What we know about ocean acidification status and trends on the West Coast

Dr. Simone Alin

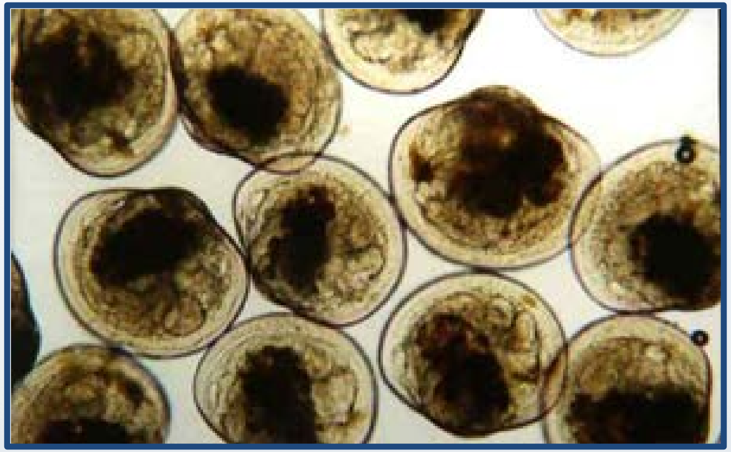
NOAA PMEL CARBON PROGRAM

With thanks to Tessa Hill, Richard Feely, Brendan Carter, Adrienne Sutton, Jan Newton, Francis Chan, Brian Gaylord, Dana Greeley, and many others

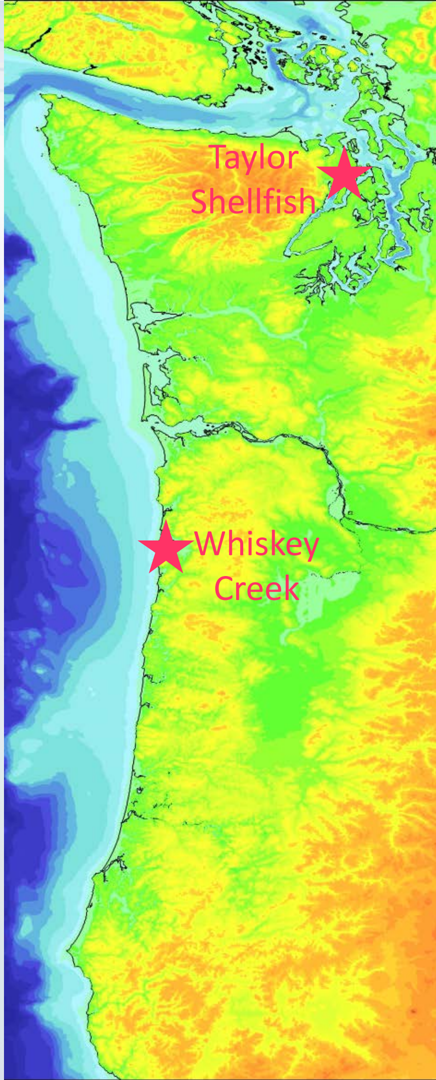
CalEPA

Indicators of Climate Change in California Workshop (June 16, 2015)

