Ocean Acidification: *the other CO_2 problem*

Adrienne Sutton
NRC Postdoctoral Associate
NOAA Pacific Marine Environmental Laboratory
Westport Maritime Museum | April 27, 2010
adrienne.sutton@noaa.gov

Limacina leseuri
Hopcroft/UAF/CoML

Limacina helicina
Hopcroft UAF/CoML

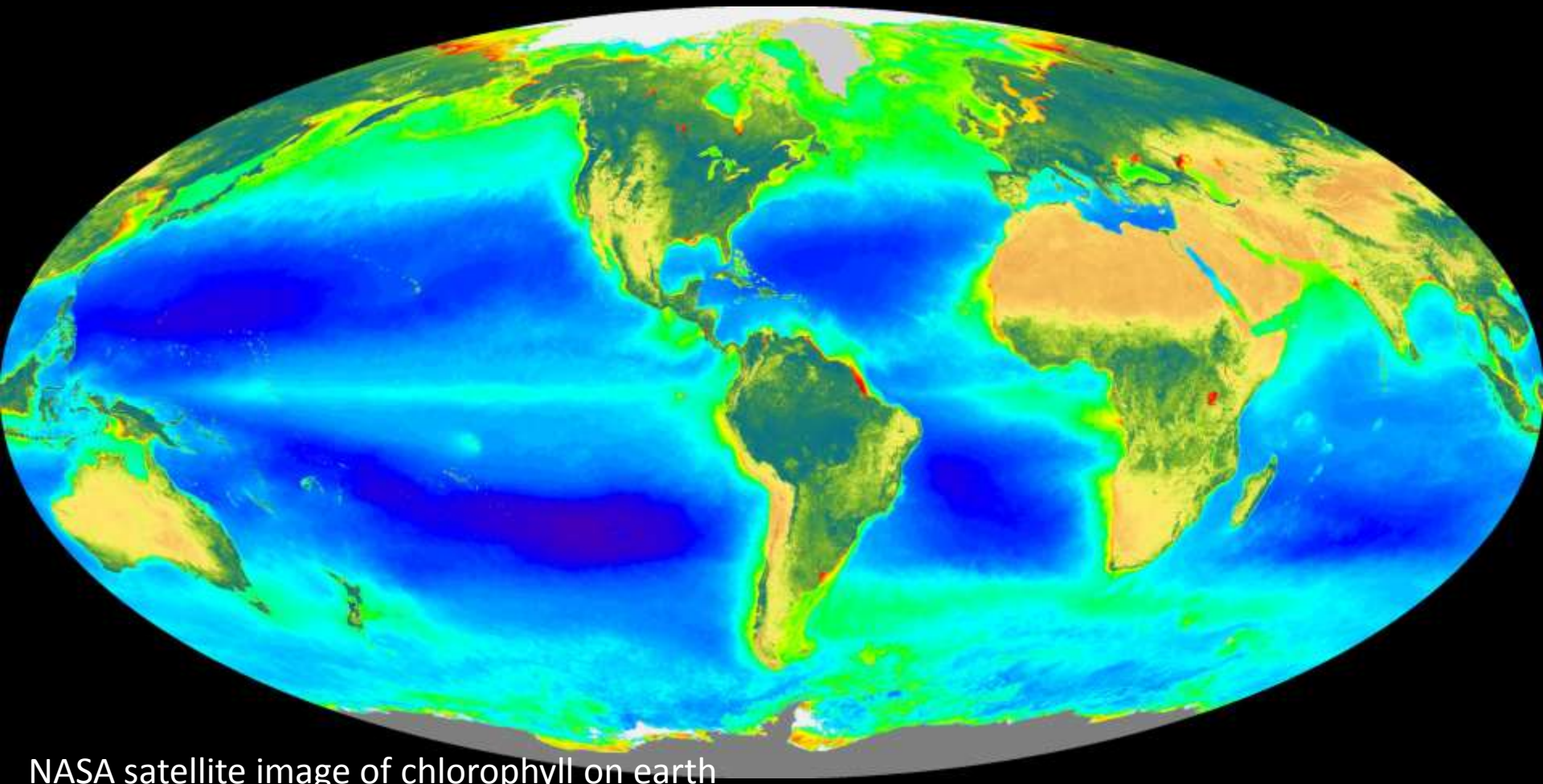
Limacina bulimoides
Hopcroft/UAF/CoML

What is ocean acidification?

