How are changes in ocean chemistry changing sea life in Puget Sound?

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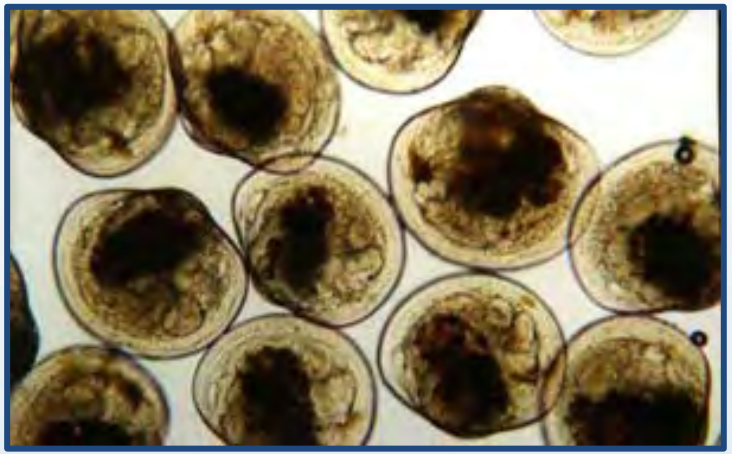
PMEL CARBON PROGRAM

With special thanks to Richard Feely, Jan Newton, Adrienne Sutton, Chris Sabine, Jeremy Mathis, and our technical staff

Questions I *will* try to answer tonight

- ***How do ocean and atmospheric carbon chemistry in Puget Sound compare to on the coast and open ocean (and why)?***
- ***What can we say so far about the effects of ocean acidification on marine ecosystems in our region?***

