Ocean Acidification:
the other CO_2 problem

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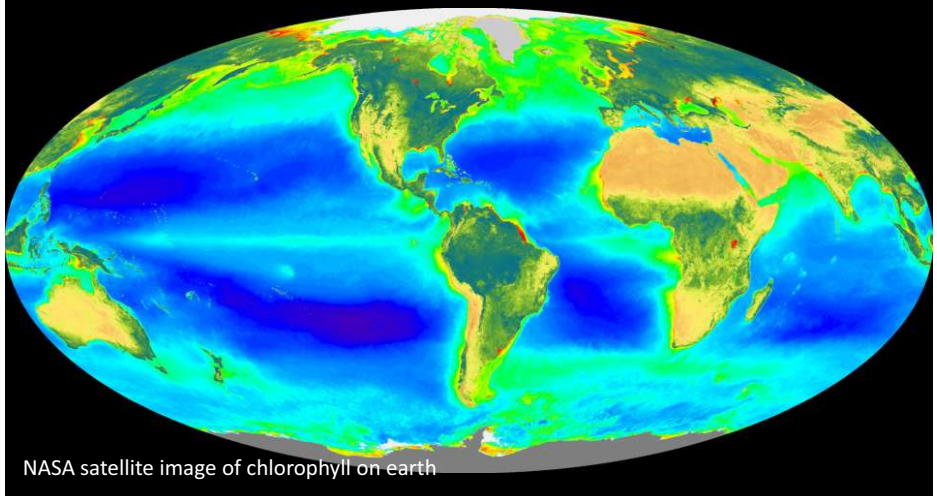
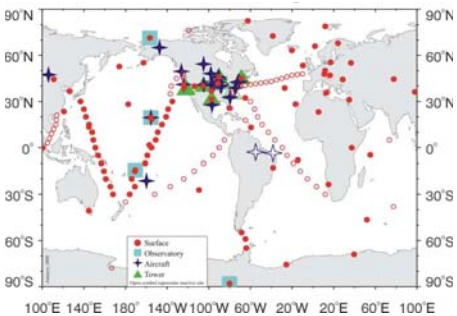
What is ocean acidification?

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?

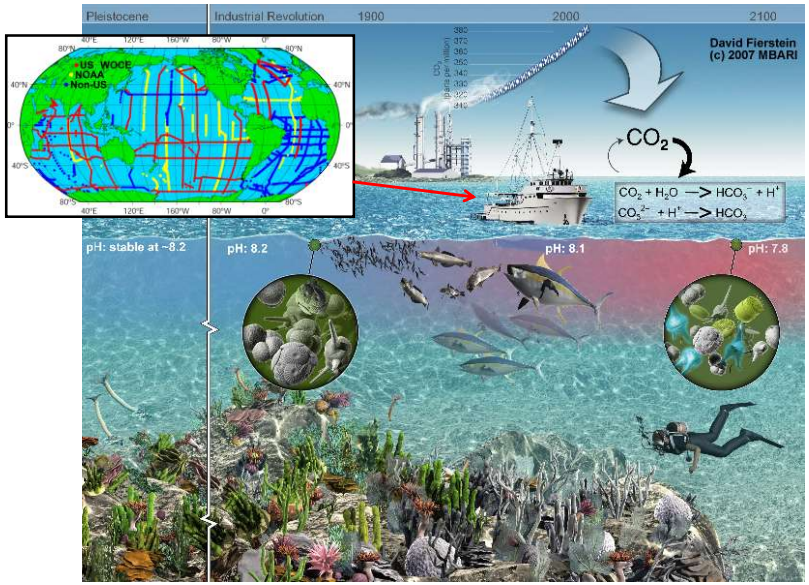


from: NOAA's Earth System Research Laboratory:
www.noaa.esrl.gov

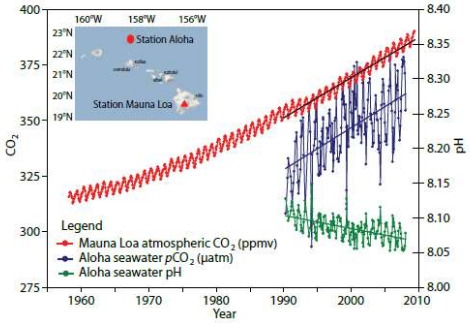
Direct observations of carbon dioxide (CO_2) in the atmosphere for over half a century

Observations show natural annual cycles and increasing trend over time

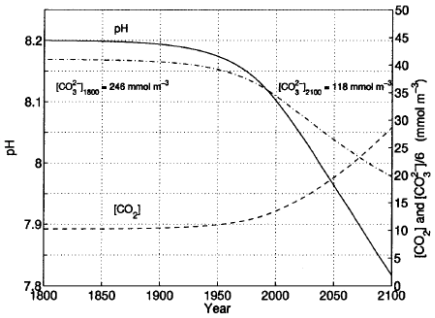
What is ocean acidification?