The chemistry of the atmosphere and the oceans are tightly linked – for example:

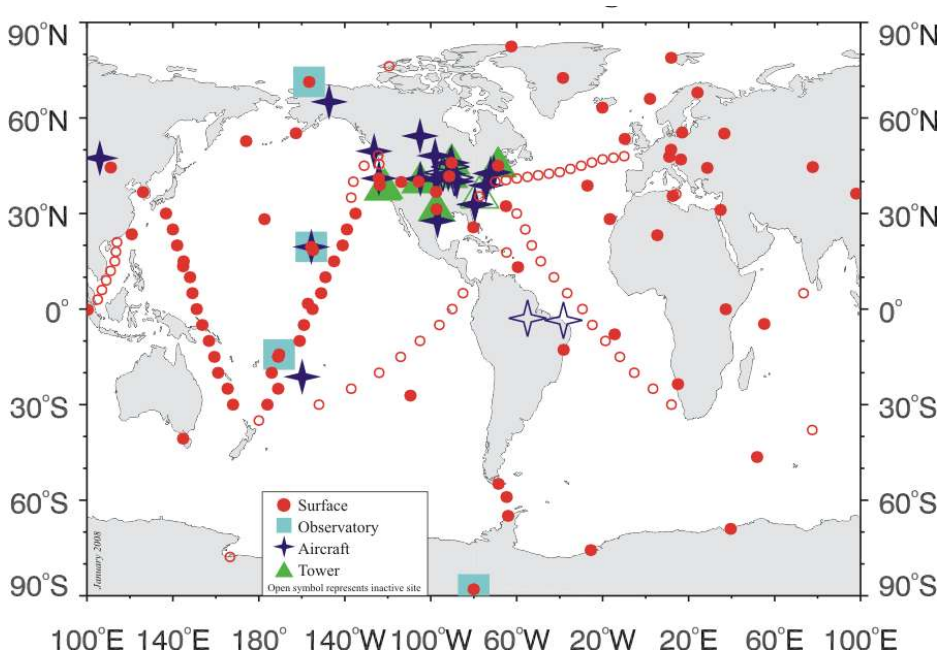
-- phytoplankton in the ocean release oxygen into the air

-- carbon dioxide in the air dissolves in seawater



NASA satellite image of chlorophyll on earth

What is ocean acidification?