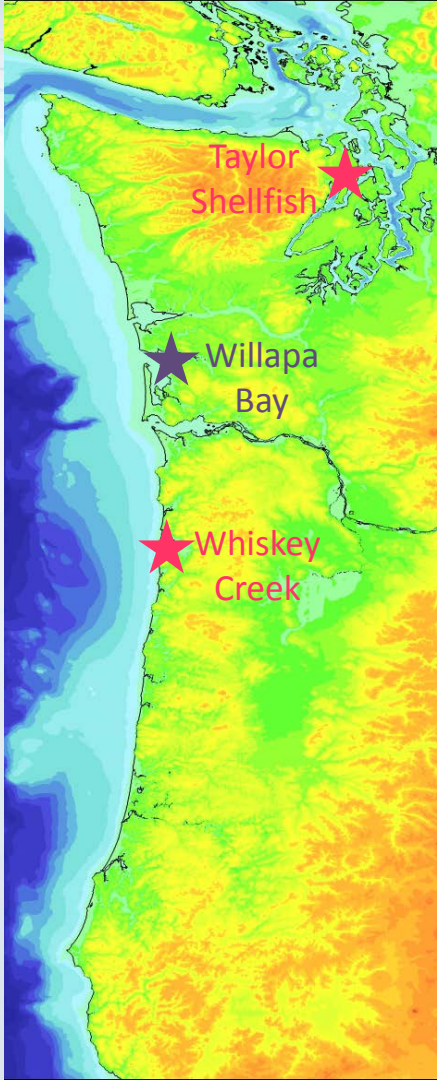
Pacific Northwest hatchery failures



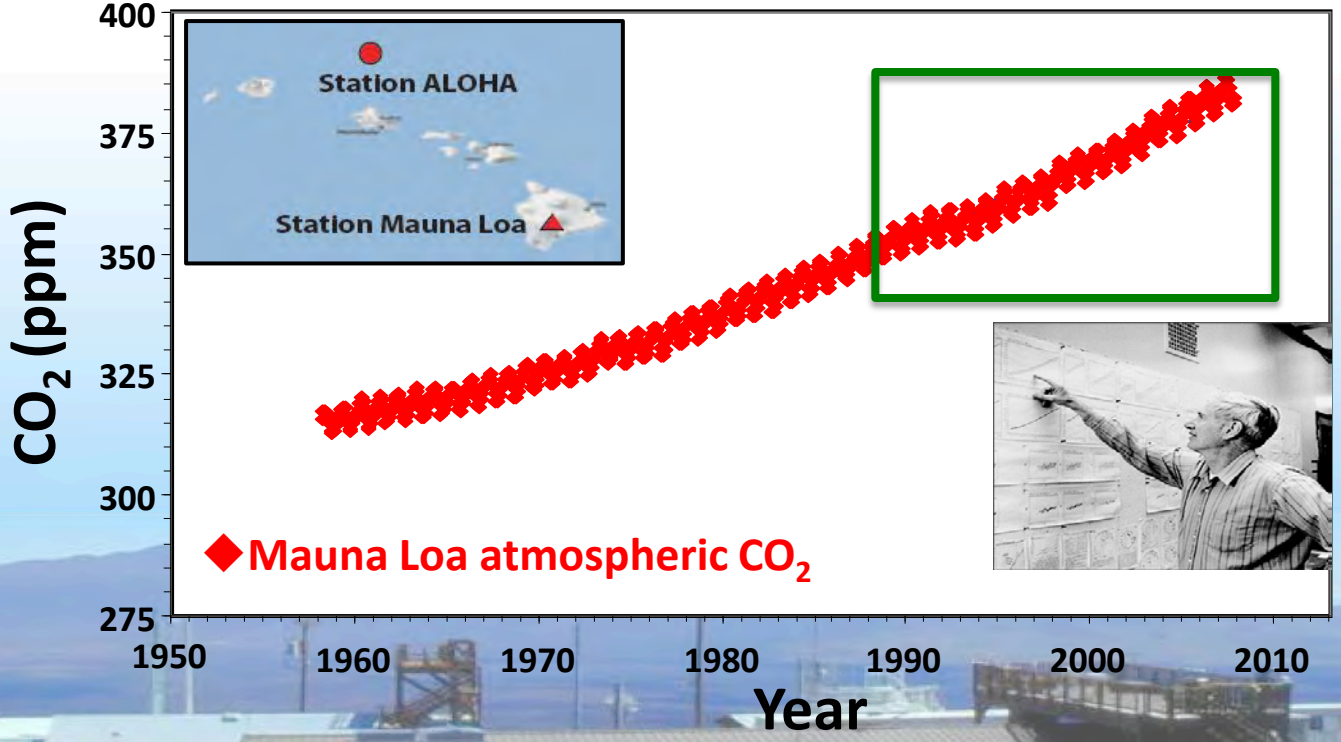
Photos: Taylor Shellfish

"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



Increasing CO_2 in the atmosphere



Station Mauna Loa

Ocean Acidification (OA) Chemistry 101

CO_2

$CO_2 + H_2O \rightarrow H_2CO_3$

carbon dioxide

water

carbonic acid

$H^+ + HCO_3^-$

hydrogen ion

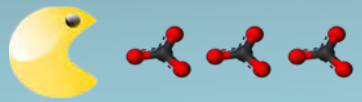
pH

bicarbonate ion

$H^+ + CO_3^{2-}$

carbonate ion

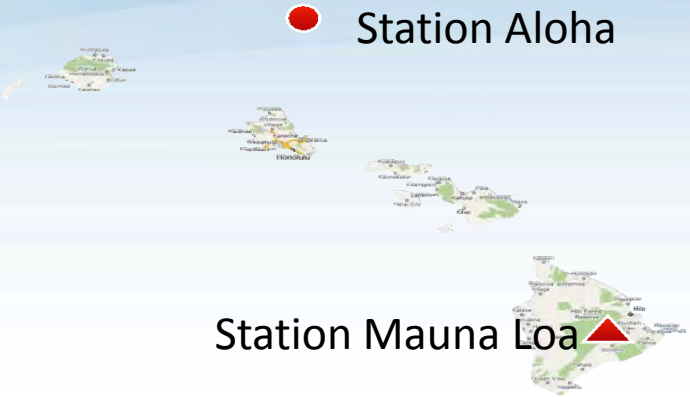
saturation state (Ω)