Pacific Northwest hatchery failures



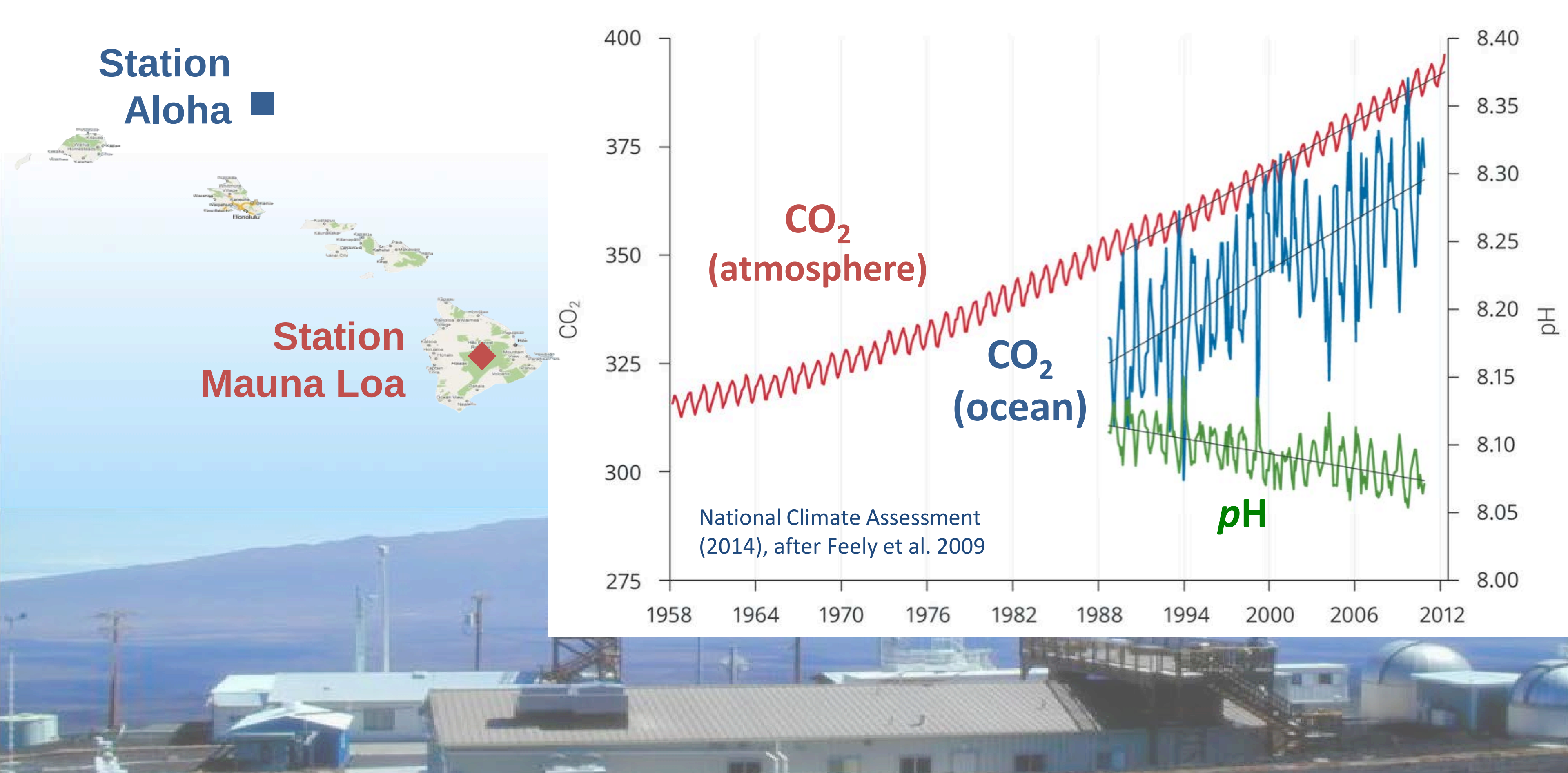
Photos: *Taylor Shellfish*



"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

CO_2 absorbed by the ocean changes ocean chemistry



Ocean Acidification (OA) Chemistry 101

CO_2

$CO_2 + H_2O \rightarrow H_2CO_3$

carbon dioxide

water

carbonic acid

$\downarrow$

hydrogen ion

*p*H

$H^+ + HCO_3^-$

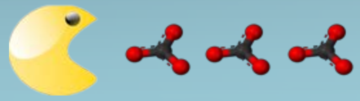
bicarbonate ion

$\downarrow$

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

carbonate ion

saturation state (Ω)

