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WASHINGTON STATE
Academy of Sciences

TH ANNUAL MEETING & SYMPOSIUM
CLIMATE CHANGE IN WASHINGTON STATE
Research Questions Critical to Preparing for the Future

Ocean Acidification

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Ocean Acidification in Washington



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Image: Wikipedia

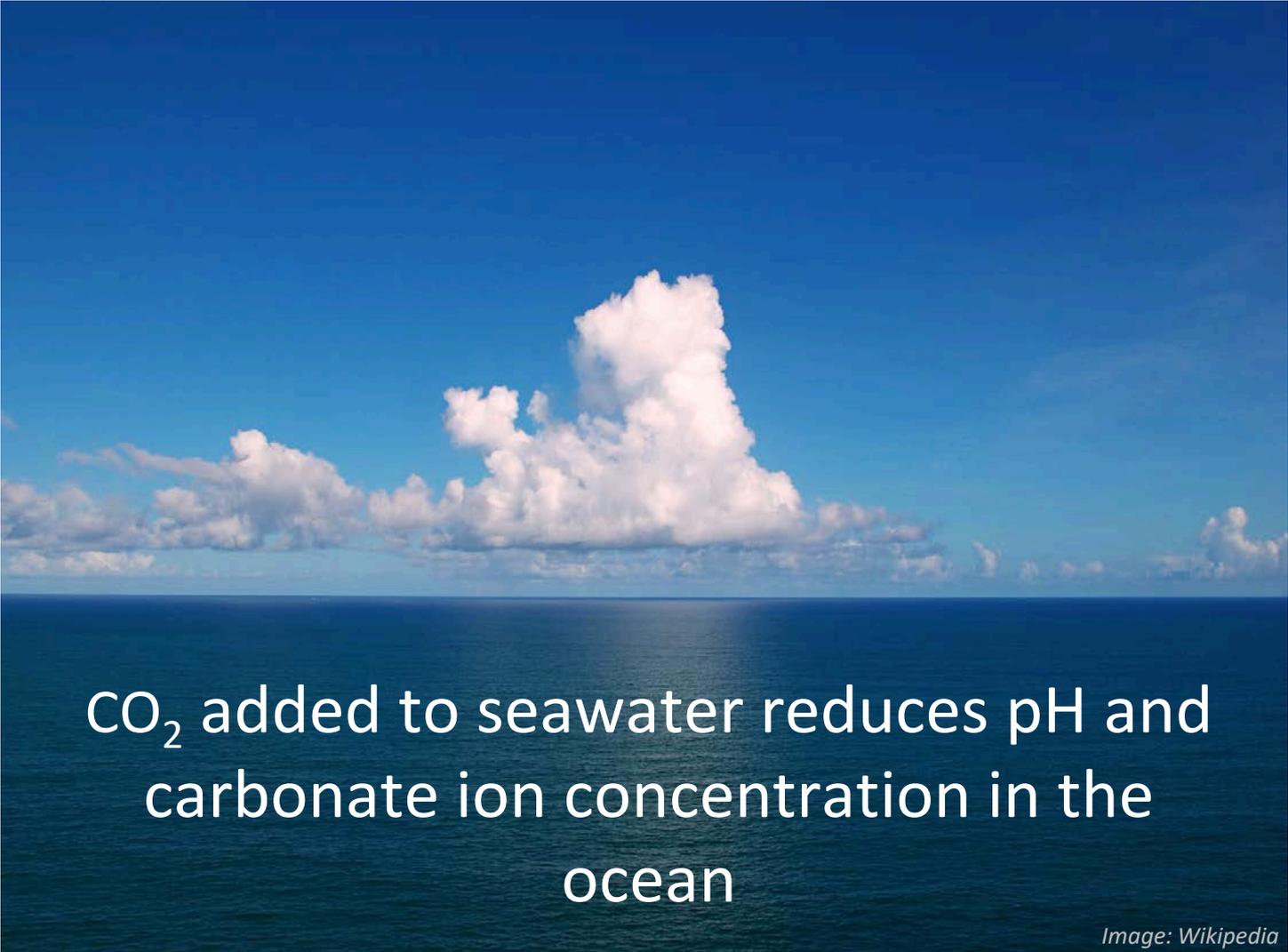


Image: mit.edu

The ocean has taken up about 28% of the carbon dioxide released by industry and deforestation