What is ocean acidification?



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



from: Wolf-Gladrow et al. 1999

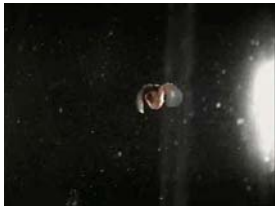
$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

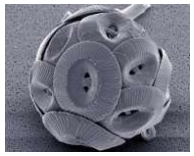
$\downarrow$

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

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

Calcium carbonate





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

Calcium carbonate

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

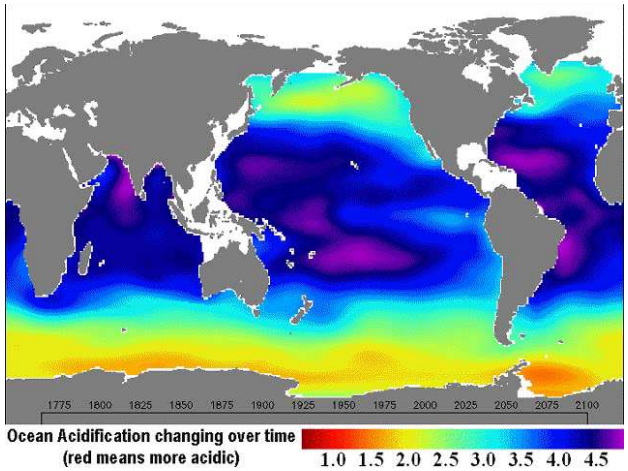
Saturation state depends on temperature, salinity, and pressure and differs among calcium carbonate minerals

"Saturation state" (Ω) of these minerals:

Supersaturated (Ω>1)
Undersaturated (Ω<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)

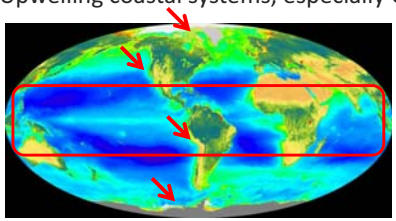
Since we understand the chemistry of $CaCO_3$ minerals and we have observations of the concentration in the oceans, we can predict future saturation states if we continue the current trajectory of CO_2 emissions

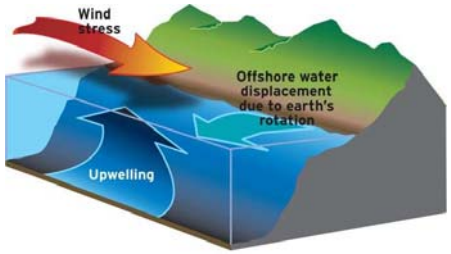
Vulnerable ecosystems

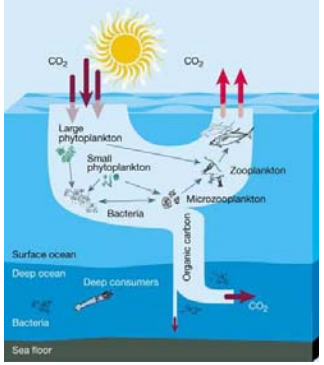
Arctic and Antarctic – CO_2 is more soluble in colder water

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

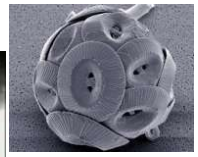
Upwelling coastal systems, especially California and Humboldt – upwelling + OA







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

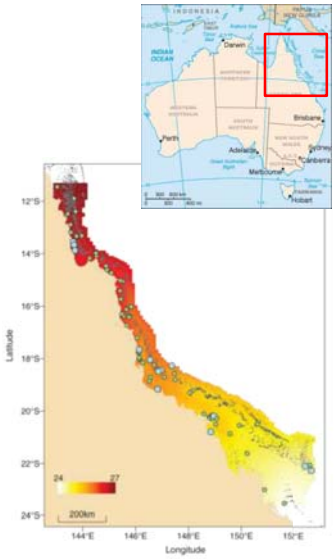
Biological impacts: experimental

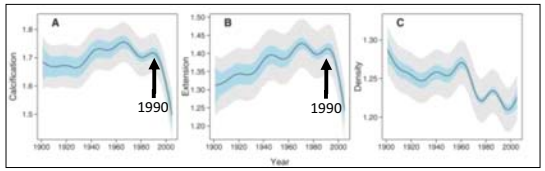
PHYSIOLOGICAL RESPONSE / MAJOR GROUP	# SPECIES STUDIED	RESPONSE TO INCREASING CO_2 a	b	c	d
PHOTOSYNTHESIS[1]					
Coccolithophores[2]	2	–	2	2	–
Prokaryotes	2	–	1	1	–
Seagrasses	5	–	5	–	–
NITROGEN FIXATION					
Cyanobacteria	4	–	3	1	–
REPRODUCTION					
Molluscs	4	4	–	–	–
Echinoderms	1	1	–	–	–