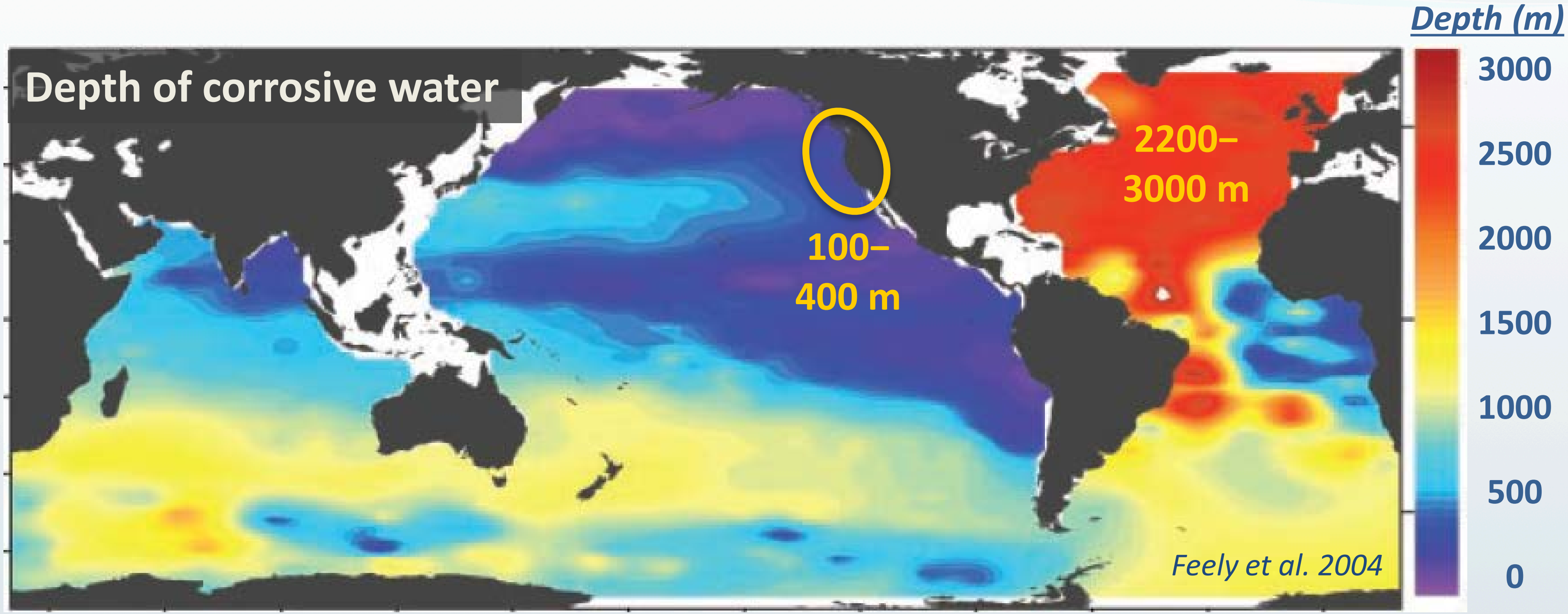


Socioeconomic benefits of West Coast fisheries

- $0.5B per year industry on West Coast
- About 60% of which is shellfish and vulnerable to decreasing saturation states
- Jobs and livelihoods
- Cultural and ceremonial importance
- Recreational value

Photos: Washington Blue Ribbon Panel on Ocean Acidification 2012

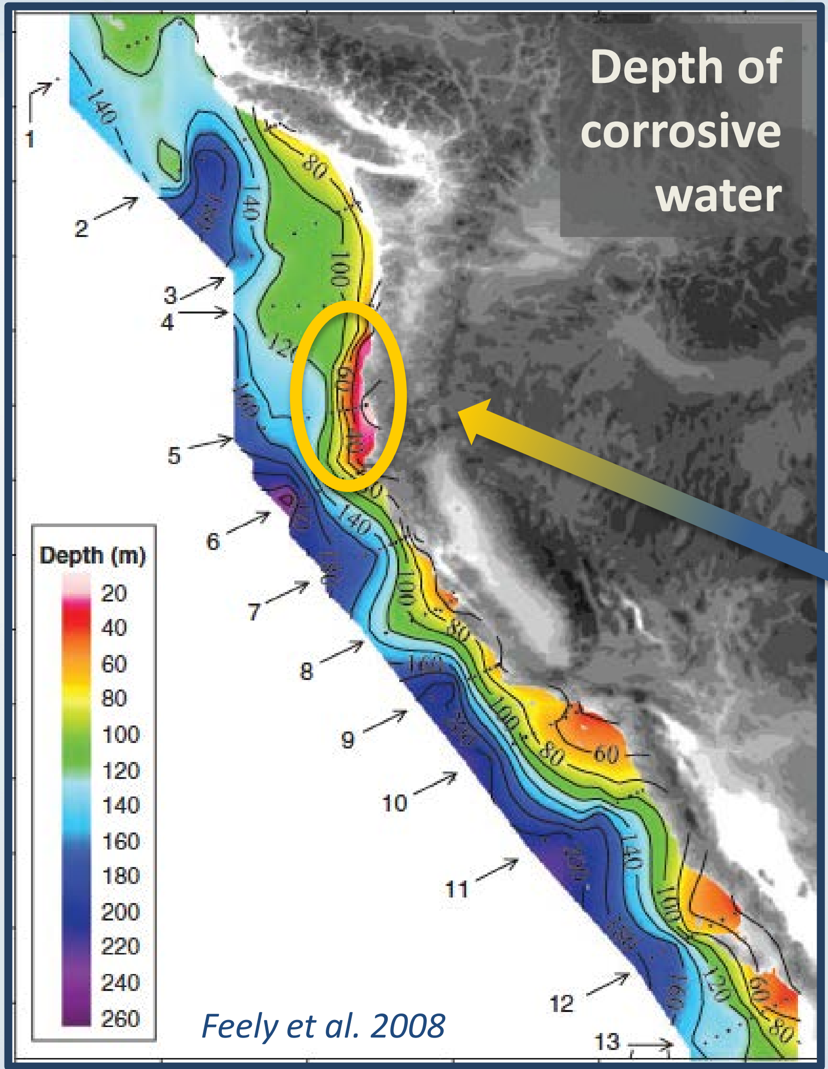
Global context for West Coast ocean acidification



- The ocean absorbs 30% of CO_2 emitted to the atmosphere by human activities.
- CO_2-driven acidification brings corrosive water closer to the surface by 1–3 m/yr (3–10 ft/yr).