CO₂ in the atmosphere contributes to climate change

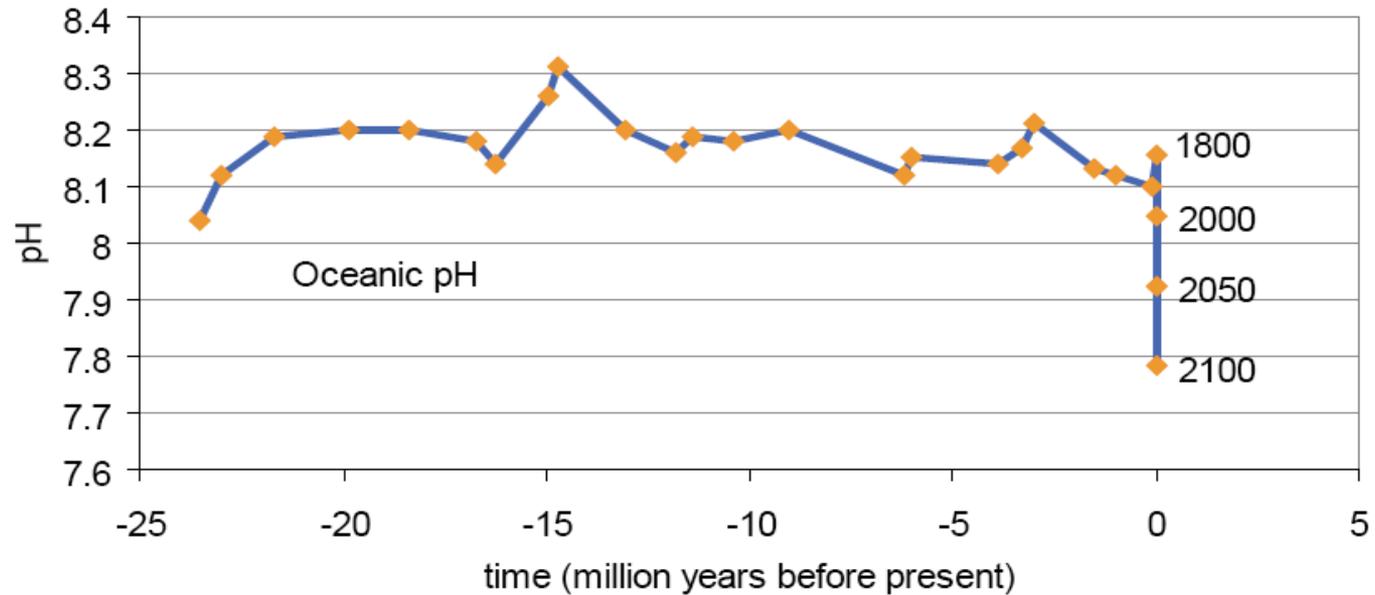
CO₂ in the water causes ocean acidification



