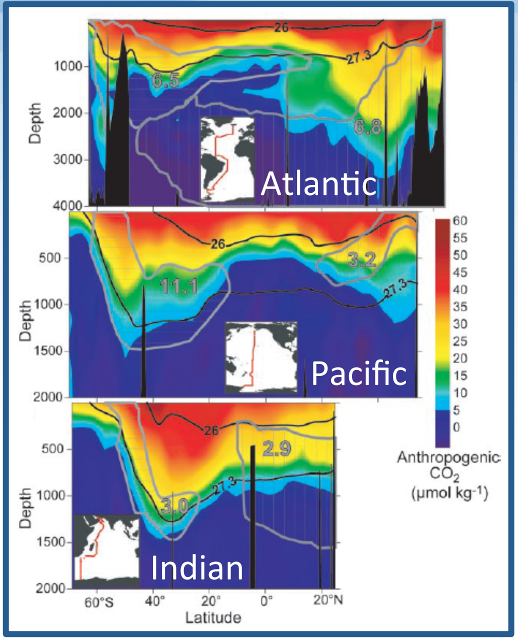






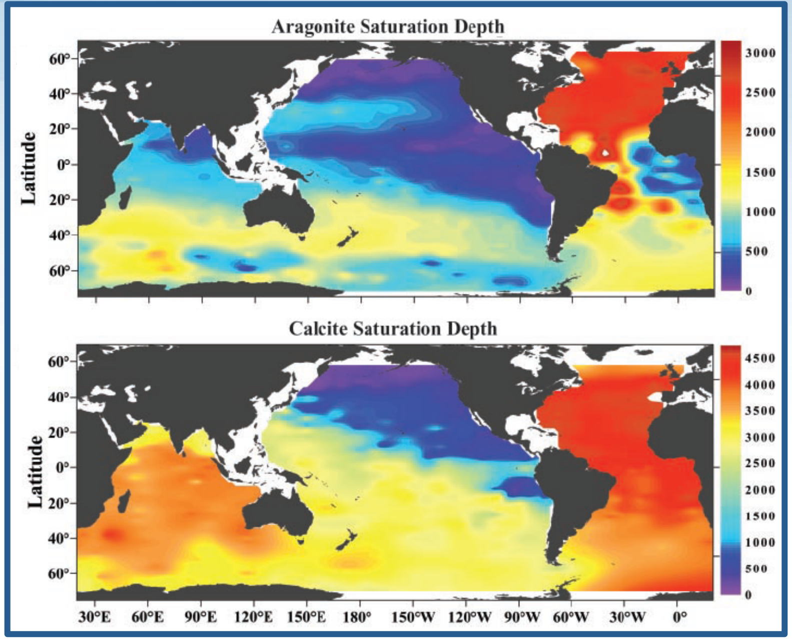
Ocean acidification in global ocean basins

Anthropogenic CO_2 inventory



Sabine et al. 2004

Saturation state depths



Feely et al. 2004

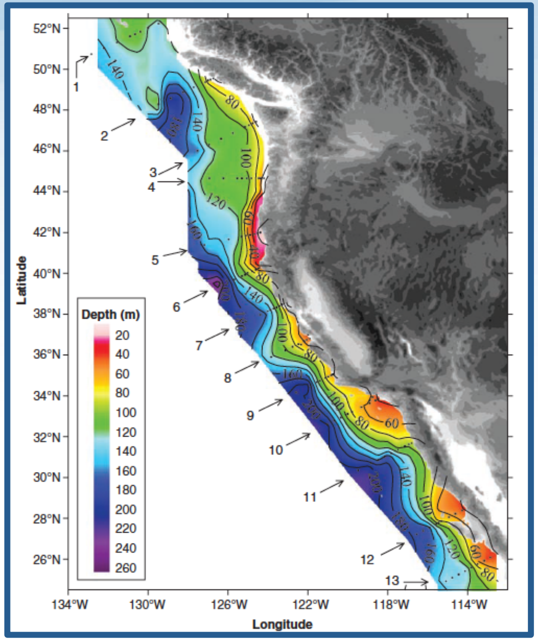
Key findings:

- Oceans had taken up roughly half of the anthropogenic CO_2 emitted between 1800 and 1994.
- Acidification driven by this uptake causes saturation horizons to shoal by 1–3 m/yr.