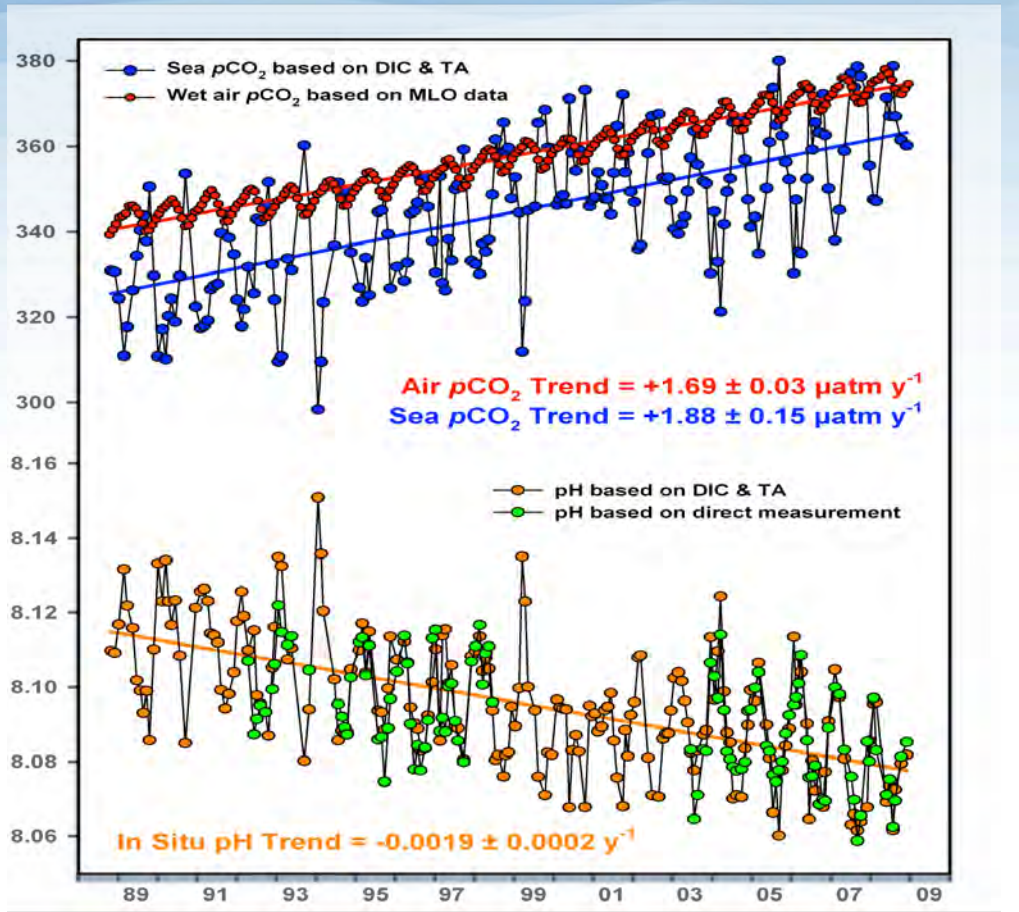
Ω above 1 are better

Ω below 1 are corrosive

CO_2 absorbed by the ocean

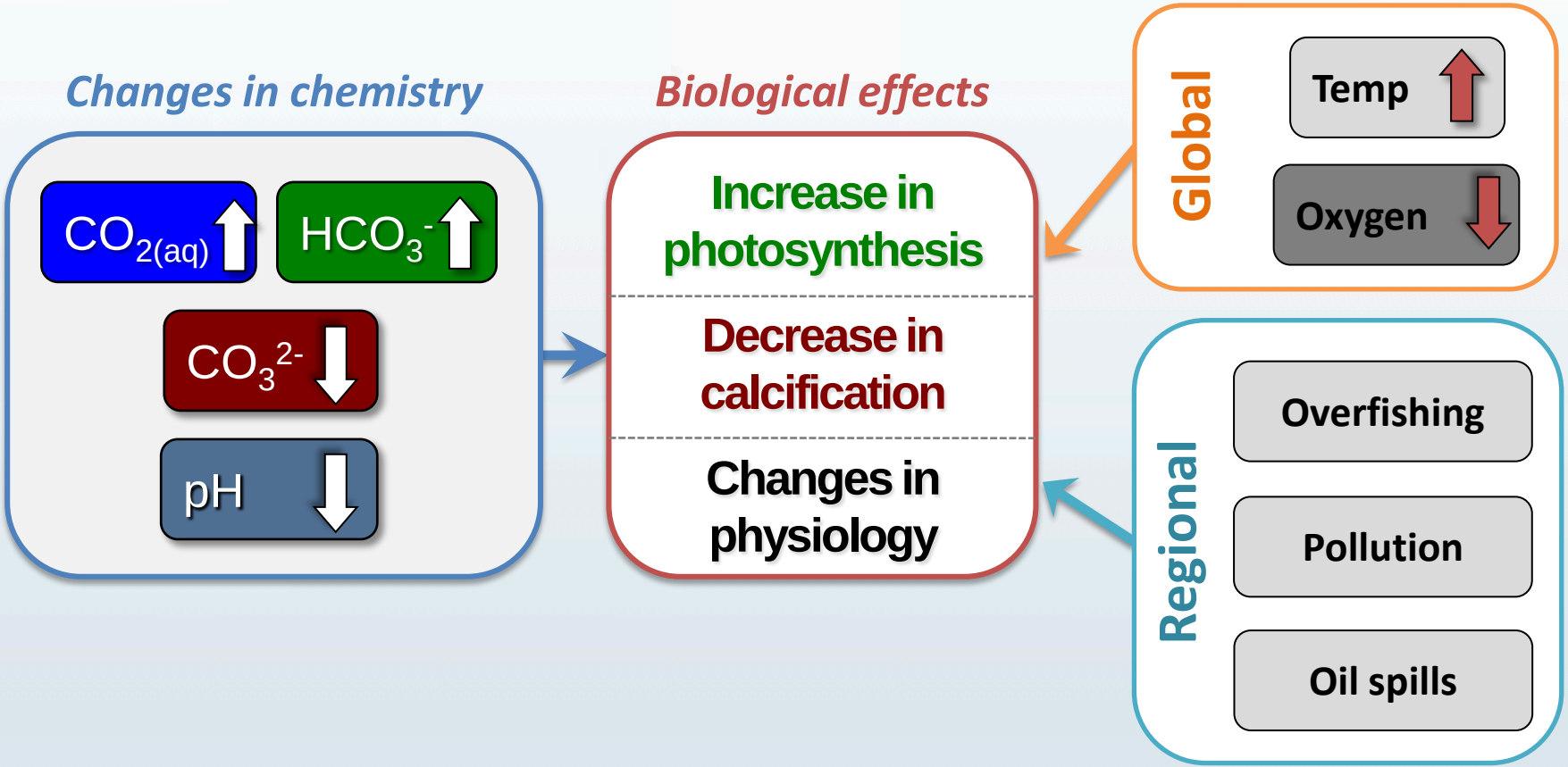


pCO_2 is the CO_2 gas content of the air or water



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

How CO_2 in seawater affects marine life



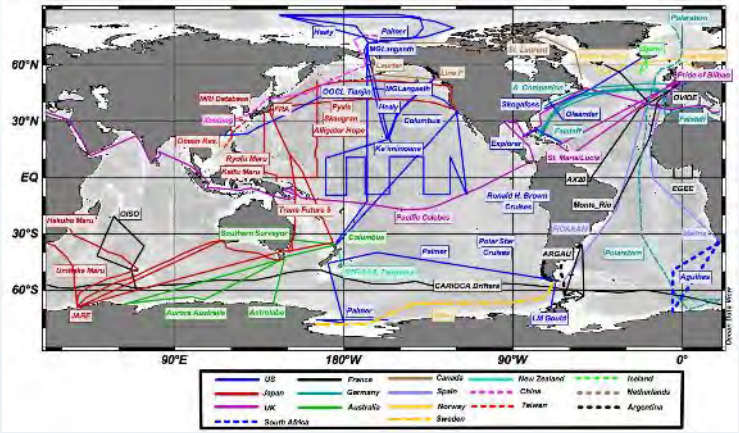
Socioeconomic benefits of shellfish to Washington State

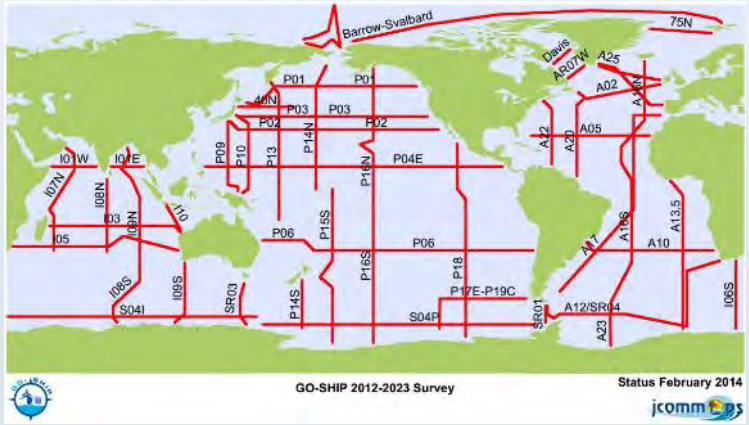
In Washington State alone:

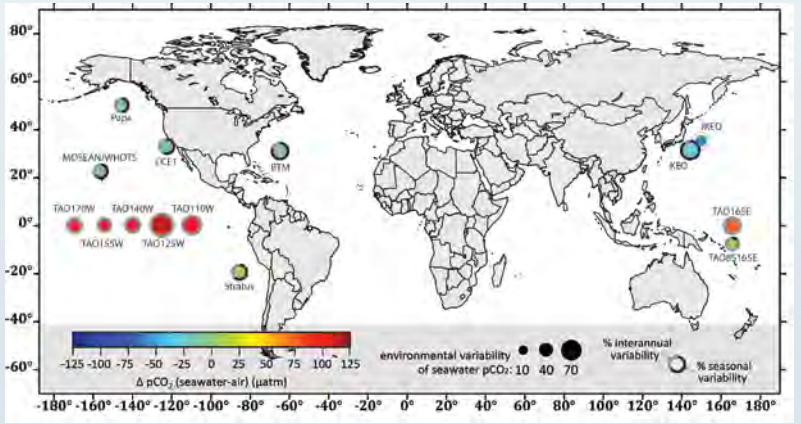
- The shellfish aquaculture industry is worth $270 million per year and employs more than 3,200 people.
- Recreational shellfish harvesting contributes another $30 million per year to the state.
- The seafood industry generates 42,000 jobs and contributes $1.7 billion to gross state product.
- Shellfish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