CO₂ added to seawater reduces pH and
carbonate ion concentration in the
ocean

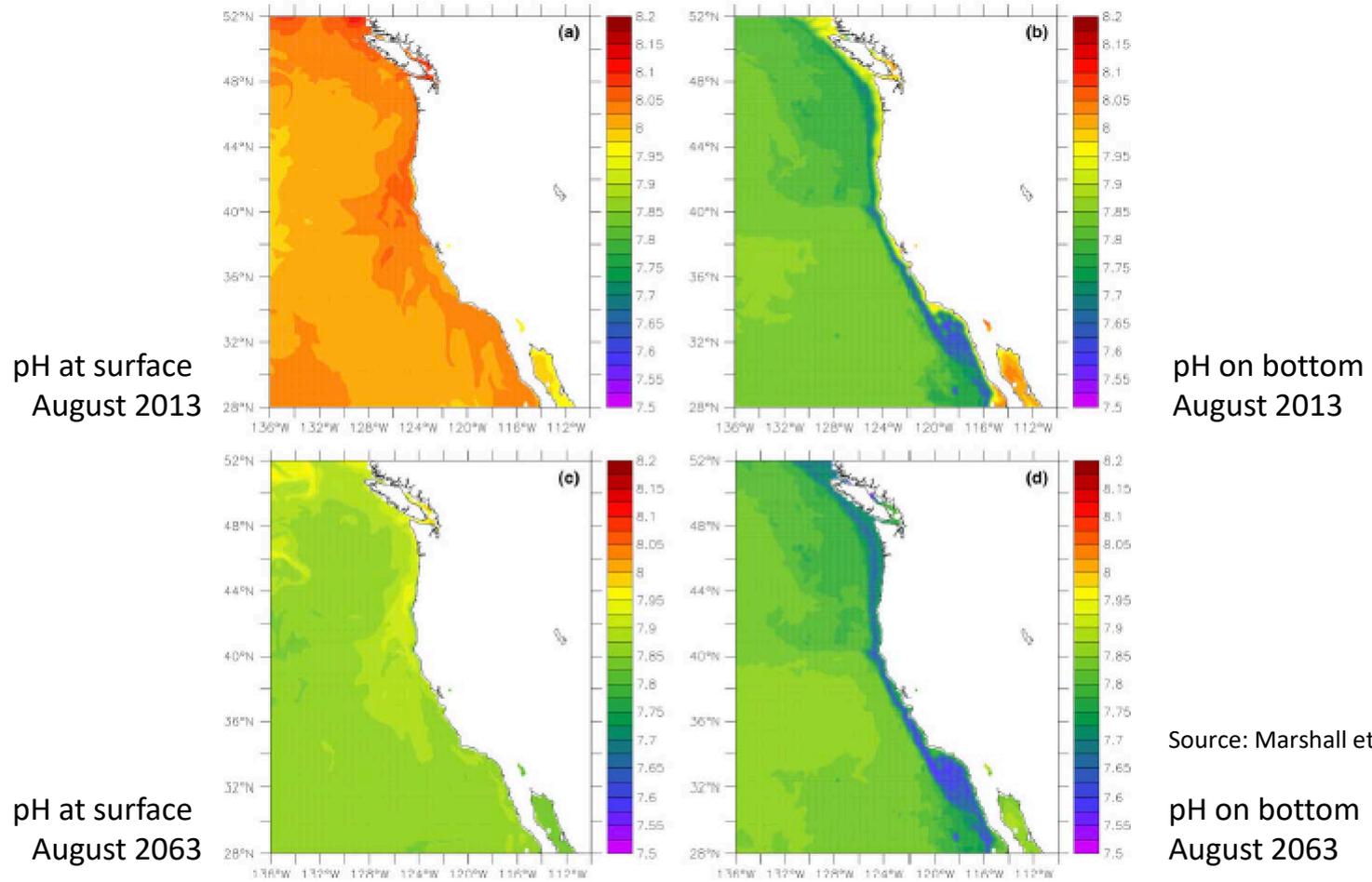
Image: Wikipedia

The rate of change is unprecedented
in 25 million years



Source: Carol Turley, PML

pH in the California Current System is projected to decline



pH at surface
August 2013

pH on bottom
August 2013

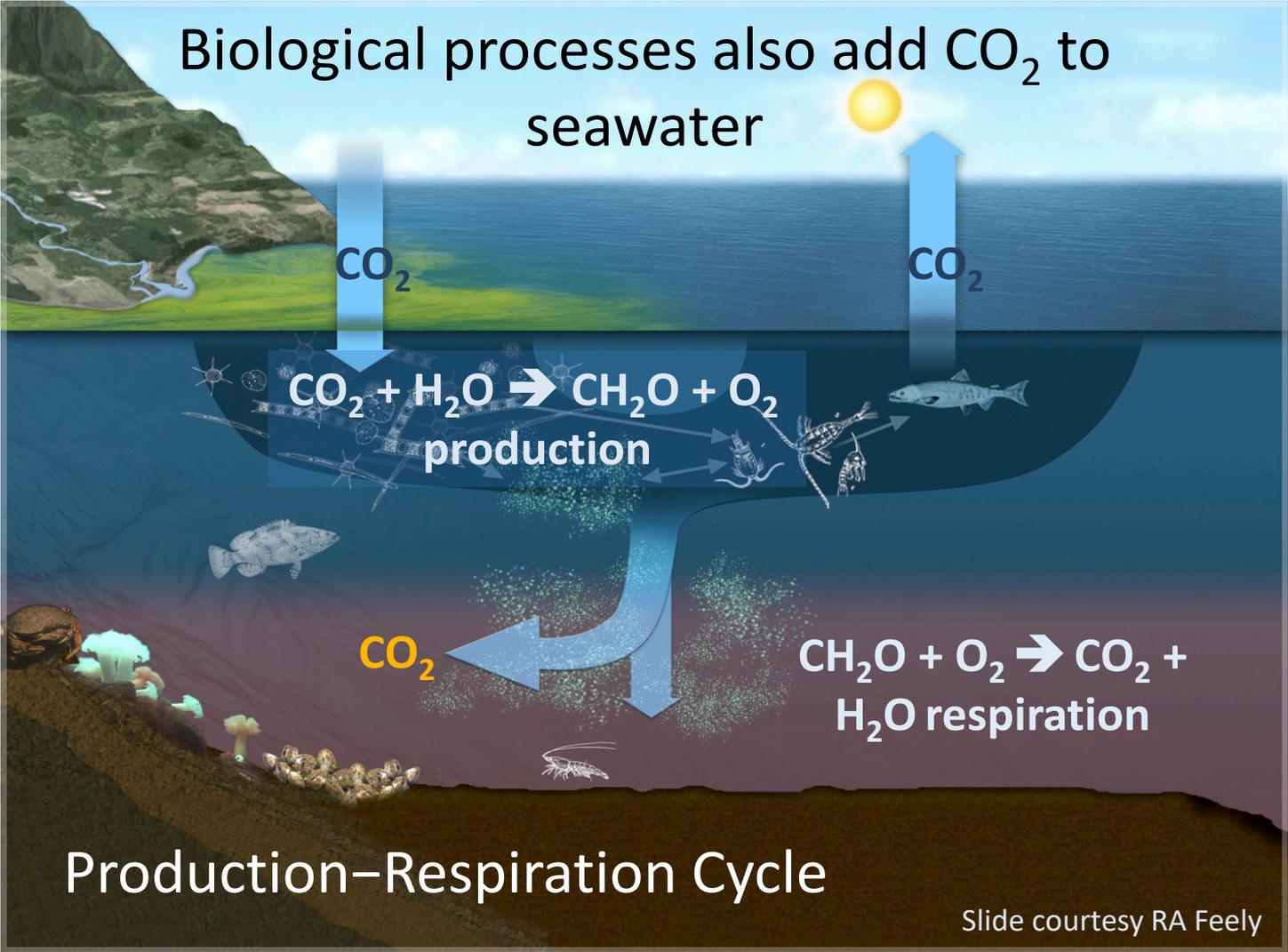
pH at surface
August 2063

Source: Marshall et al. 2017

pH on bottom
August 2063

Fig. 3 ROMS projections of pH in August 2013 (a, b) and August 2063 (c, d), at the surface (a, c) and bottom (b, d). ROMS runs are initialized January 1, 2010, or January 1, 2060, and are forced by GFDL ESM2M under IPCC RCP 8.5. pH within ROMS is calculated from carbonate variables simulated using the model of Fennel *et al.* (2006, 2008).