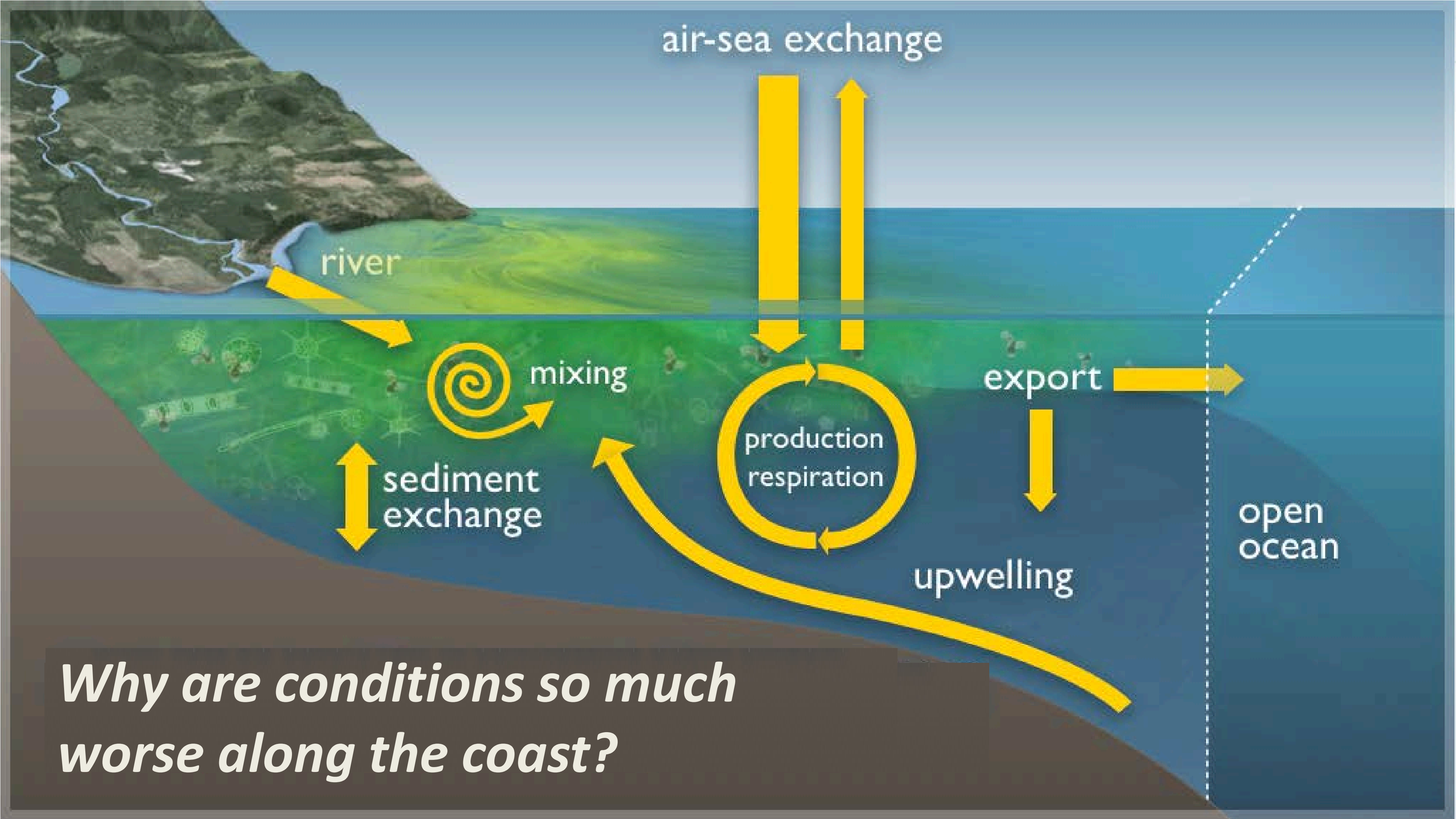
First West Coast observations of ocean acidification

May–June 2007



Feely et al. 2008

Corrosive waters reach the surface along the West Coast at times during the summer upwelling season.



Why are conditions so much worse along the coast?

Present-day conditions along the West Coast

- Spatial surveys of carbonate chemistry done on ship-based research "cruises" in 2007, 2011, 2012, 2013, and 2016.

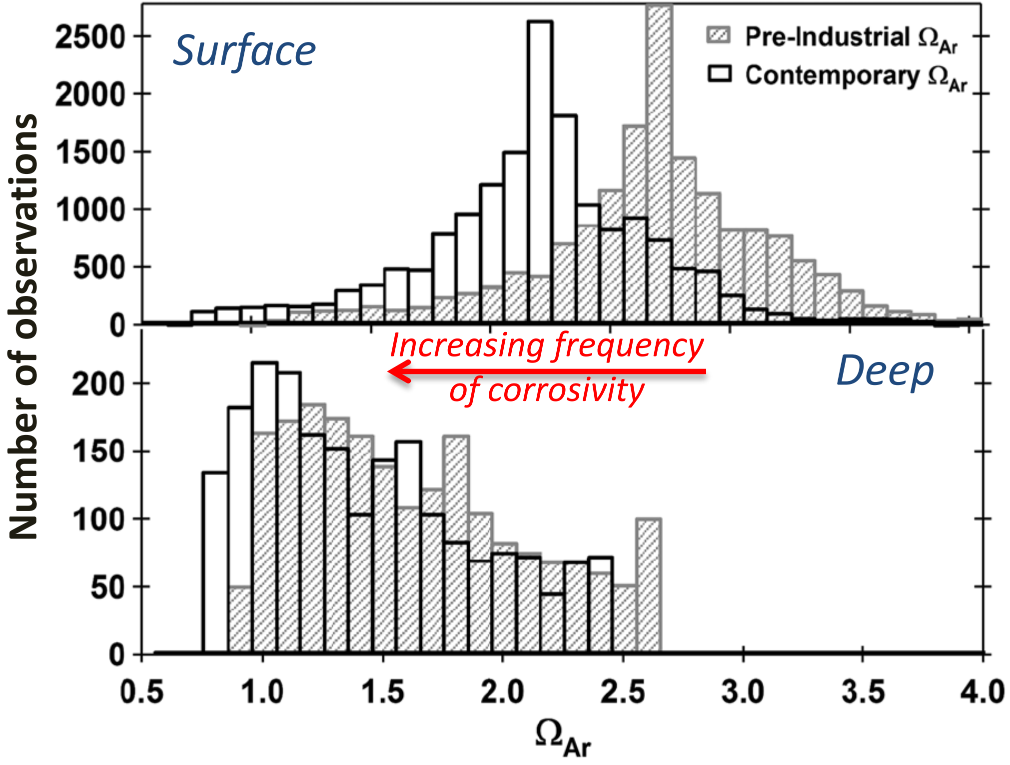
- We also measure high-resolution changes in chemistry at several time-series moorings along the West Coast (☆).