Washington Blue Ribbon Panel on Ocean Acidification 2012

Open-ocean observations

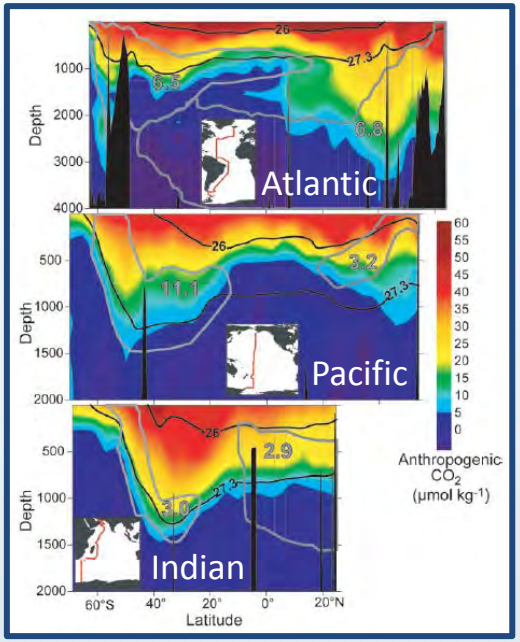






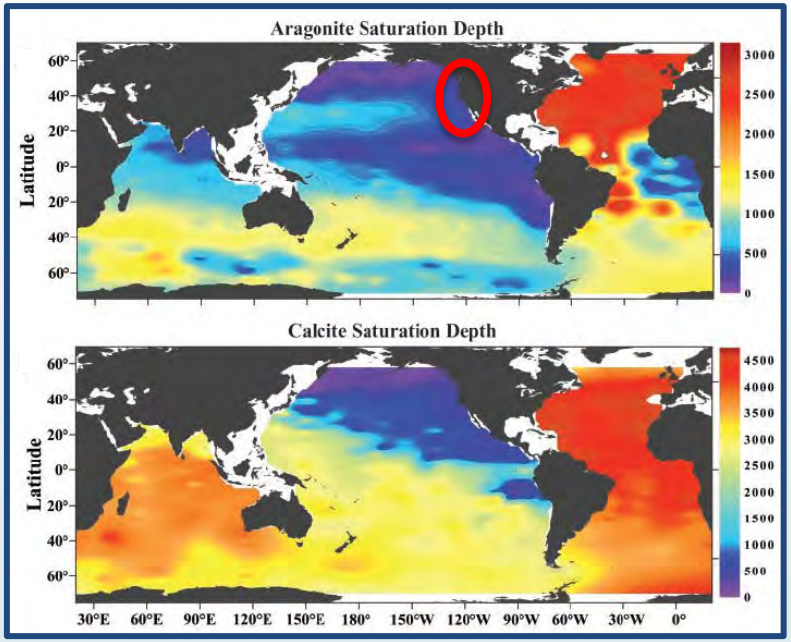
Ocean acidification in global ocean basins

Ocean inventory of human CO_2



Sabine et al. 2004

Saturation state depths



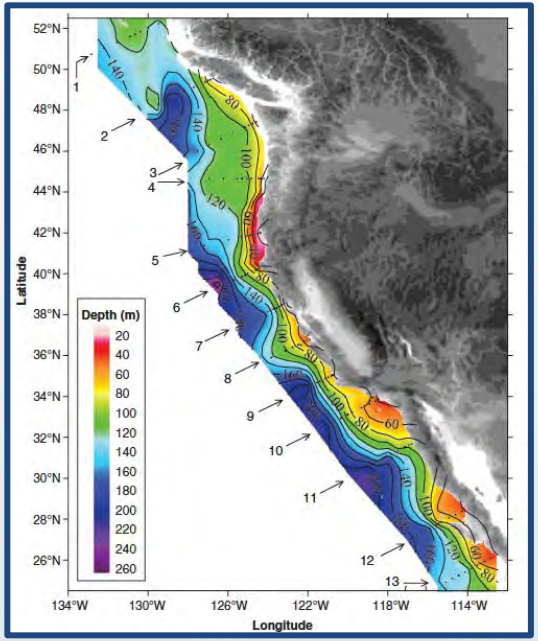
Feely et al. 2004

- Oceans had taken up roughly half of the CO_2 emitted by human activities 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