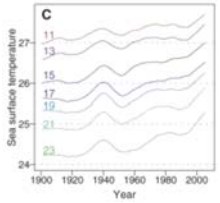
[1] Strong interactive effects with nutrient and trace metal availability, light, and temperature
[2] Under nutrient replete conditions

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

Biological impacts: in the field







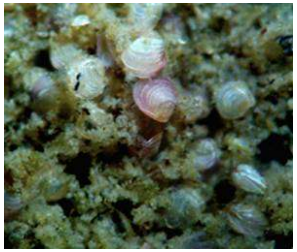
328 coral samples from 69 sites along the Great Barrier Reef

Threshold passed around 1990

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

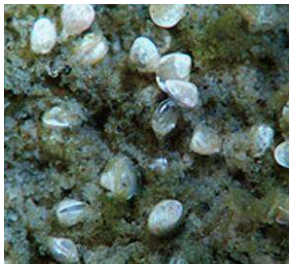
From: De'ath et al. 2009

Biological impacts: in the field



Control

$\Omega_{arag} = 1.5$



$\Omega_{arag} = 0.3$

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

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

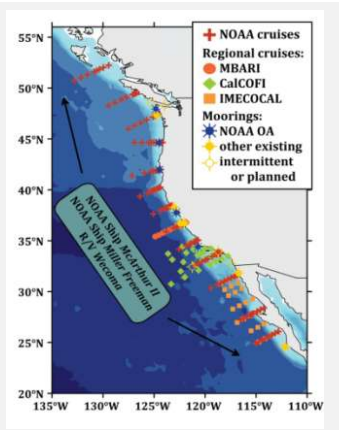
buffer water used in hatcheries

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

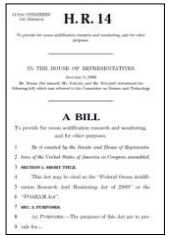


Example of what an observing system on the U.S. west coast could look like

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



Local

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

Marine Spatial Planning

Jennifer Hennessey
Washington Dept. of Ecology

Marine Spatial Planning

- What is it?
- Why are we talking about it?
  - State law
  - Federal action
- What are the next steps?
- How can I get more information or be involved?

Marine Spatial Planning Defined

Marine Spatial Planning (MSP) is a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine environments to achieve ecological, economic, and social objectives.

- Coordinating decisions
- Uses data – often displayed as maps
- Proactive
- Strategic
- Multi-use

Marine Spatial Planning Process

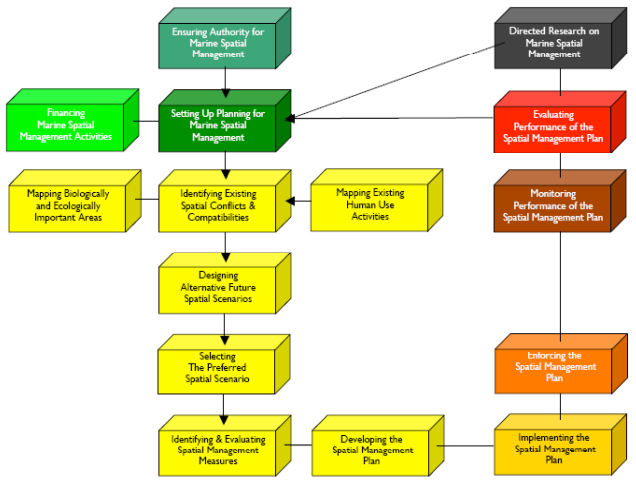
Typically, results in:

- Vision
- Comprehensive Plan
- Management strategies and measures

NOT the same as zoning.

Outcome depends on the scope of the plan.

Marine Spatial Planning Steps



New State Law

Substitute Senate Bill 6350 enacted in March 2010 which requires the state to:

- Recommend an approach to marine spatial planning through an interagency team. Report due by December 15, 2010.

Some key questions for the report:

What are the gaps in management that marine spatial planning can or should seek to fill?

What are the key spatial data needs and important uses to consider for conducting marine spatial planning?

How to conduct marine spatial planning in a way that integrates into existing management plans, including goals and objectives?

New State Law

If the state receives federal or non-state funds, the law also directs state agencies to:

1. Compile and incorporate spatial data into current plans.
2. Develop guidance on the operation and siting of renewable energy facilities.
3. Conduct comprehensive marine spatial planning for all of Washington's waters.

What must be in a state plan?