- Areas of corrosive conditions at the surface and everywhere at 125 m during summer. Upwelling, production/respiration, and rivers are important contributors.

Feely, Alin, Chan, Hill et al., in prep

Estimated chemistry changes since pre-industrial

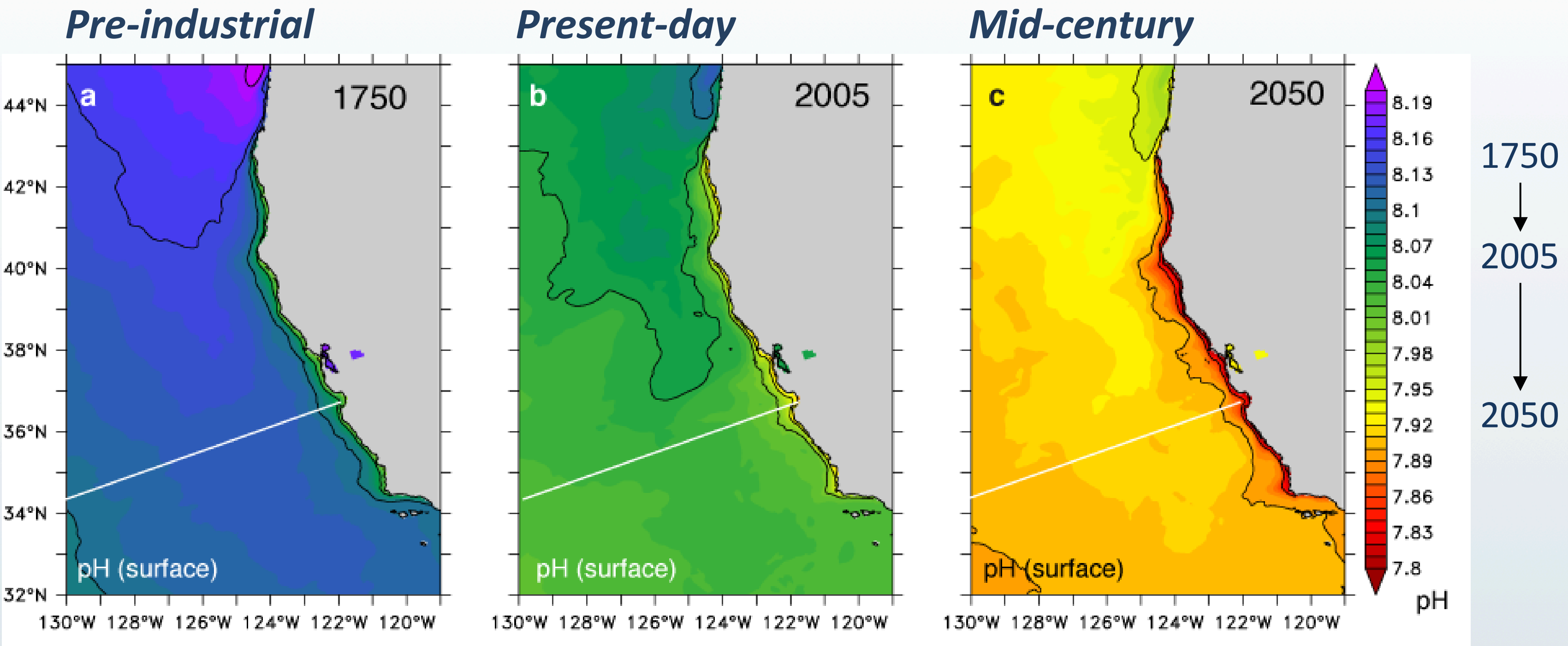
Aragonite saturation state off Newport, Oregon