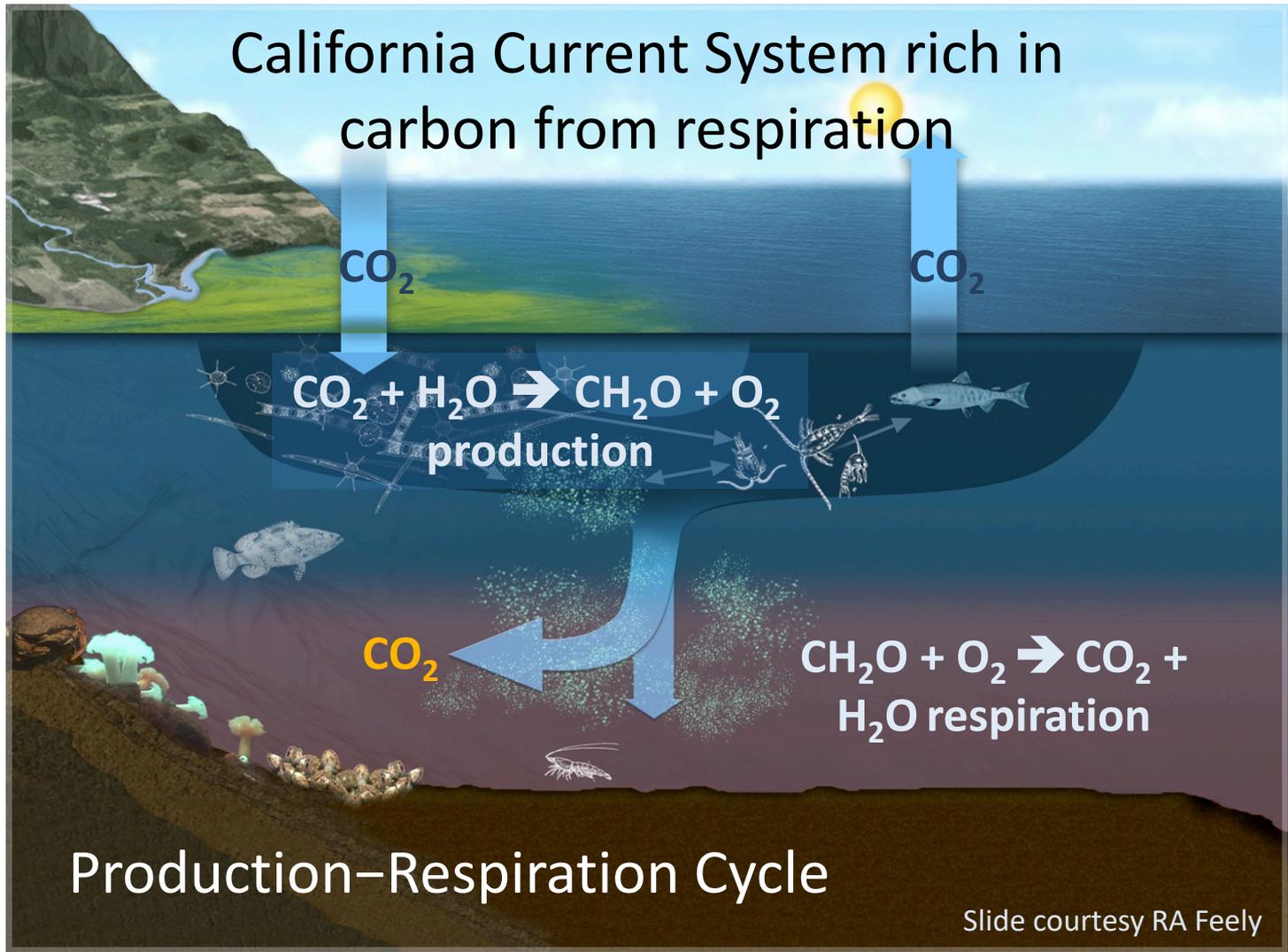
Biological processes also add CO₂ to seawater