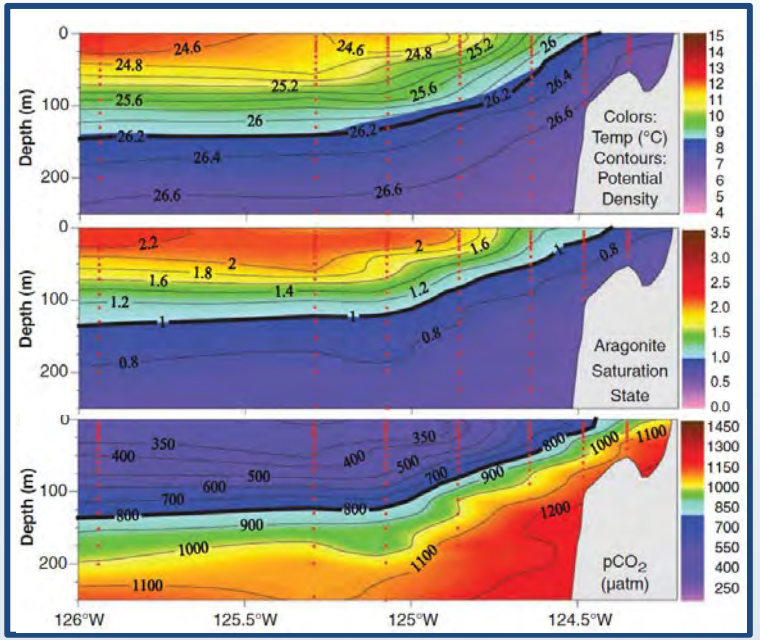
May–June 2007

Saturation state depths

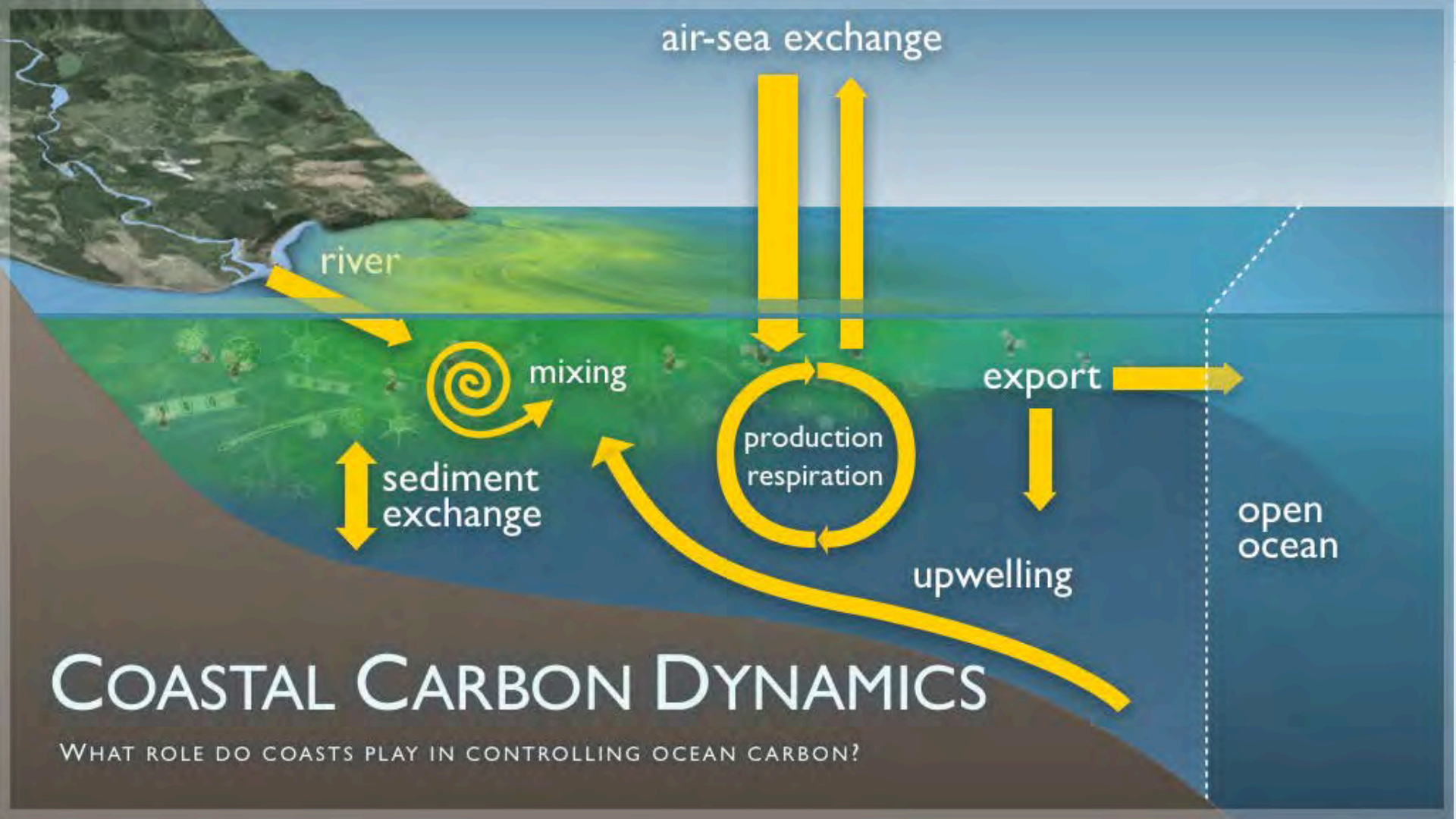


Feely et al. 2008

Corrosive water at the surface

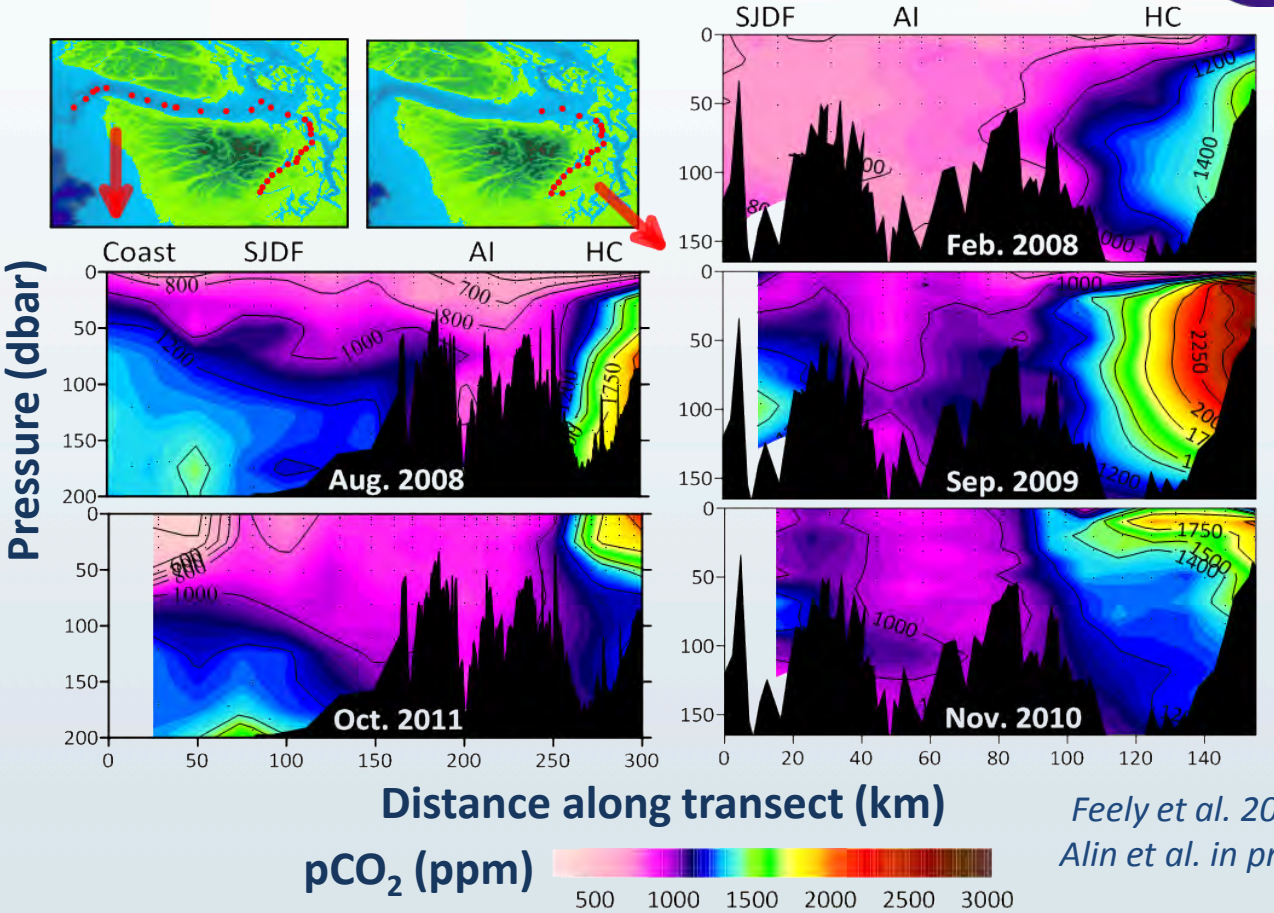


Corrosive water (with respect to aragonite) was observed upwelling to the surface along northern California coast, decades sooner than expected based on open-ocean observations and models.