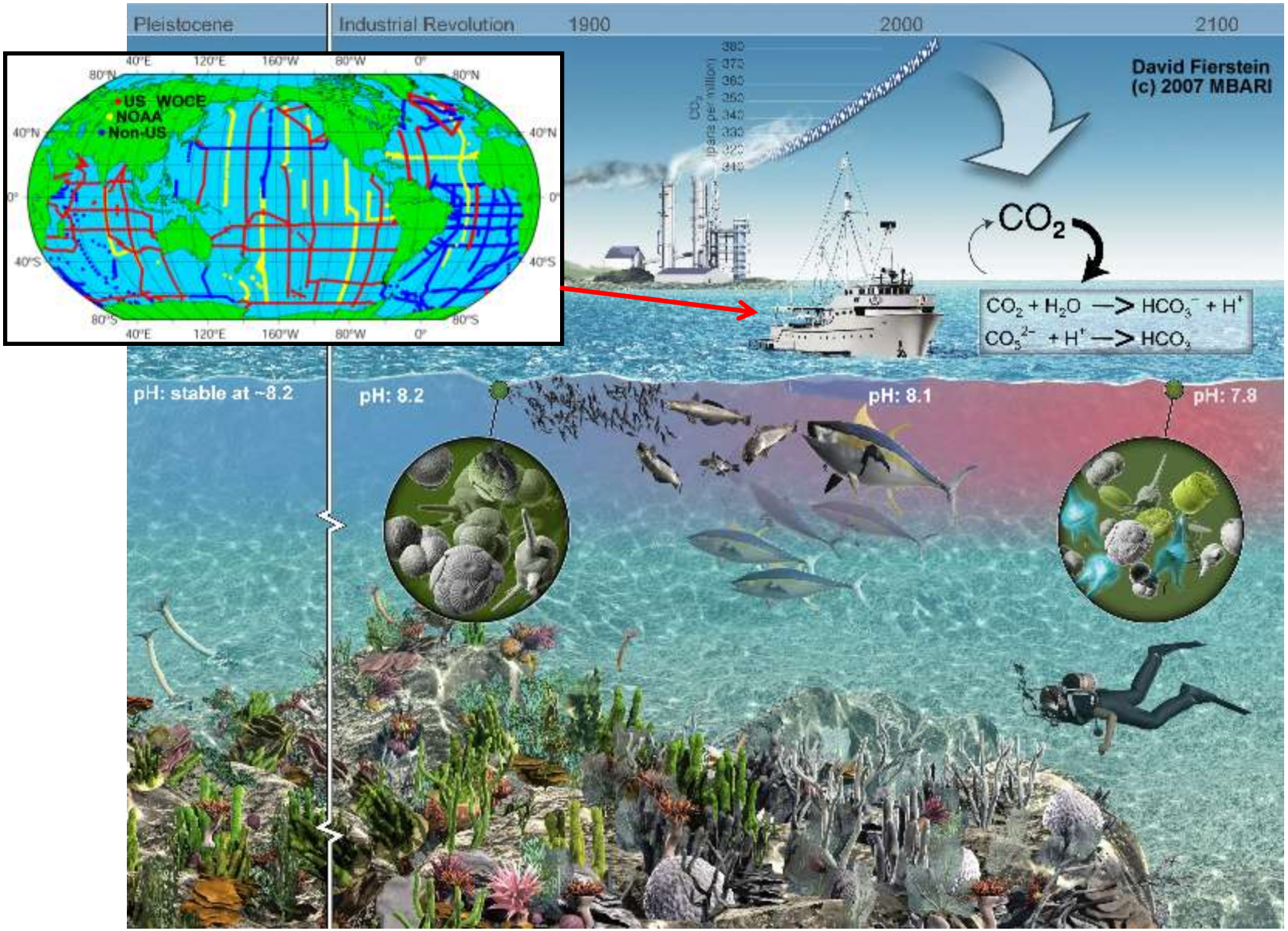


from: NOAA's Earth System Research Laboratory: www.noaa.esrl.gov

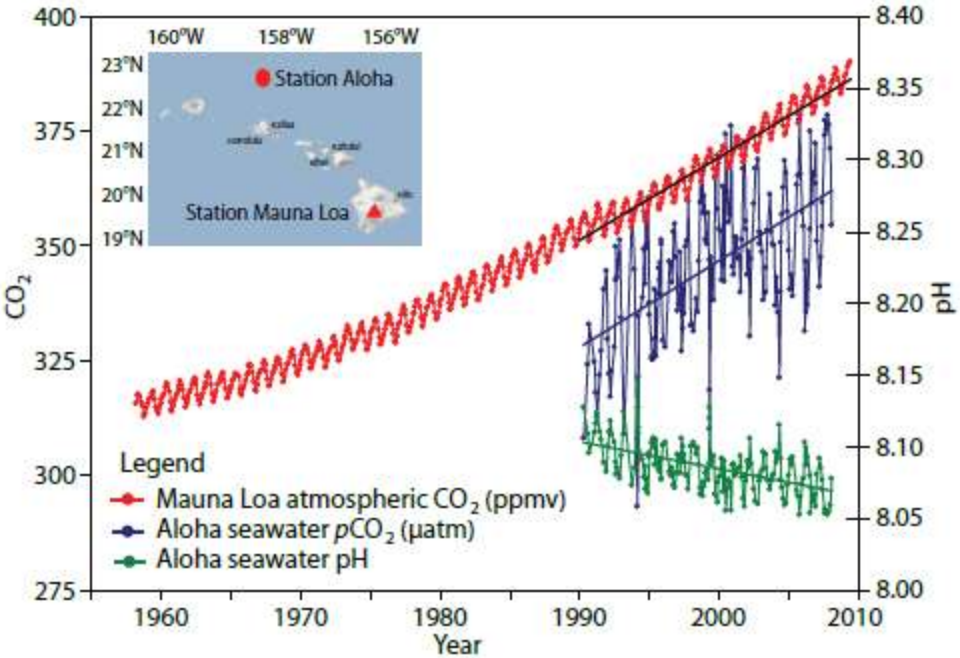
Direct observations of carbon dioxide (CO_2) in the atmosphere for over half a century

Observations show natural annual cycles and increasing trend over time

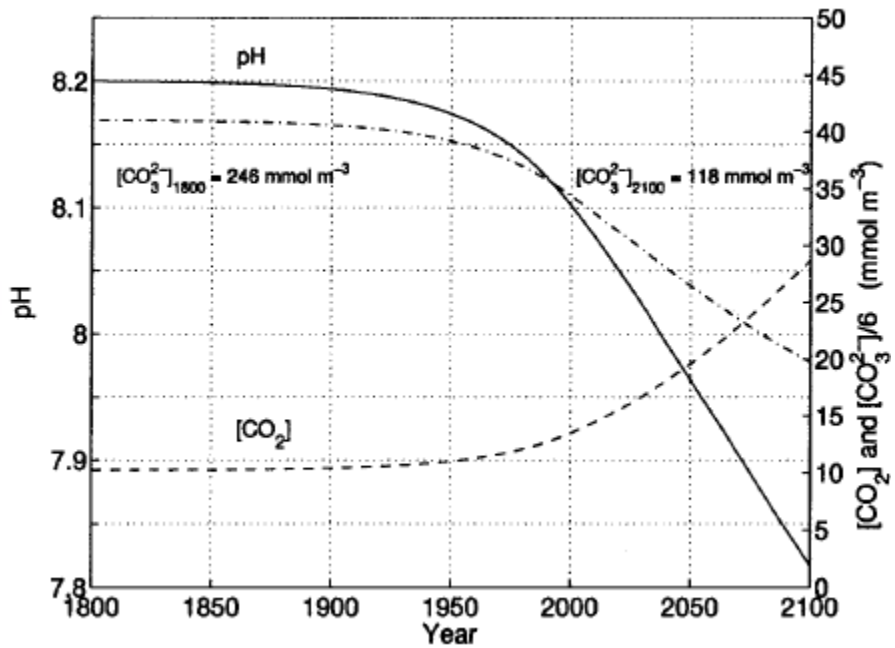
What is ocean acidification?