Production-Respiration Cycle

Slide courtesy RA Feely

California Current System rich in carbon from respiration

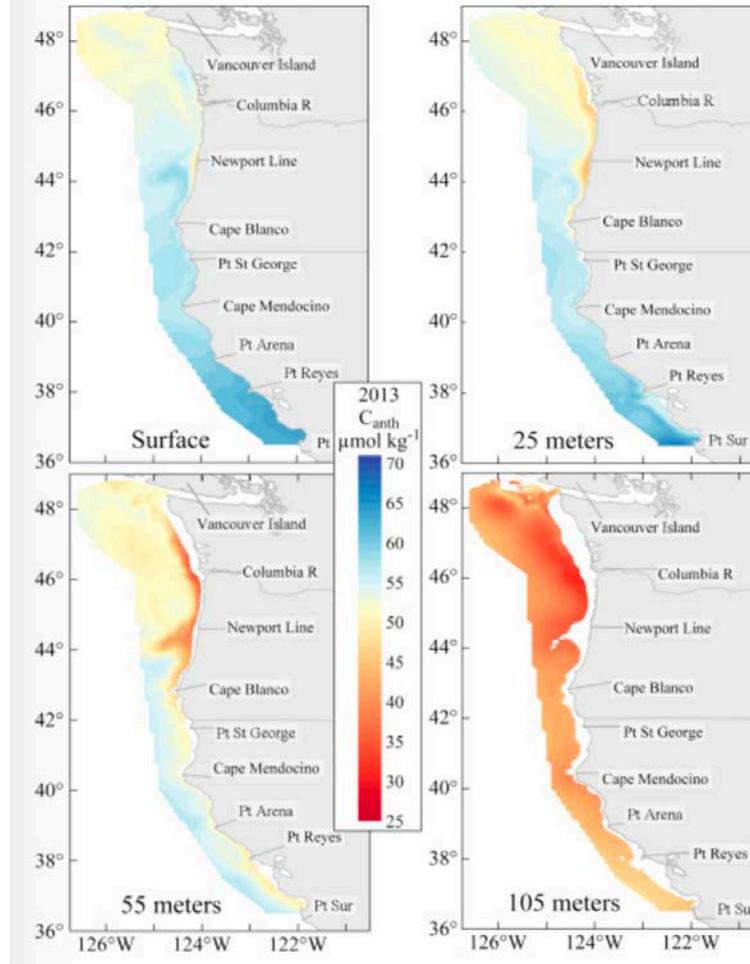


Production-Respiration Cycle

Slide courtesy RA Feely

The anthropogenic fraction of carbon can be calculated

C_{anth} at surface
2013



C_{anth} at 25 m
2013

C_{anth} at 55 m
2013

Source: Feely et al. 2016

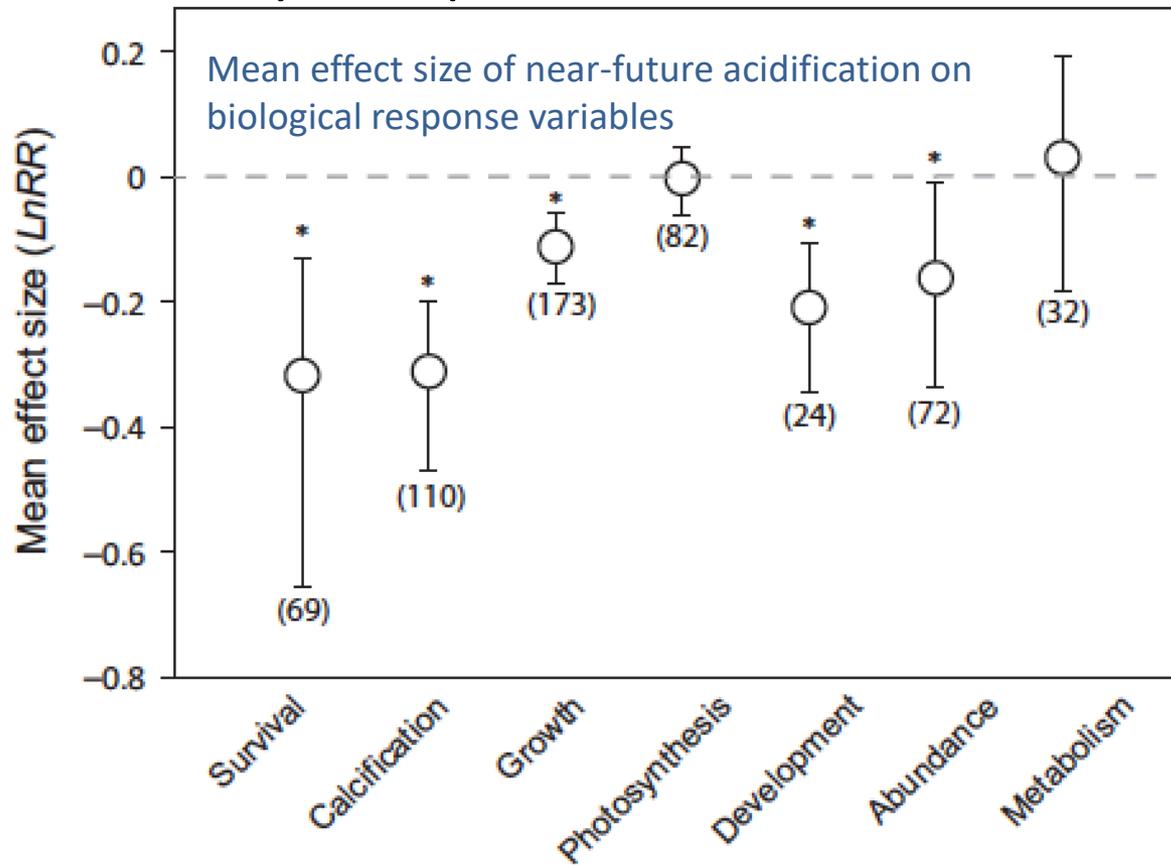
C_{anth} at 105 m
2013

Biological effects?