air-sea exchange
river
mixing
export
production
respiration
sediment
exchange
open
ocean
upwelling
COASTAL CARBON DYNAMICS
WHAT ROLE DO COASTS PLAY IN CONTROLLING OCEAN CARBON?

Ocean acidification in estuaries: Puget Sound

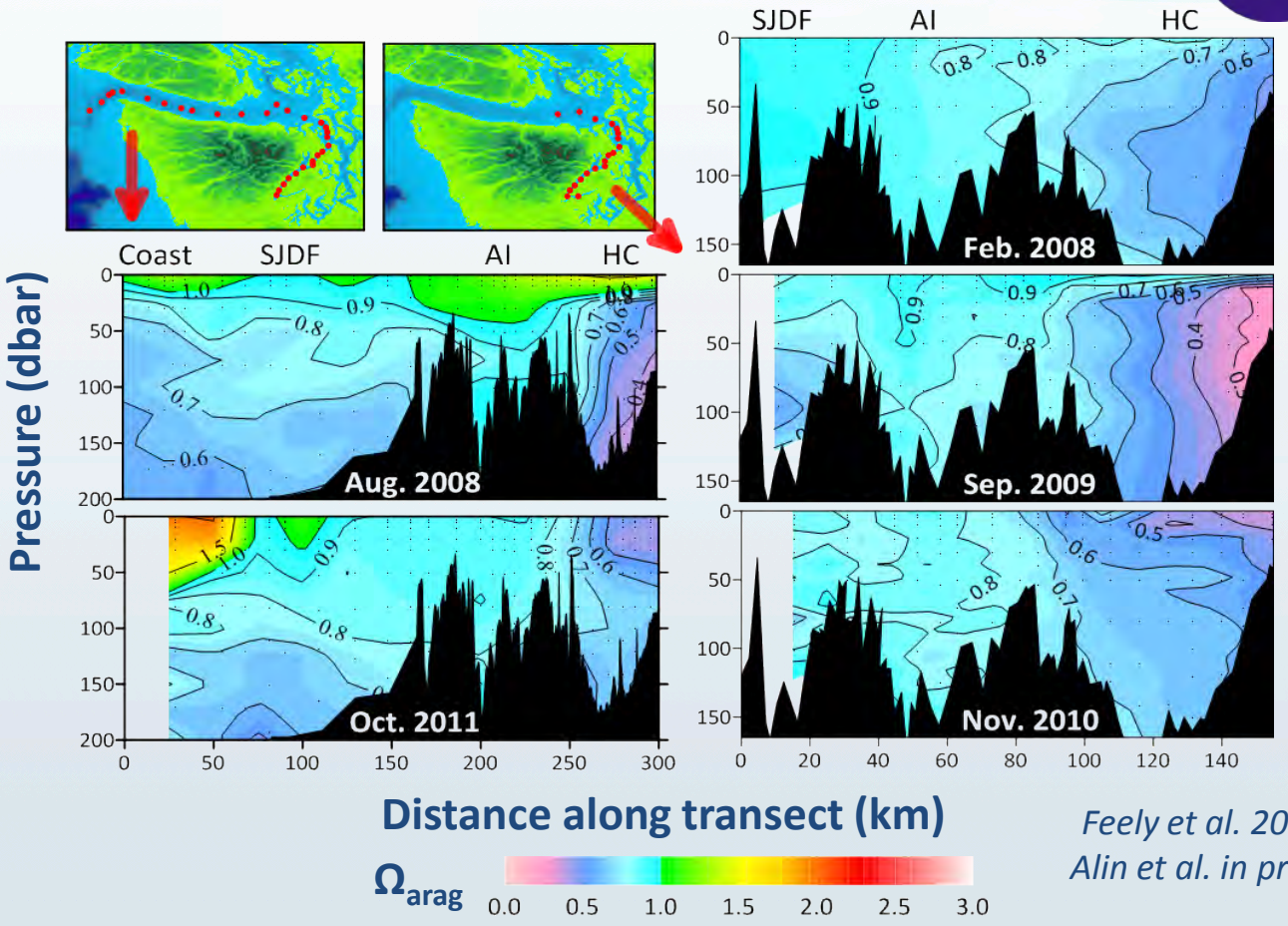
Since 2008, we have observed pCO_2 values over 3000 ppm near the surface in Hood Canal.