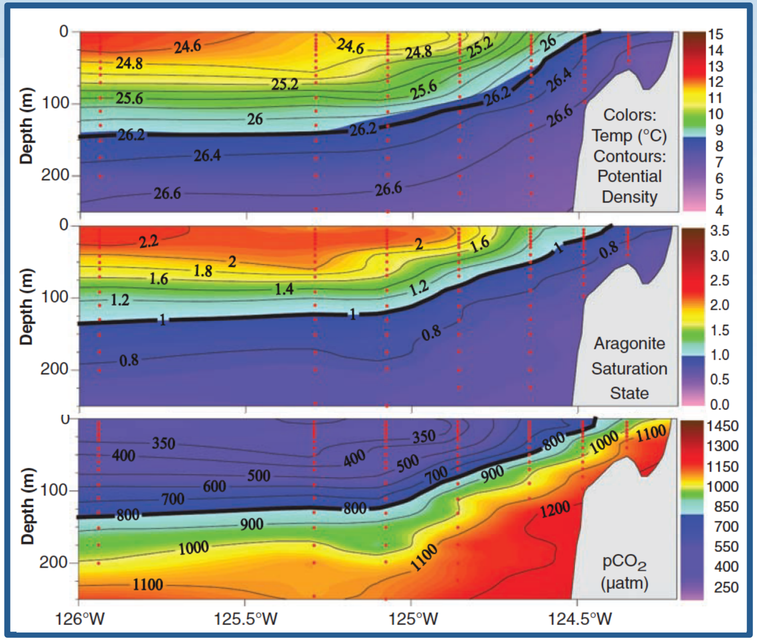
First coastal observations of ocean acidification