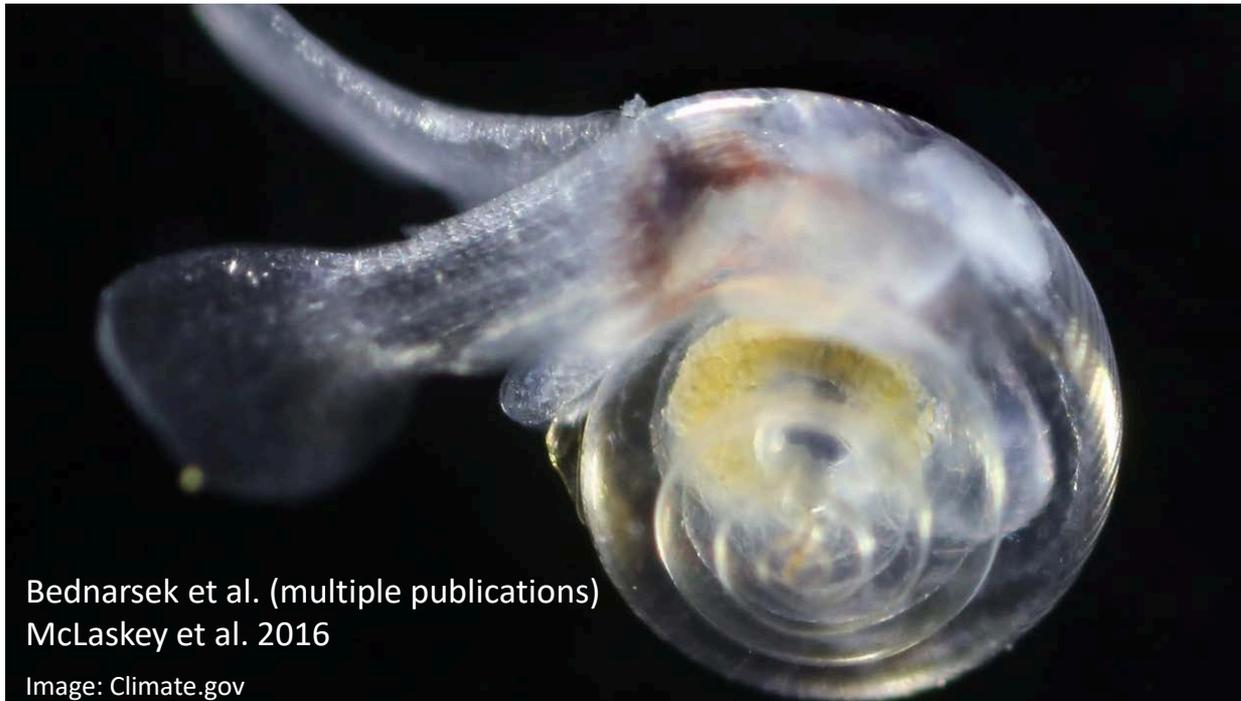
Photo credit: George Grall

Biological effects occur across critical life processes, multiple trophic levels, and habitats



Kroeker et al. 2013
Haigh et al. 2015
Sunday et al. 2016

Planktonic shells are thinner under OA conditions
Calcification rates decline
Changes in behavior occur
Chitinous forms are negatively affected



Bednarsek et al. (multiple publications)
McLaskey et al. 2016

Image: Climate.gov

Bivalves shells and byssus are smaller, weaker under OA conditions



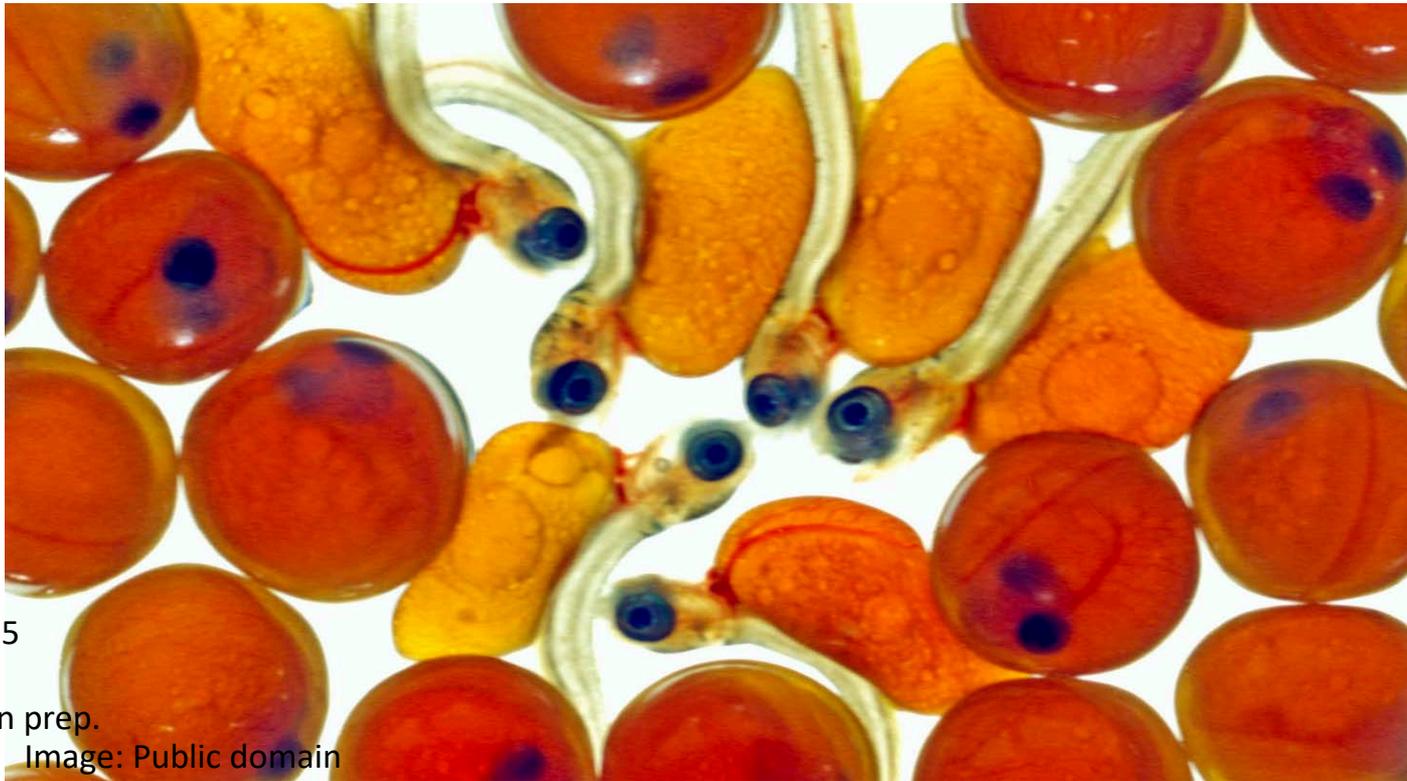
Mortality of Dungeness crab larvae and juveniles increases under OA conditions