What is ocean acidification?



from: Doney et al. 2009. Oceanography Vol. 22 No. 4



from: Wolf-Gladrow et al. 1999

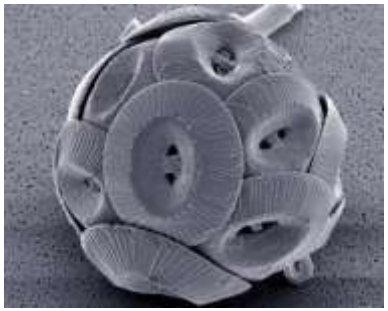
$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

$$\downarrow$$

$$H^+ + CO_3^{2-} \rightarrow HCO_3^-$$

$$Ca^+ + CO_3^{2-} \rightarrow CaCO_3$$

Calcium carbonate



Some photo credits: John Meyer, James Watt, David Csepp

Calcium carbonate

2 main forms of $CaCO_3$ minerals: aragonite and calcite

Saturation state depends on temperature, salinity, and pressure and differs among calcium carbonate minerals

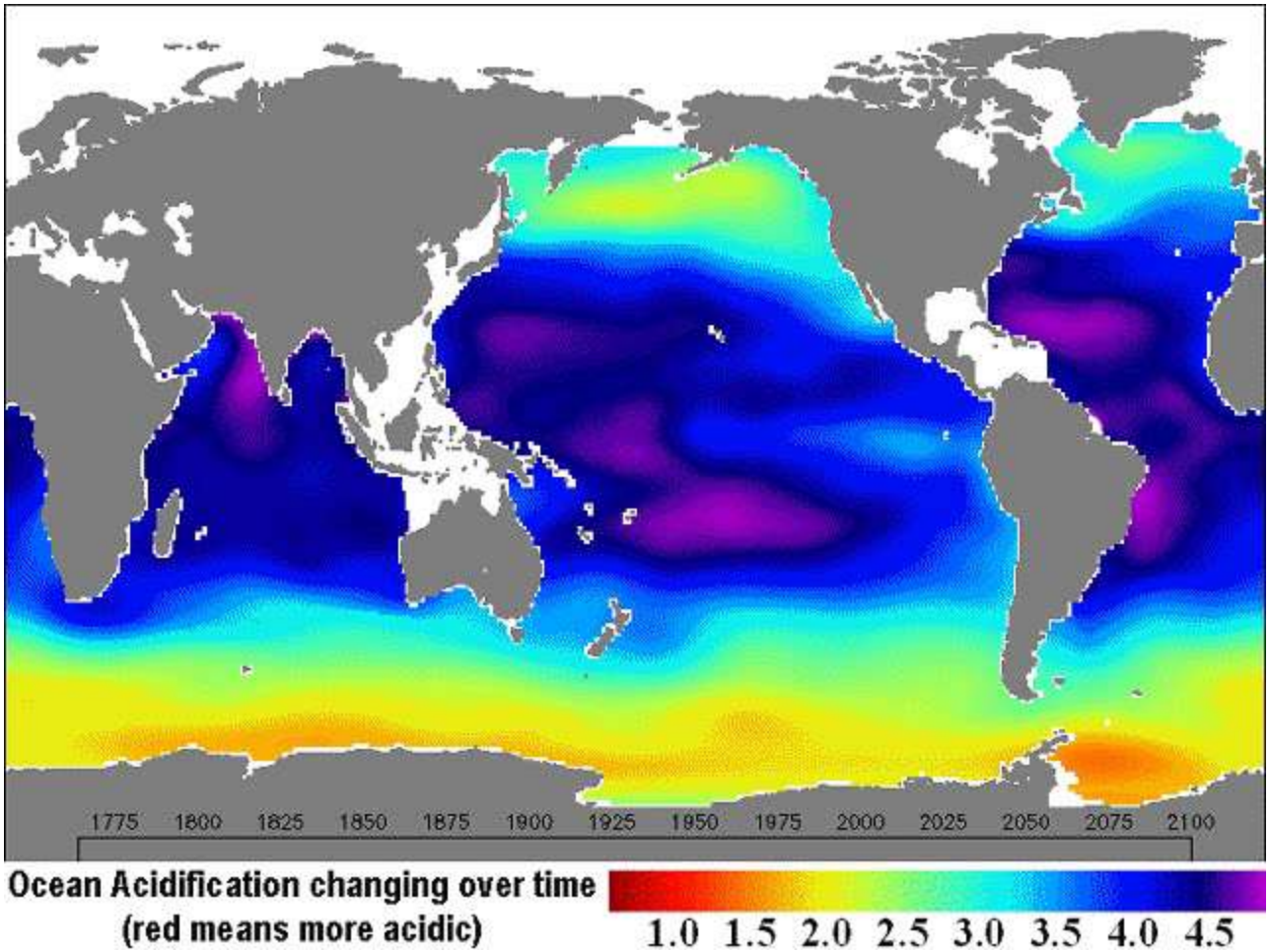
"Saturation state" (Ω) of these minerals:

Supersaturated ($\Omega>1$)

Undersaturated ($\Omega<1$)

The surface water of the ocean where most organisms live is currently supersaturated with $CaCO_3$ minerals

Ocean acidification: future



From: Feely et al. 2009

(animation)

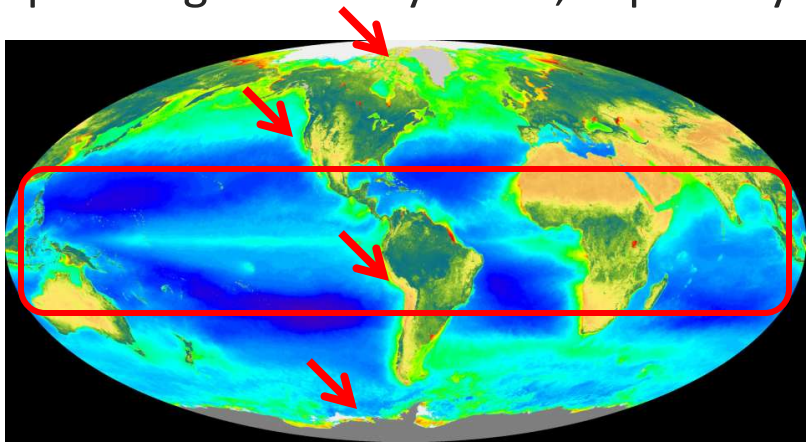
Since we understand the chemistry of $CaCO_3$ minerals and we have observations of the concentration in the oceans, we can predict future saturation states if we continue the current trajectory of CO_2 emissions