May–June 2007

Saturation state depths



Corrosive water at the surface



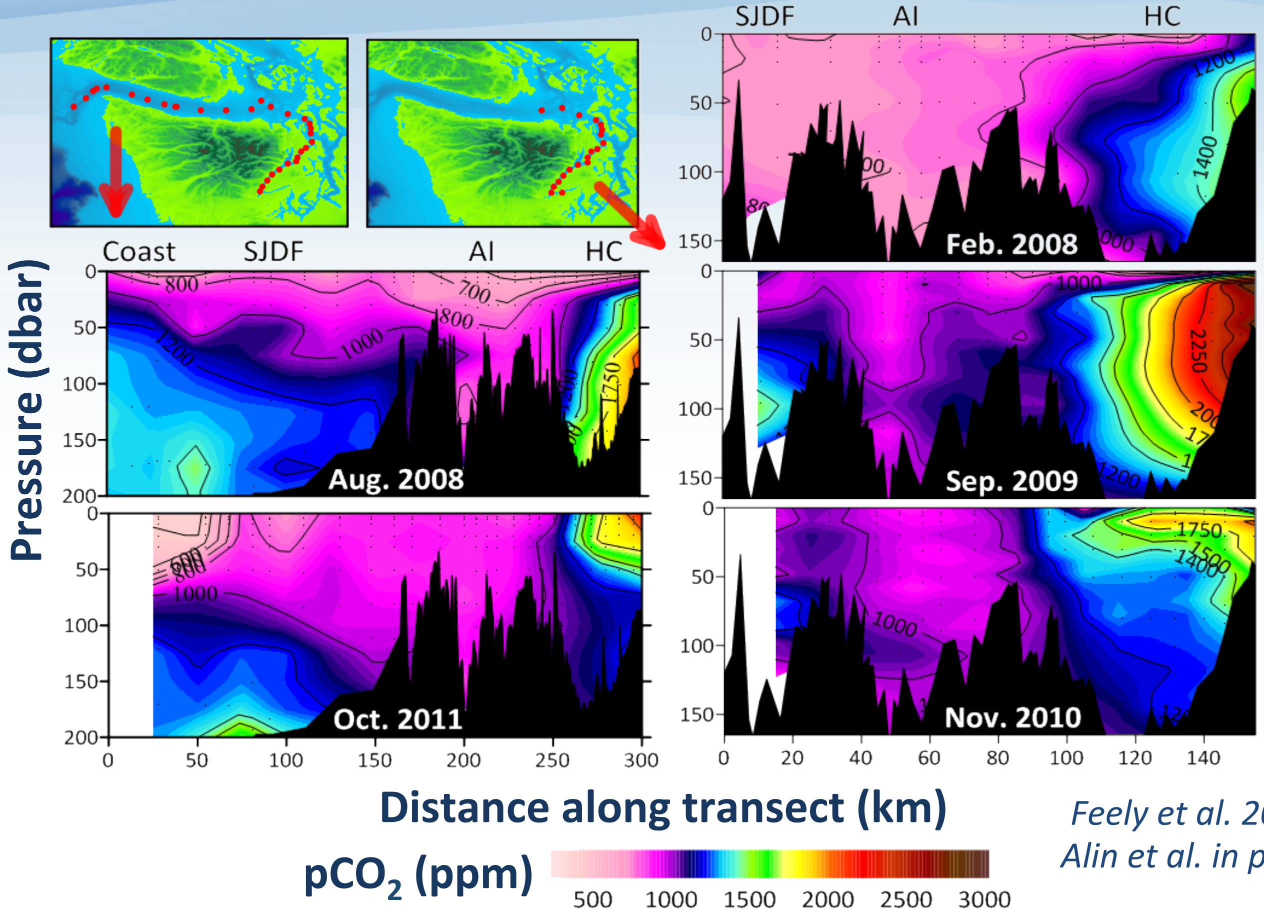
Feely et al. 2008

Key finding:

- Water undersaturated with respect to aragonite was observed upwelling to the surface along northern California coast, decades sooner than expected based on open-ocean observations and models.

Ocean acidification in estuaries: Puget Sound

Quality



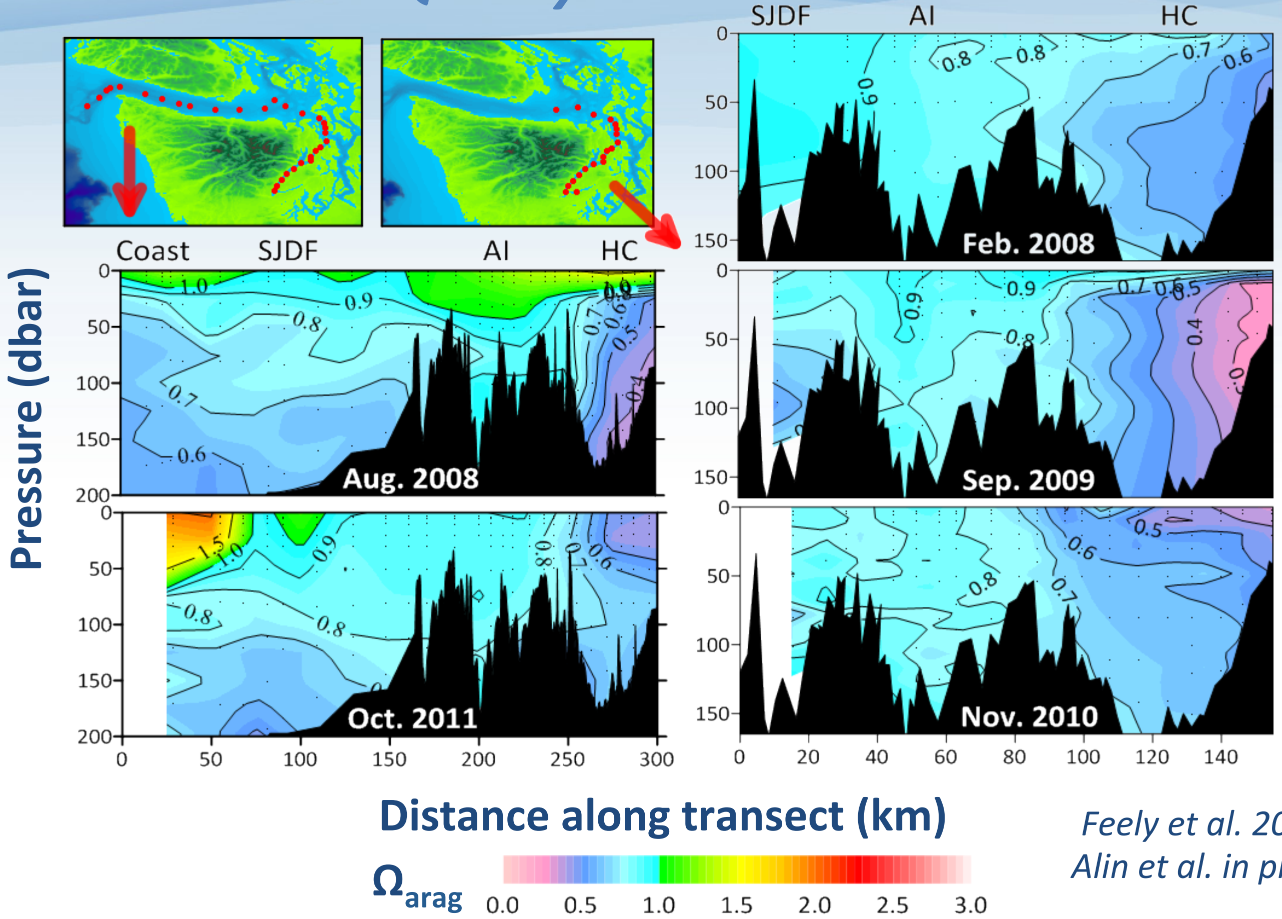
Key findings:

- Since 2008, we have observed pCO_2 values over 3000 ppm near the surface in Hood Canal.

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

Ocean acidification in estuaries: Puget Sound

Quality



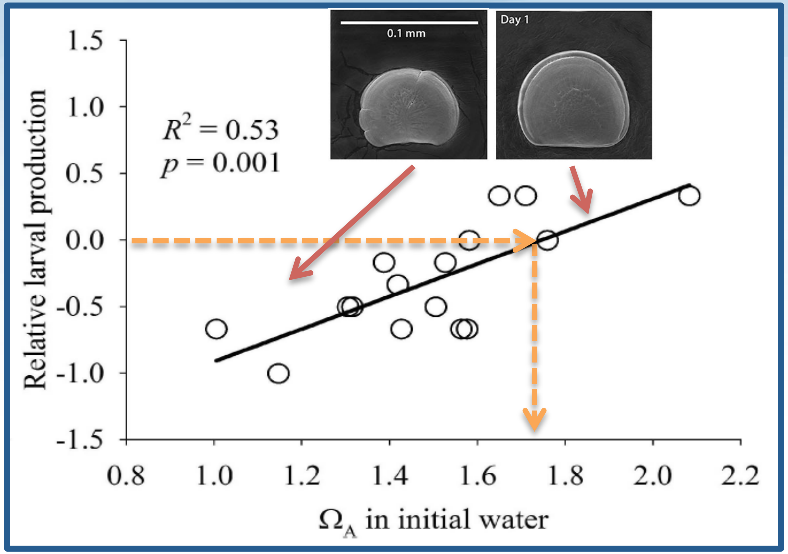
Key findings:

- Since 2008, we have observed Ω_{arag} values as low as 0.26 in Puget Sound.

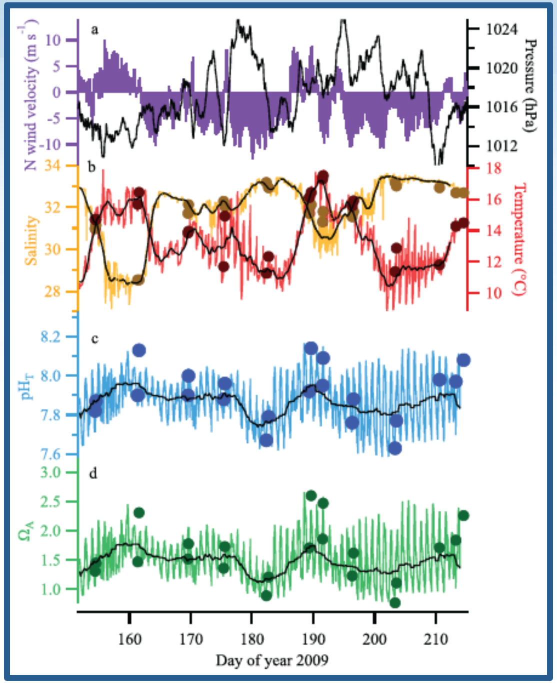
Feely et al. 2010, Alin et al. in prep.