Copper rockfish show changes in behavior under OA conditions



Pink salmon show dose-dependent reductions in
critical life-history and behavioral traits;
predator response is affected



Haigh et al. 2015

Ou et al. 2015

Williams et al. in prep.

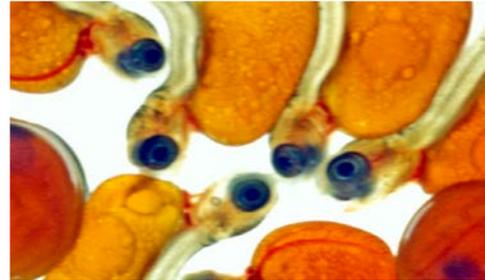
Image: Public domain

Harmful algae grow faster and are more toxic under OA conditions



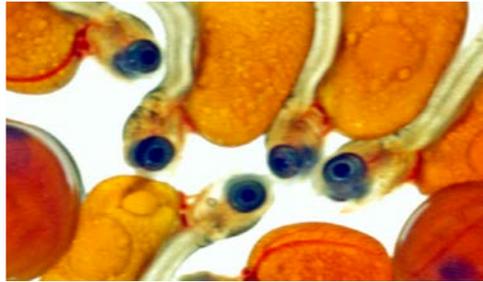
Tatters et al. 2015
Cochlan et al. 2016
Eberlein et al. 2016
Ou et al. 2017

Image : D. Anderson, Woods Hole Center for Oceans and Human Health

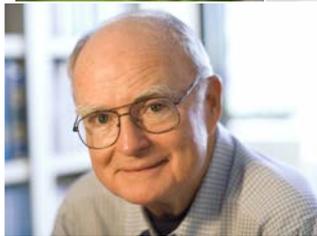


In Washington, threats to valued resources and iconic species spurred action





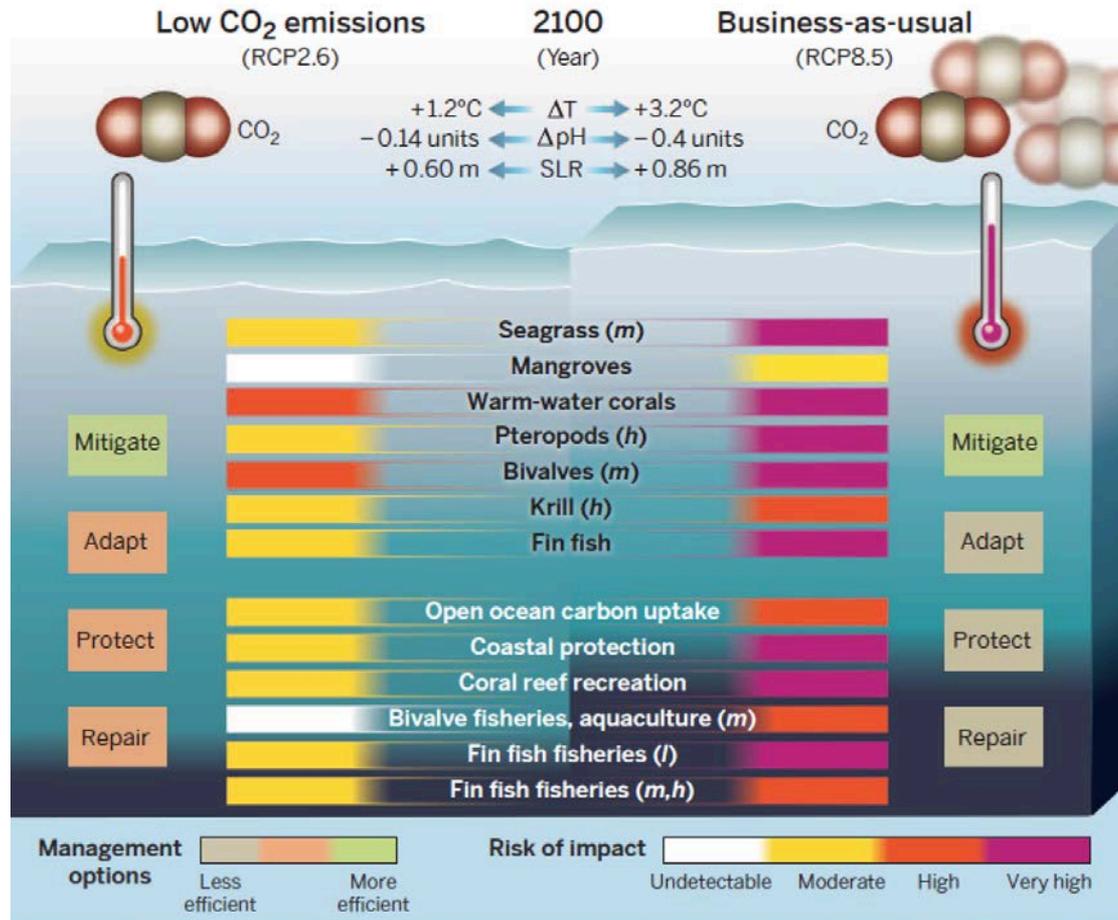
Political leadership has led to actions in Washington and elsewhere