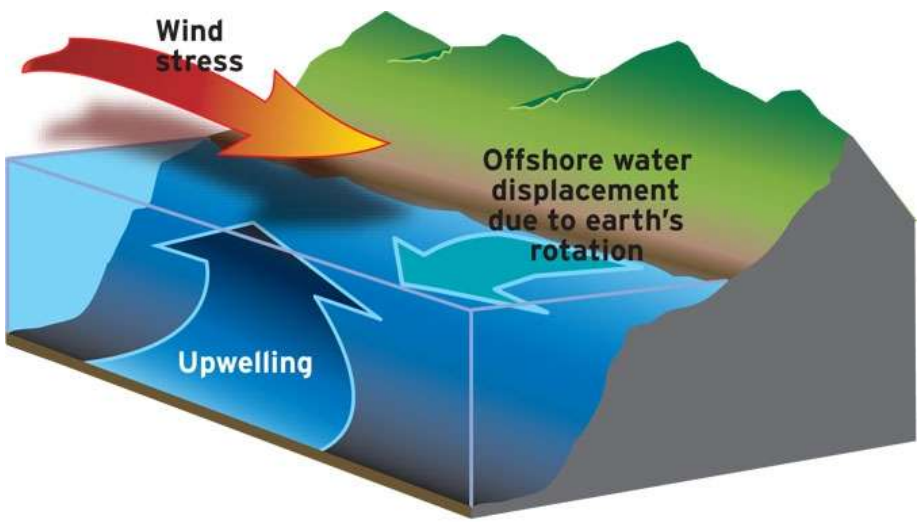
Vulnerable ecosystems

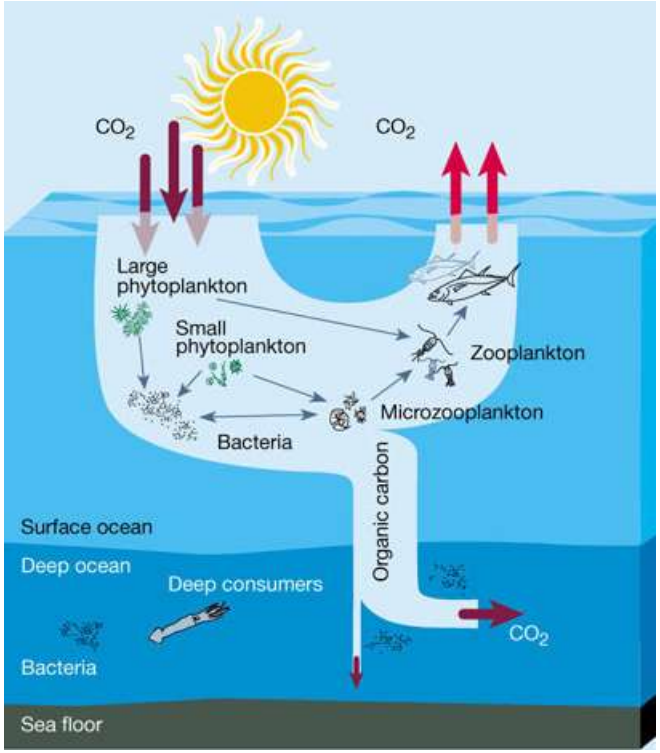
Arctic and Antarctic – CO_2 is more soluble in colder water

Coral reef ecosystems – corals do best in supersaturated waters (e.g., Ω_{arag}>4)

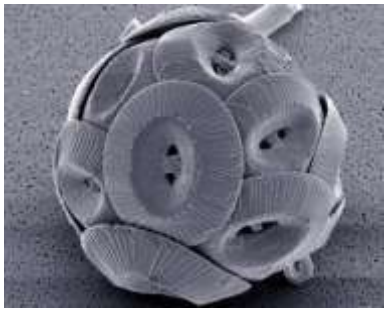
Upwelling coastal systems, especially California and Humboldt – upwelling + OA







Biological impacts



Some photo credits: John Meyer, James Watt, David Csepp

Biological impacts: experimental

PHYSIOLOGICAL RESPONSE	MAJOR GROUP	# SPECIES STUDIED	RESPONSE TO INCREASING CO_2 a	b	c	d
CALCIFICATION						
	Coccolithophores	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	6	5	–	1	–
	Echinoderms	3	2	1	–	–
	Tropical Corals	11	11	–	–	–
	Coralline Red Algae	1	1	1	–	–