Oyster production declines with elevated CO_2

Quality



Photos: G. Waldbusser, E. Brunner



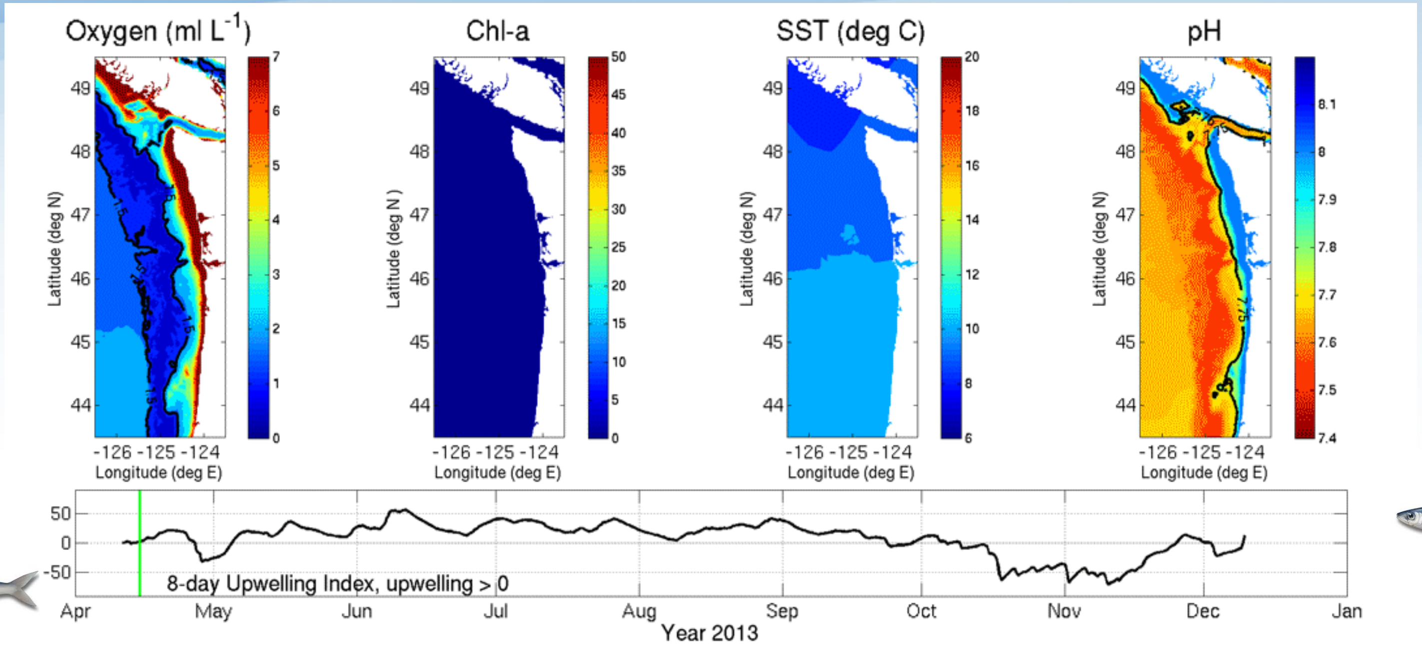
Barton et al. 2012

Key outcomes:

- Break-even point identified between net growth and mortality.
- Larvae have smaller shells with signs of dissolution at lower saturation states.
- Monitoring at hatcheries facilitates adaptation strategies.