Research Priorities for Washington

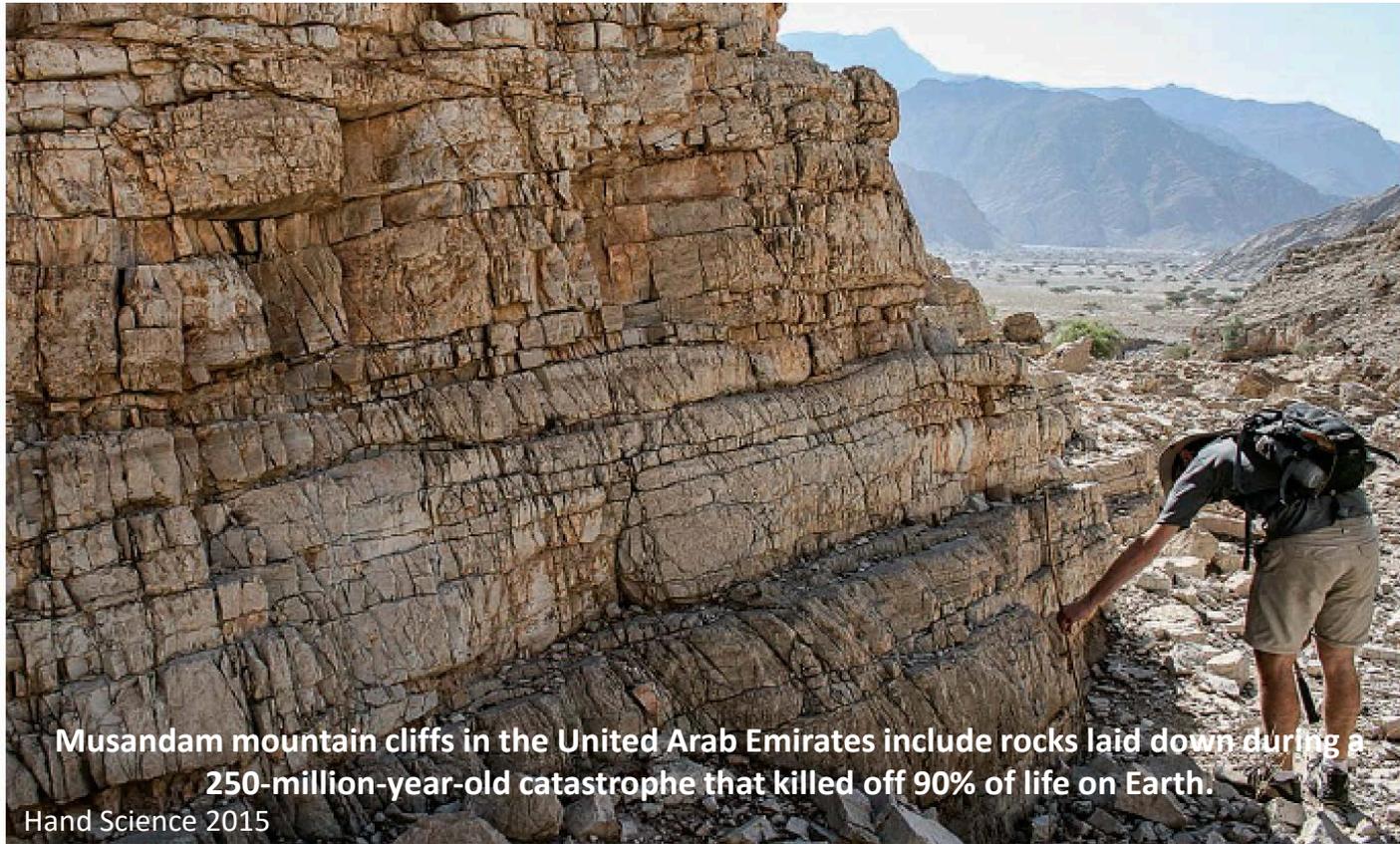
- Understand status and trends of OA in Washington's marine waters
- Quantify the relative contribution of different acidifying factors to OA in Washington's marine waters
- Describe biological responses of local species to OA and associated stressors
- Describe real-time corrosive seawater conditions, develop short-term forecasts and long-term projections of global and local acidification effects

We can choose between alternative futures



Gattuso et al. 2015

“Signature of acidification found in Permian extinctions 250 million years ago” [E. Hand, Science 2015]



Musandam mountain cliffs in the United Arab Emirates include rocks laid down during a 250-million-year-old catastrophe that killed off 90% of life on Earth.

Hand Science 2015