from: Doney et al. 2009. Oceanography Vol. 22 No. 4

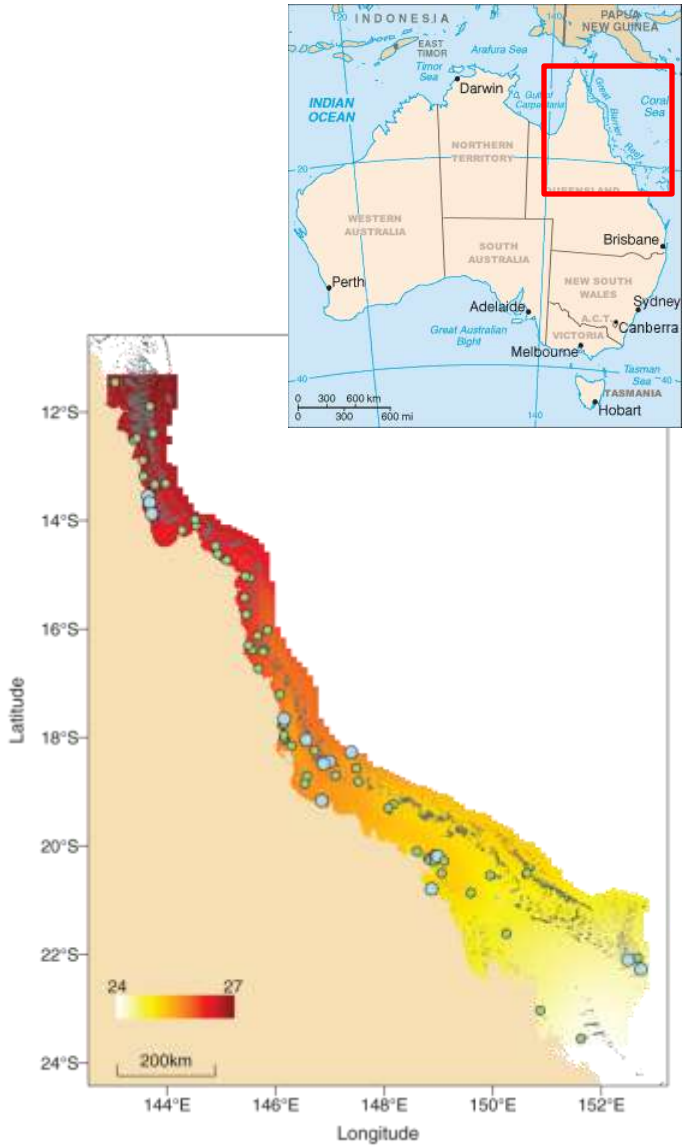
Biological impacts: experimental

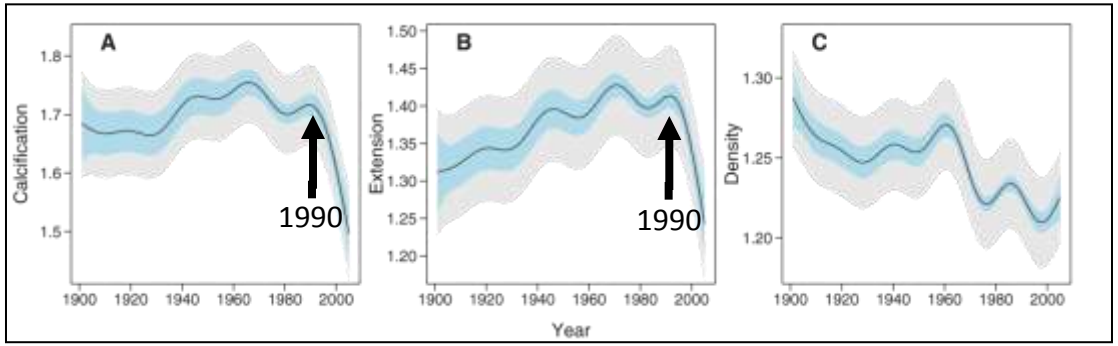
PHYSIOLOGICAL RESPONSE	MAJOR GROUP	# SPECIES STUDIED	RESPONSE TO INCREASING CO_2 a	b	c	d
PHOTOSYNTHESIS[1]						
	Coccolithophores[2]	2	–	2	2	–
	Prokaryotes	2	–	1	1	–
	Seagrasses	5	–	5	–	–
NITROGEN FIXATION						
	Cyanobacteria	4	–	3	1	–
REPRODUCTION						
	Molluscs	4	4	–	–	–
	Echinoderms	1	1	–	–	–

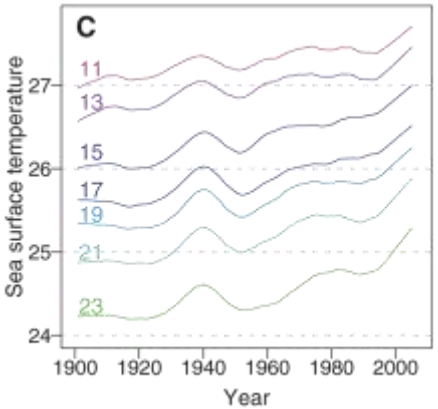
[1] Strong interactive effects with nutrient and trace metal availability, light, and temperature
[2] Under nutrient replete conditions

from: Doney et al. 2009. Oceanography Vol. 22 No. 4

Biological impacts: in the field







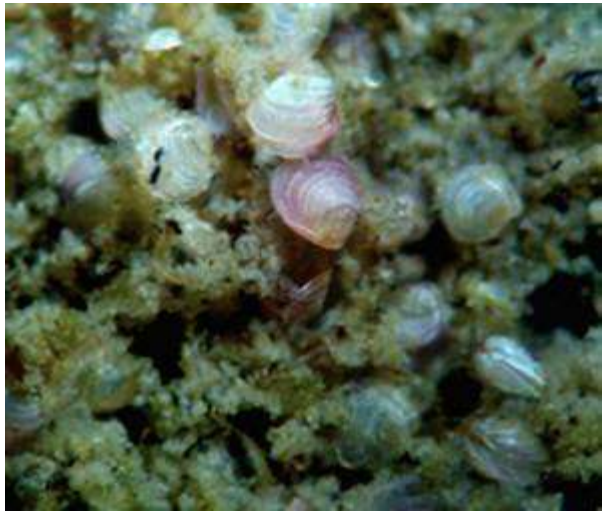
328 coral samples from 69 sites along the Great Barrier Reef

Threshold passed around 1990

Multiple stressors (sea surface temperature + OA) are likely main cause of decline in coral growth and density

