Ecosystems

Ocean Acidification Program – Simone Alin Richard Feely, Adrienne Sutton, Chris Sabine, Jeremy Mathis
“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*
CO₂ + H₂O → H₂CO₃ (carbonic acid) → H⁺ + HCO₃⁻ (bicarbonate ion) → H⁺ + CO₃²⁻ (carbonate ion)

The pH saturation state (Ω) is affected by the increase in carbon dioxide (CO₂) levels, leading to ocean acidification (OA).
How CO₂ in seawater affects marine life

**Changes in chemistry**
- CO₂(aq)↑
- HCO₃⁻↑
- CO₃²⁻↓
- pH↓

**Biological effects**
- Increase in photosynthesis
- Decrease in calcification
- Changes in physiology

**Global**
- Temp↑
- Oxygen↓

**Regional**
- Overfishing
- Pollution
- Oil spills

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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

- IMPROVE
- MONITOR
- ENGAGE
- SYNTHESIZE
- MANAGE
- FORECAST
- ASSESS

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
Ocean acidification in global ocean basins

Key findings:
- Oceans had taken up roughly half of the anthropogenic CO₂ emitted between 1800 and 1994.
- Acidification driven by this uptake causes saturation horizons to shoal by 1–3 m/yr.

Anthropogenic CO₂ inventory

Saturation state depths

Sabine et al. 2004

Feely et al. 2004
First coastal observations of ocean acidification
May–June 2007

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.

Feely et al. 2008
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.
Key findings:
• Since 2008, we have observed $\Omega_{\text{arag}}$ values as low as 0.26 in Puget Sound.
Oyster production declines with elevated CO₂

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.

Photos: G. Waldbusser, E. Brunner

Barton et al. 2012
Seasonal predictions of coastal chemistry

**Quality**

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

*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)
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.
- 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)

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

Ocean Acidification

How will changes in ocean chemistry affect marine life?

$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 
\text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+$

2 bicarbonate ions

GOA-ON

Global Ocean Acidification Observing Network
Into the future…

- 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.

Photos: G. Waldbusser, E. Brunner