Seasonal predictions of coastal chemistry

Quality



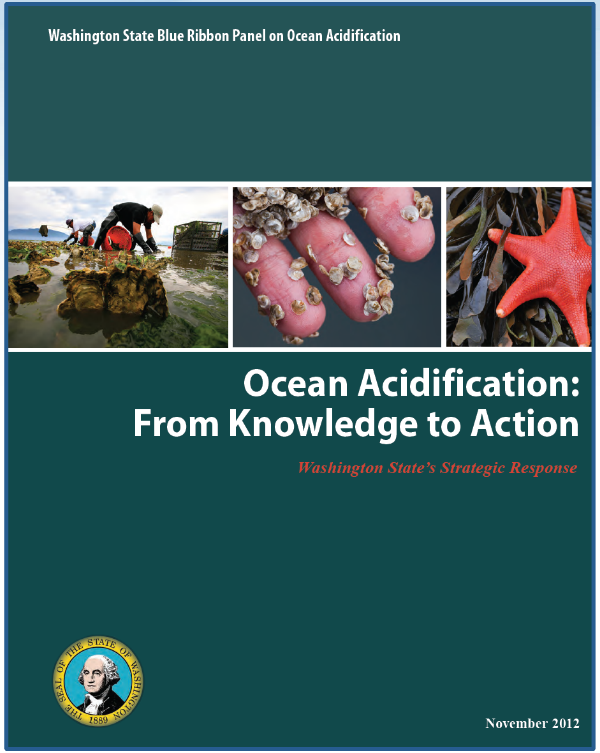
Key result: First seasonal forecast of pH and aragonite saturation state (Ω_{arag}) in 2013 captured large-scale patterns and most of upwelling season patterns quite well.

UW Coastal Modeling Group

Siedlecki et al. in prep, using empirical relationships from Alin et al. in prep

Policy linkages from shellfish-science partnership

Performance



- **Washington State Blue Ribbon Panel on Ocean Acidification** – Outgrowth of partnership with shellfish growers (2011–2012)

- **West Coast OA & Hypoxia Science Panel** – California, Oregon, Washington, and British Columbia (2013–present)

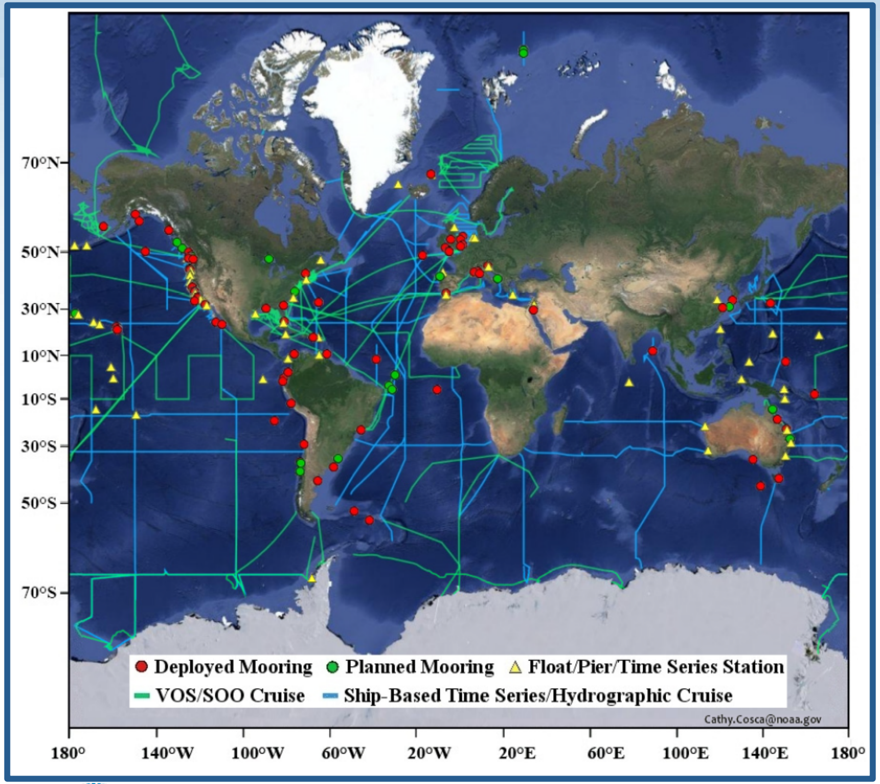
The West Coast
Ocean Acidification & Hypoxia
Science Panel