From: De'ath et al. 2009

Biological impacts: in the field

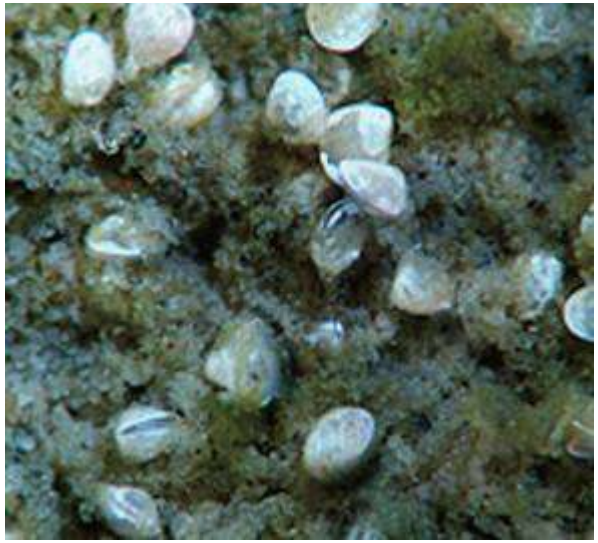


Control

$\Omega_{arag} = 1.5$

Hard shell clam *Mercenaria*

- Common in soft bottom habitats
- Dissolution within 24 hours in undersaturated water; shell gone within 2 weeks
- Dissolution is source of mortality in estuaries & coastal habitats



$\Omega_{arag} = 0.3$

Bivalve juvenile stages can be particularly sensitive to carbonate chemistry

from: Green et al. 2004

Impacts to ecosystem services: hatcheries

Pacific Northwest Oyster Hatcheries:

- Failure of larval oyster recruitments in recent years
- Commercial oyster hatchery failures threatens $100M industry (3000 Jobs)
- Low pH waters a possible leading factor in failures
- Larval oyster may be “canary in goldmine” for near-shore acidification?

Solutions

Alternatives to burning fossil fuels

Manage local stressors

overfishing and destructive fishing

coastal pollution

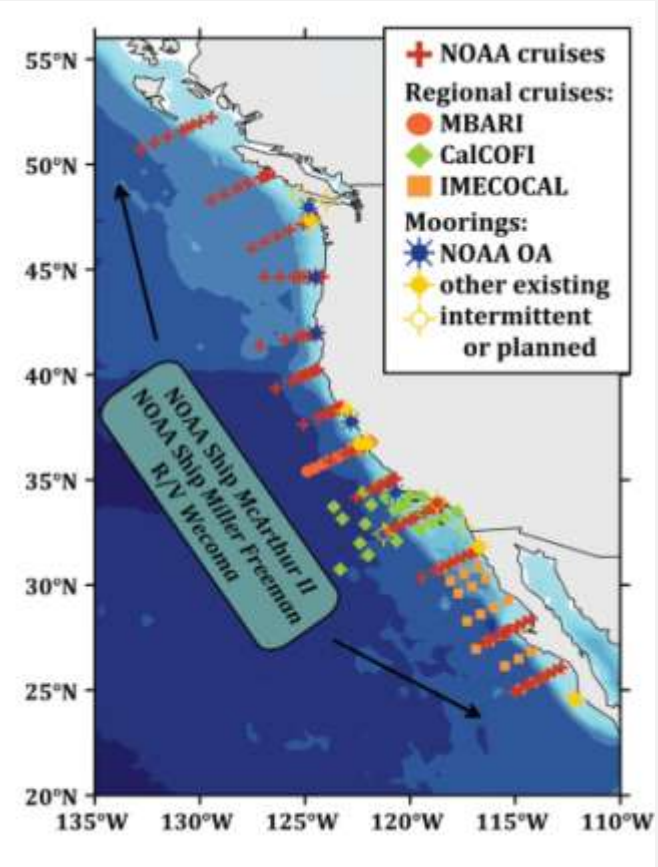
buffer water used in hatcheries

OA research priorities: biology

From National Academy of Sciences:

- understand the physiological mechanisms of biological changes
- assess the potential for organisms to adapt
- investigate the response of individuals, populations, and communities
- understand ecosystem-level consequences
- investigate the interactive effects of multiple stressors

OA research priorities: observations



Example of what an observing system on the U.S. west coast could look like

First ocean acidification mooring in the Gulf of Alaska: preliminary results show a clear seasonal trend in pH and a strong correlation with CO_2

Who's involved

National

H. R. 14

IN THE HOUSE OF REPRESENTATIVES

A BILL

Local

UNIVERSITY of WASHINGTON

OSU Oregon State UNIVERSITY

Thank you. Questions?

Useful links for more information:

www.nrdc.org/oceans/acidification/aboutthefilm.asp

(*Acid Test* documentary)

www.tos.org/oceanography/issues/issue_archive/22_4.html

www.pmel.noaa.gov/co2/OA

www.epoca-project.eu

www.whoi.edu/OCB-OA

www.aseachange.net

Educators (teaching and lab modules):

cmore.soest.hawaii.edu/education/teachers/science_kits/ocean_acid_kit.htm

www.us-ocb.org/publications/OCB-OA_labkit102609.pdf

i2i.stanford.edu/carbonlab/co2lab.swf