Harris et al. 2013

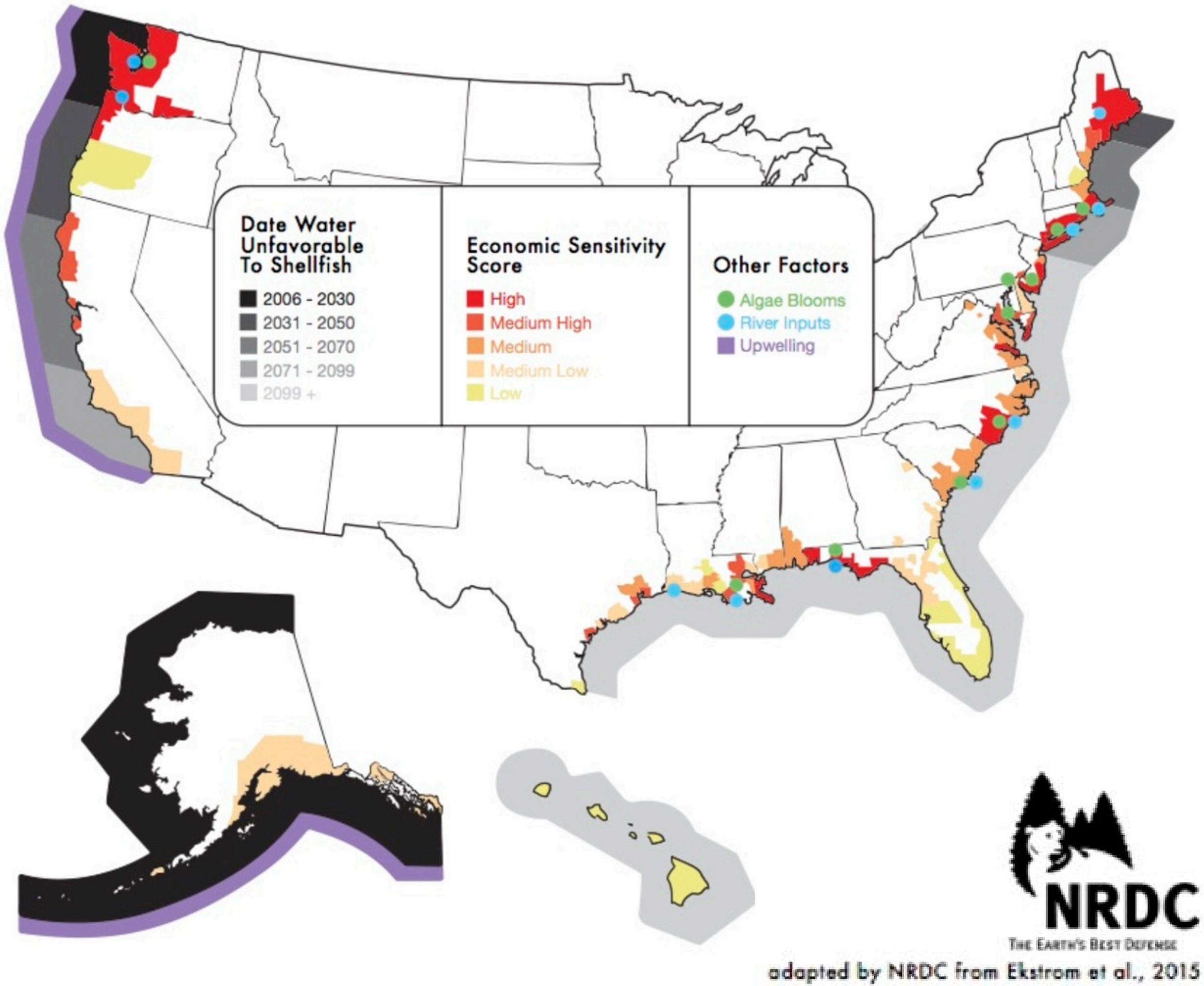
- Estimated mean present-day Ω_{arag} is 0.52 lower than during the pre-industrial (Oregon).
- Frequency of corrosive conditions in shelf water has increased by 20–26% (Oregon, Washington).

Past, present, and projected *p*H along West Coast



- Projected change over next 35 years is accelerating and projected to be greater than since 1750.

Gruber et al. 2012



Socioeconomic vulnerability analysis

- Combines information about environmental conditions, economic sensitivity, and exacerbating factors.
- West Coast and Alaska have highest vulnerability, decreasing to south.

So what do we know about ocean acidification on the West Coast?

- Many areas experience corrosive conditions
- Strong variability
    - North to south
    - Onshore to offshore
    - Seasonal to decadal
- Ocean acidification will exacerbate *naturally* challenging conditions.