Creating an OA observing system

Performance since 2008

- Partnering with over 100 international scientists from 30 countries to build a global observing network for OA.
- Deployment of 21 OA moorings with two carbonate system measurements.
- Leading West Coast OA cruises in 2011, 2012, 2013.
- Continued carbonate measurements in Puget Sound.
- Surface pCO_2 and pH measurements on West Coast and Alaska fisheries and research cruises.
- ***See poster by Cathy Cosca for details.***

Global OA Observing Network (GOA-ON)



NOAA OCEAN ACIDIFICATION PROGRAM

INTEGRATED OCEAN OBSERVING SYSTEM

Ocean Acidification International Coordination Centre IAEA OA-ICC

http://www.goa-on.org

Discovering impacts on species and ecosystems

Performance

Pre-industrial

Present-day

2050

Photos: N. Bednaršek

Key findings:

- We are observing dissolution impacts on zooplankton in the field, with implications for marine food webs.
- ***See poster by Nina Bednaršek for details.***

Outreach, education, and science facilitation

Performance

NEXT GENERATION SCIENCE STANDARDS
PRACTICES · CONTENT · CROSSCUTTING

SEATTLE AQUARIUM

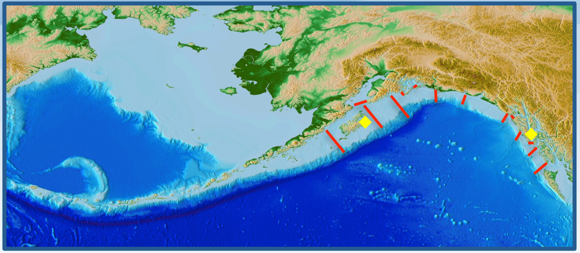
PACIFIC SCIENCE CENTER

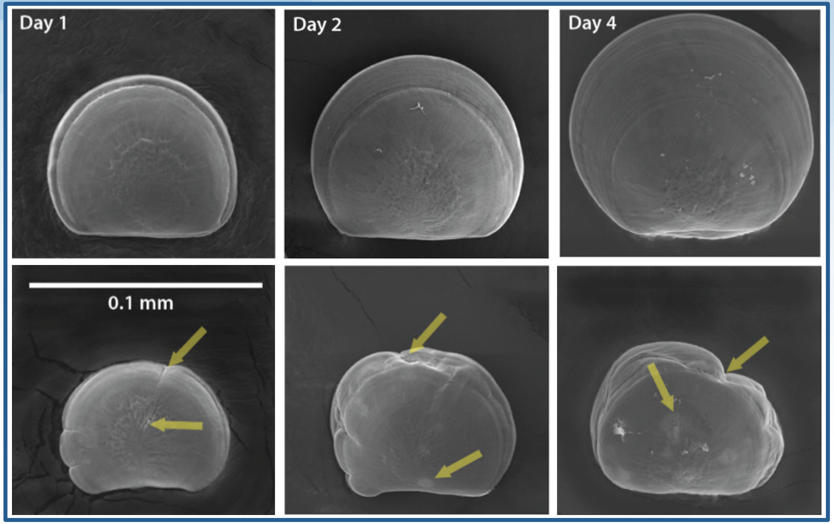
GOA-ON
Global Ocean Acidification Observing Network

OAP
OCEAN ACIDIFICATION PROGRAM

WENDY SCHMIDT OCEAN HEALTH XPRIZE
Turning the Tide on Ocean Health

Into the future…





Photos: G. Waldbusser, E. Brunner

- Maintain and strategically expand the OA observing system.
- Incorporate new sensors and platforms into GOA-ON.
- Facilitate better chemical observations through partnerships and outreach.
- Expand partnerships with biologists and modelers to understand processes and impacts.
- Support policy and water quality monitoring/regulation community.