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

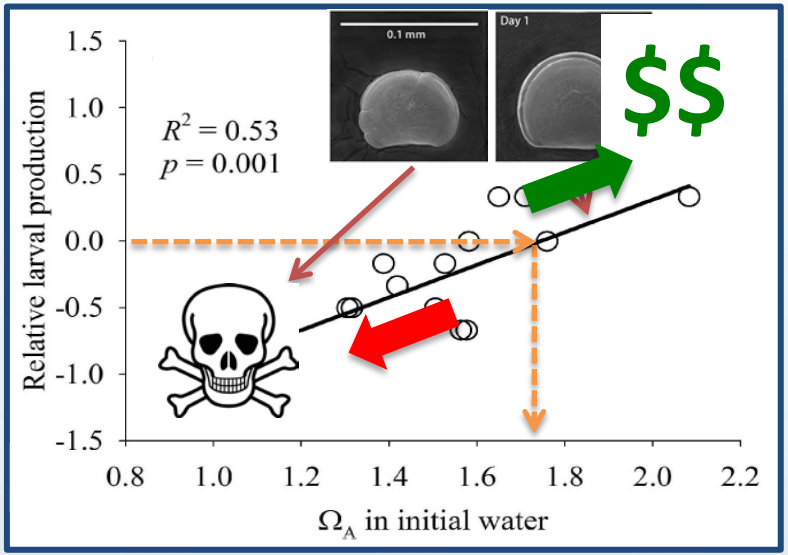
Ocean acidification in estuaries: Puget Sound

Since 2008, we have observed saturation state (Ω_{arag}) values as low as 0.26 in Puget Sound.

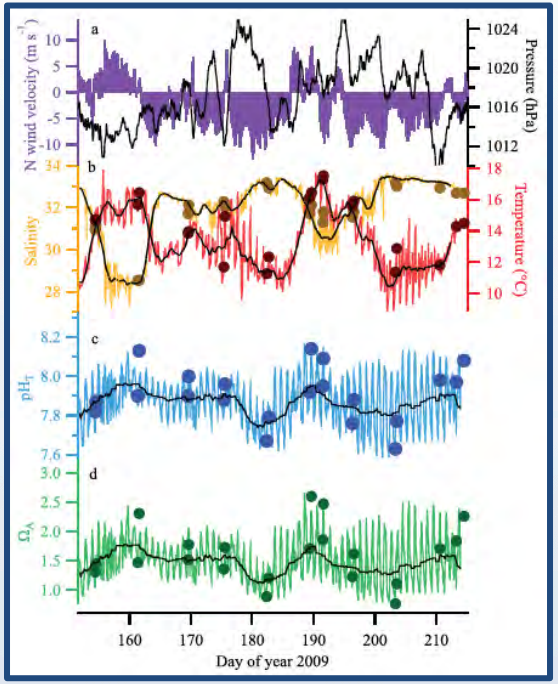


Feely et al. 2010, Alin et al. in prep.

Oyster production declines with elevated CO_2

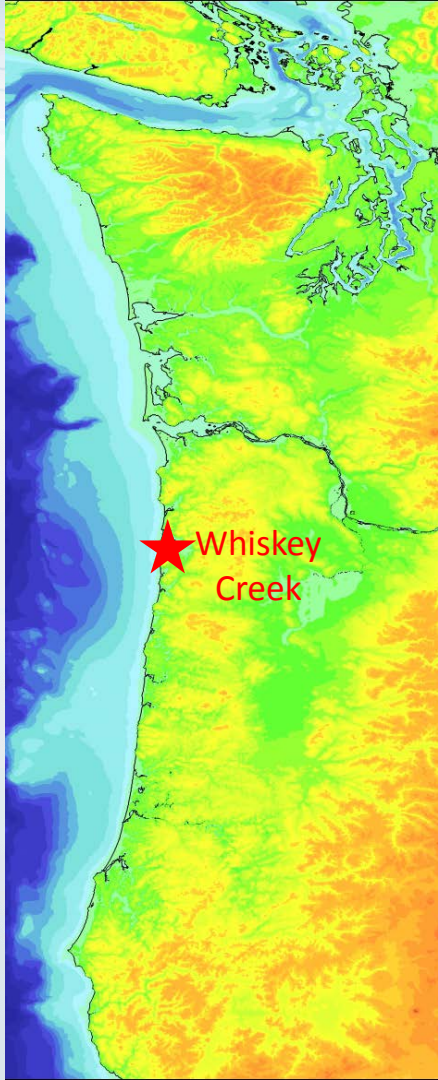


Photos: G. Waldbusser, E. Brunner

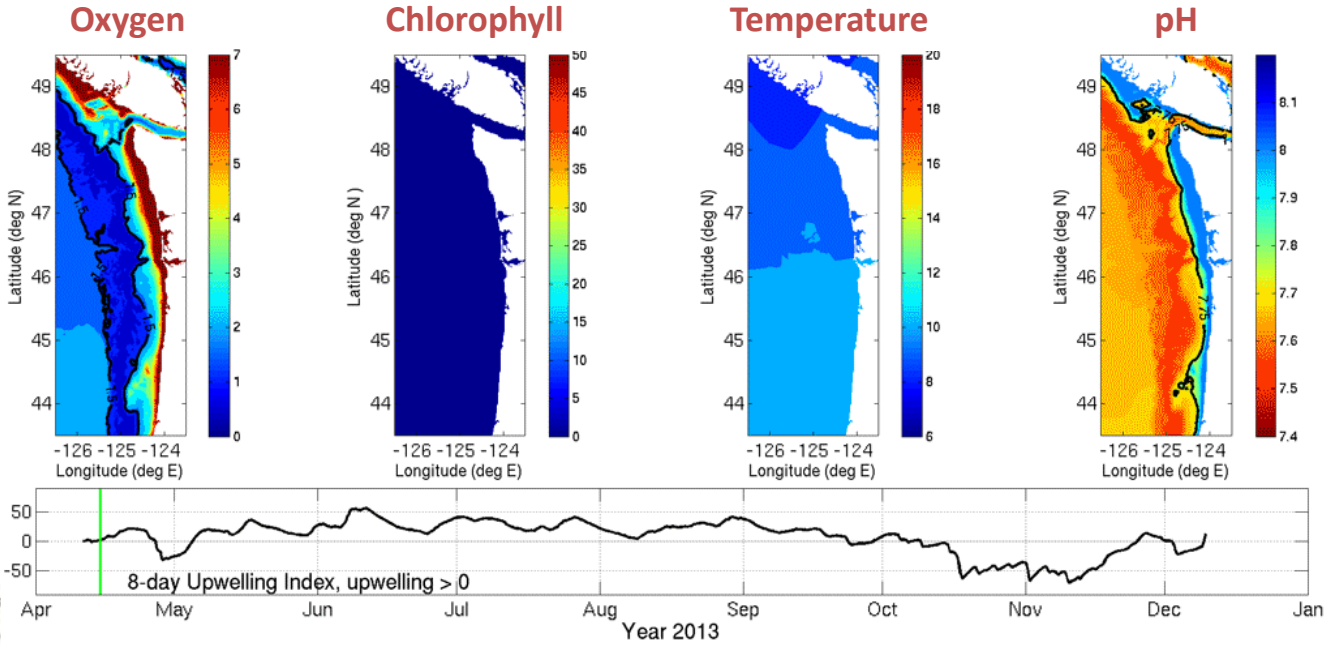


Barton et al. 2012

- 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.