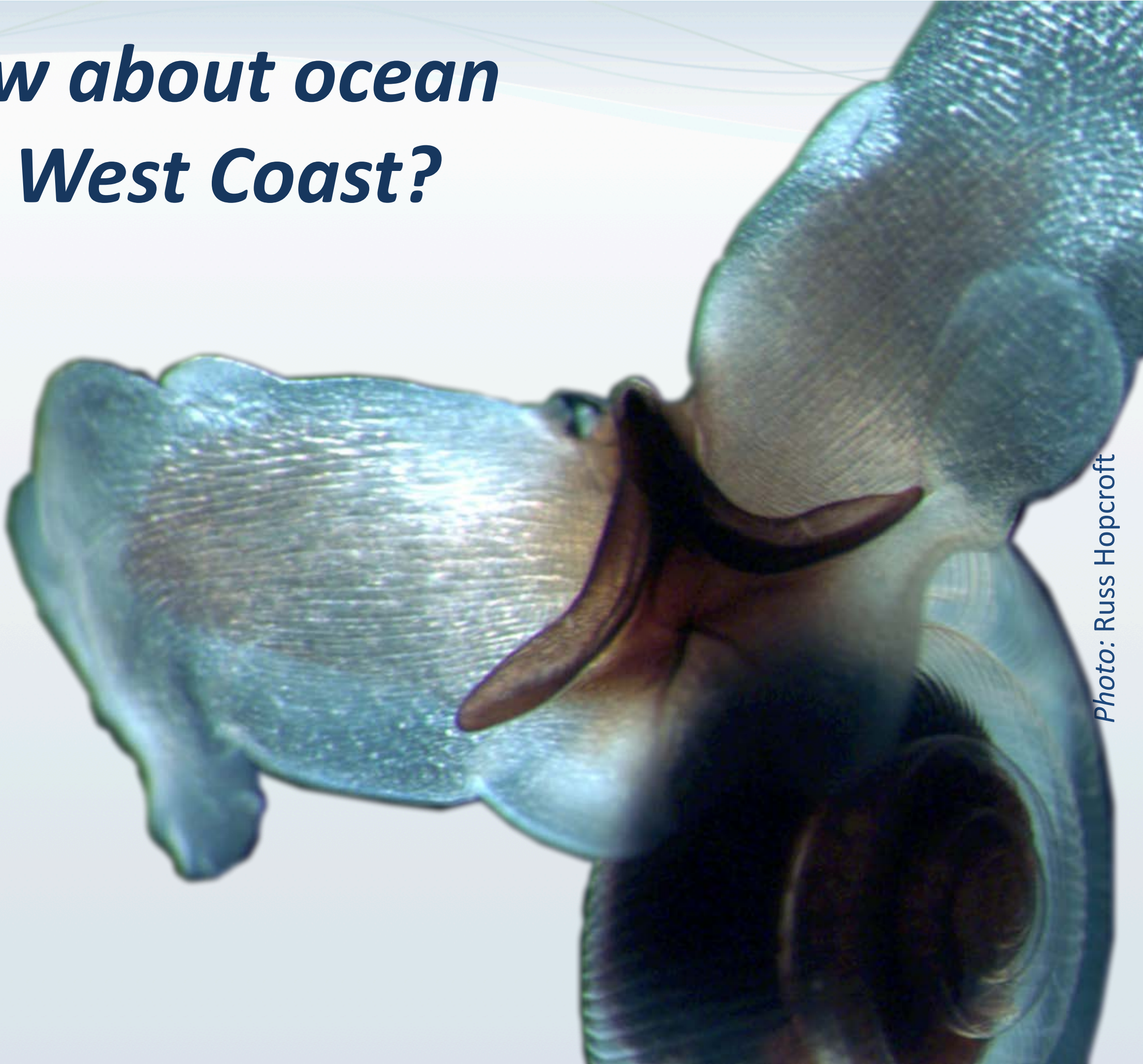
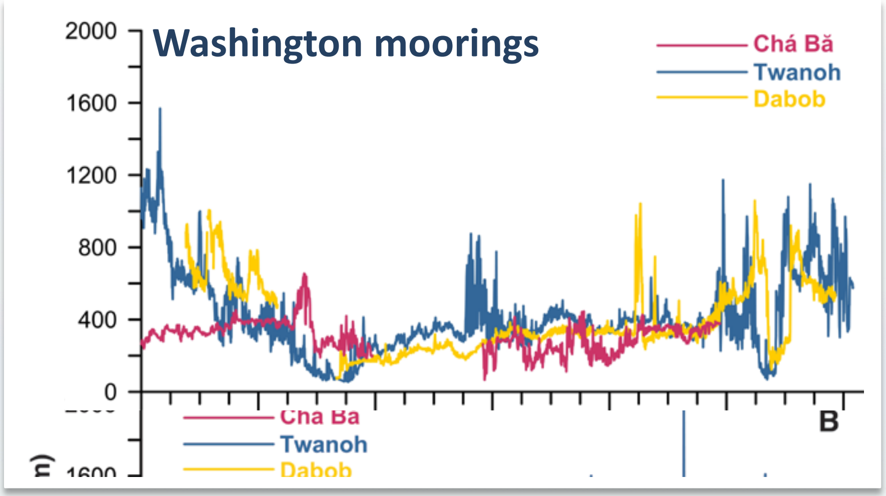
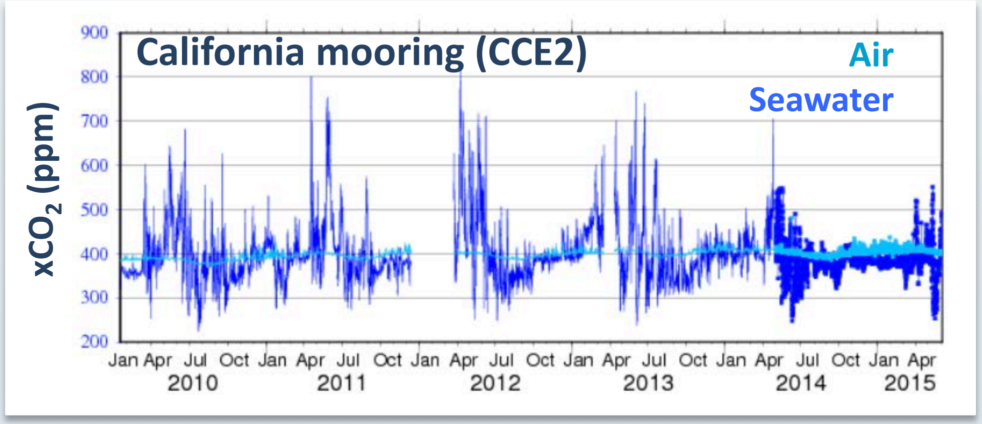