- Ecosystem assessment and indicators
- Management measures
- Series of maps
- State recommendations for uses in federal waters
- Implementation plan
- Framework for renewable energy

Ocean Policy Task Force

"To succeed in protecting the oceans, coasts, and Great Lakes, the United States needs to act within a unifying framework under a clear national policy, including a comprehensive, ecosystem-based framework for the long-term conservation and use of our resources."

– President Barack Obama, June 12, 2009
Creation of the Ocean Policy Task Force

- Interim Framework for Coastal and Marine Spatial Planning Released December 14, 2009.
- Final framework expected Spring 2010.

Next Steps

State Ocean Caucus – interagency team

Examine key questions for MSP in Washington and develop recommendations for framework in report.
Engage MRCs, tribes and public in process.

West Coast Governors' Agreement

Feedback on national framework on the role of regional groups.
Develop regional approach based on existing work and needs.

Next Steps: Interagency Report

Interagency team meets monthly to examine key questions.

Public process

April-June	Survey: management needs and other information
April-June	Briefings to key groups
July (TBD)	Spatial data workshop for technical experts
September	Public comment period on draft recommendations

How to learn more or get involved?

Marine Spatial Planning

http://www.ecy.wa.gov/programs/sea/msp/

Ocean resources

http://www.ecy.wa.gov/programs/sea/ocean/

Contact me:
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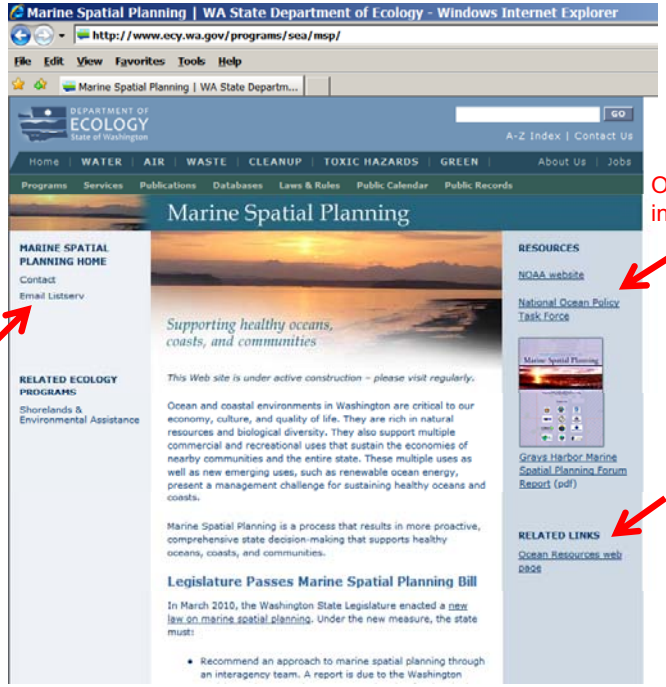

WEST COAST GOVERNORS' AGREEMENT on OCEAN HEALTH

CALIFORNIA OREGON WASHINGTON

Priorities

1. Ensuring clean coastal waters and beaches
2. Protecting and restoring healthy ocean and coastal habitats
3. Promoting the effective implementation of ecosystem-based management of our ocean and coastal resources
4. Reducing adverse impacts of offshore development
5. Increasing ocean awareness and literacy among our citizens
6. Expanding ocean and coastal scientific information, research, and monitoring
7. Fostering sustainable economic development throughout our diverse coastal communities

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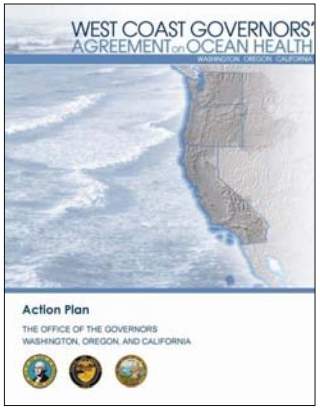
CALIFORNIA OREGON WASHINGTON



In coming weeks:

- 8 final plans released
- 2 new draft plans out for public comment

WEST COAST GOVERNORS' AGREEMENT on OCEAN HEALTH
CALIFORNIA OREGON WASHINGTON

Action Coordination Teams (ACTs)

1. Climate change
2. Polluted runoff
3. Marine debris
4. *Spartina* eradication
5. Renewable ocean energy
6. Ocean education
7. Sediment management
8. Seafloor mapping
9. Integrated Ecosystem Assessments (IEAs)*
10. Sustainable communities*

Members from:

+ Each of the 3 states

+ Federal agencies

+ Tribal governments

+ Academia

+ NGOs

+ Industry

WEST COAST GOVERNORS' AGREEMENT on OCEAN HEALTH
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Examples of work plan activities

- Renewable energy planning guidebook
- Climate change regional impacts study
- *Spartina* eradication, treatment of known infestations in OR, CA, and BC
- Lessons-learned and support for regional sediment management
- Seafloor mapping