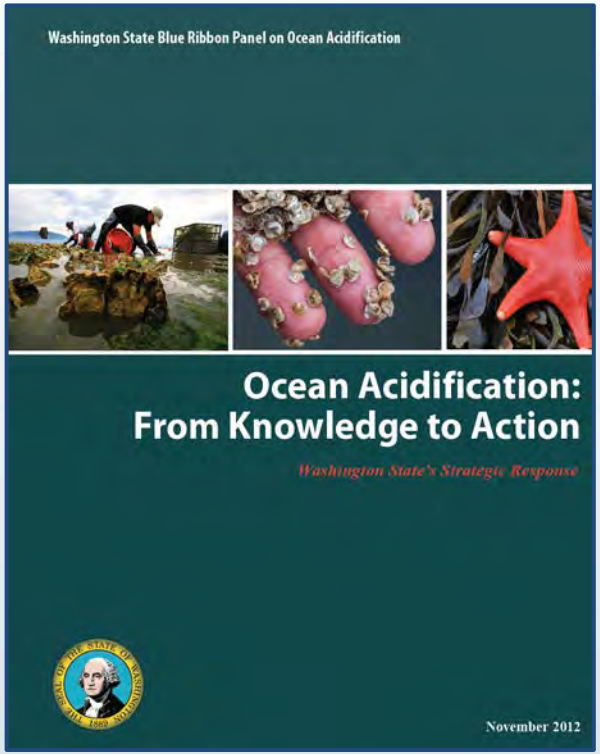
Seasonal predictions of coastal chemistry



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.

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

Policy progress arising from shellfish-science linkage



- **Washington State Blue Ribbon Panel on Ocean Acidification** – Outgrowth of partnership between scientists, shellfish growers and restoration groups (2011–2012)
- **West Coast OA & Hypoxia Science Panel** – California, Oregon, Washington, and British Columbia (2013–present)

The West Coast Ocean Acidification & Hypoxia Science Panel

Discovering impacts on species and ecosystems in the wild

Pre-industrial ***Present-day*** ***2050***

Photos: N. Bednaršek

We are observing dissolution impacts on zooplankton in the field under current conditions, with implications for marine food webs of the future.

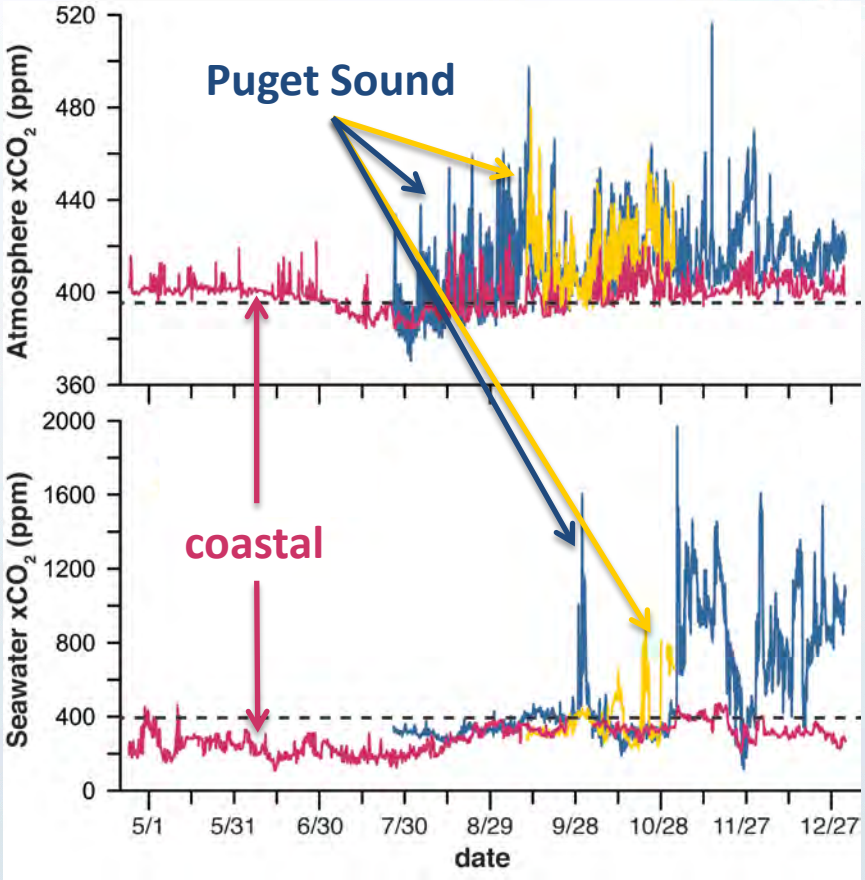
What do we know about ocean acidification and its impact in Puget Sound?

- Very high CO_2 and very low pH and saturation states exist here – *mostly for natural reasons*.
- These conditions occur more frequently now.
- Deadly conditions for *non-native but commercially important* Pacific oysters start at ~1.7 saturation state (equivalent to pH ~8.0).
- Clean Water Act criteria: pH 7.0–8.5, *with <0.2 pH units change due to human impacts.*
- Pteropods harmed at values close to 1 (pH ~7.75).
- Juvenile pink salmon in the North Pacific eat a LOT of pteropods, as likely do other fish, birds, etc.
- A lot of specifics about potential impacts remain unknown, but are significant.
- ***Overall, ocean acidification will definitely make a bad day worse.***
- ***Existing water quality regulations are not biologically meaningful.***

Photo: Russ Hopcroft

Ocean acidification in estuaries: Puget Sound

Both air and seawater in Puget Sound contain more carbon dioxide than coastal or open ocean air and water.



Alin et al. in PSEMP report 2014