Photo: Russ Hopcroft

OA indicators along West Coast: under development



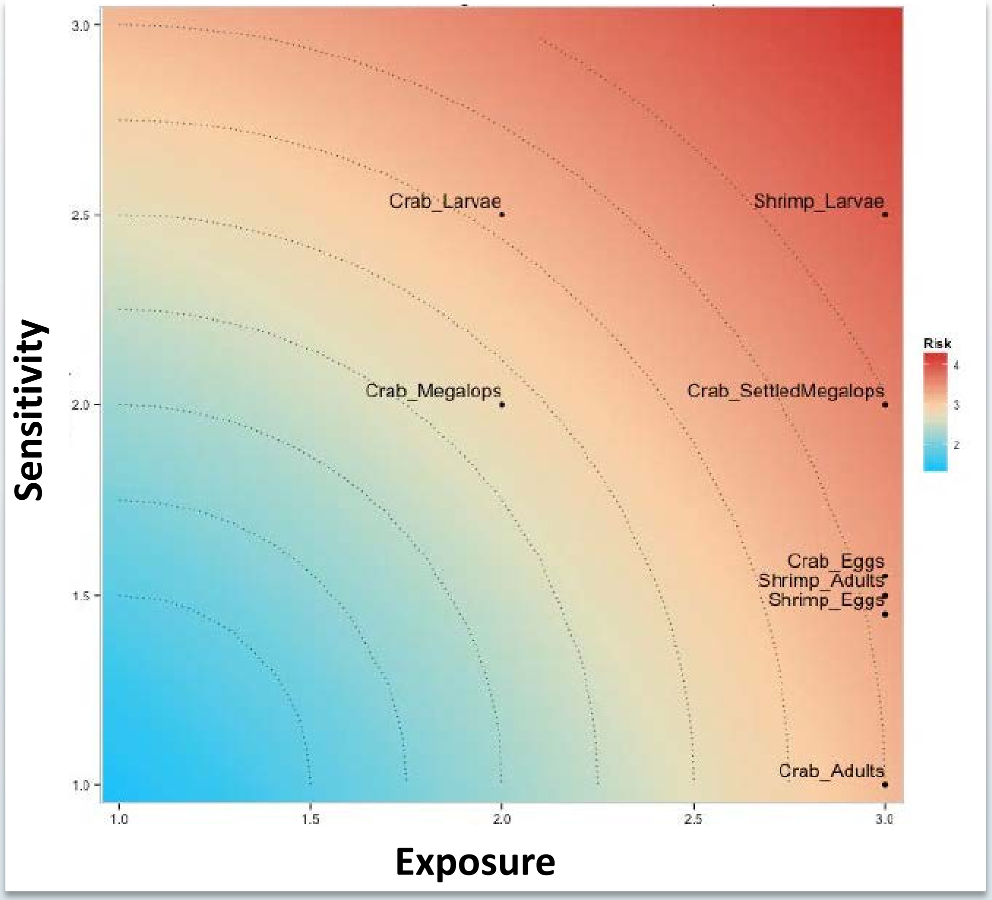


Indicators might track changes in:

- Annual CO_2, pH, $\Omega_{aragonite}$ extremes
- Annual averages
- Corrosive events ("carbonate weather")
  - Frequency
  - Duration
  - Intensity
- Seasonal first & last appearance of corrosive waters in key habitats

Alin et al. in press, Sutton et al. in prep.

Indicator – Mapping biogeochemistry vs. species distributions



Species by Life History Stage	Sensitivity Value	Percent Exposure	Exposure Value	Risk Score
Crab Eggs	1.5	87.6	3	3.4
Crab Larvae	2[1]	35.5	2	2.8
Crab Megalops	2	29.1	2	2.8
Crab Settled Megalops	2	58.6	3	3.6
Crab Adults	1[2,3]	76.2	3	3.2
Shrimp Eggs	1.5[4]	95.9	3	3.4
Shrimp Larvae	2.5[4,5]	81.3	3	3.9
Shrimp Adults	1.5[6]	89.1	3	3.4

- Risk assessment for individual species is underway.
- Ultimately we hope to be able to overlay maps of species distributions with forecasts of biogeochemical conditions.

Hodgson et al. 2013 CCS IEA

Closing thoughts

- Acidity is projected to increase (= pH decrease) and aragonite saturation state to decrease at accelerating rates in the future due to ongoing CO_2 emissions.
- Many potential indicators to track (under development).
- Clean Water Act specifies *p*H criteria that may provide a route for management/regulation based on changing chemistry.
- However, regional inputs through rivers and stormwater runoff may be more amenable to state level action.