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Ocean Acidification

effects on marine organisms

Hypothesis

- What is Ocean Acidification?
- Justify your hypothesis.
- How might you test your hypothesis?

What is Ocean Acidification

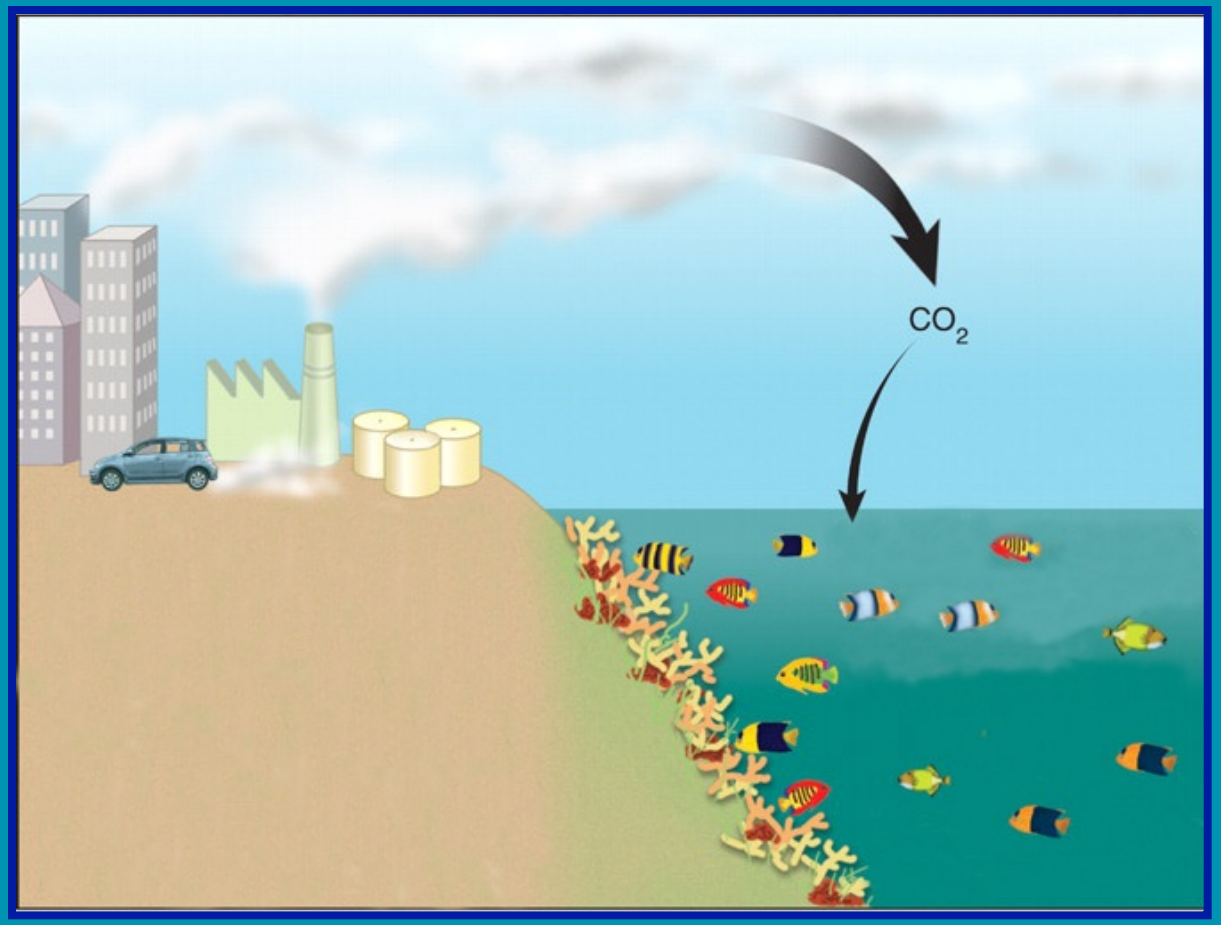
Ocean acidification is the name given to the ongoing decrease in the pH of the Earth's oceans

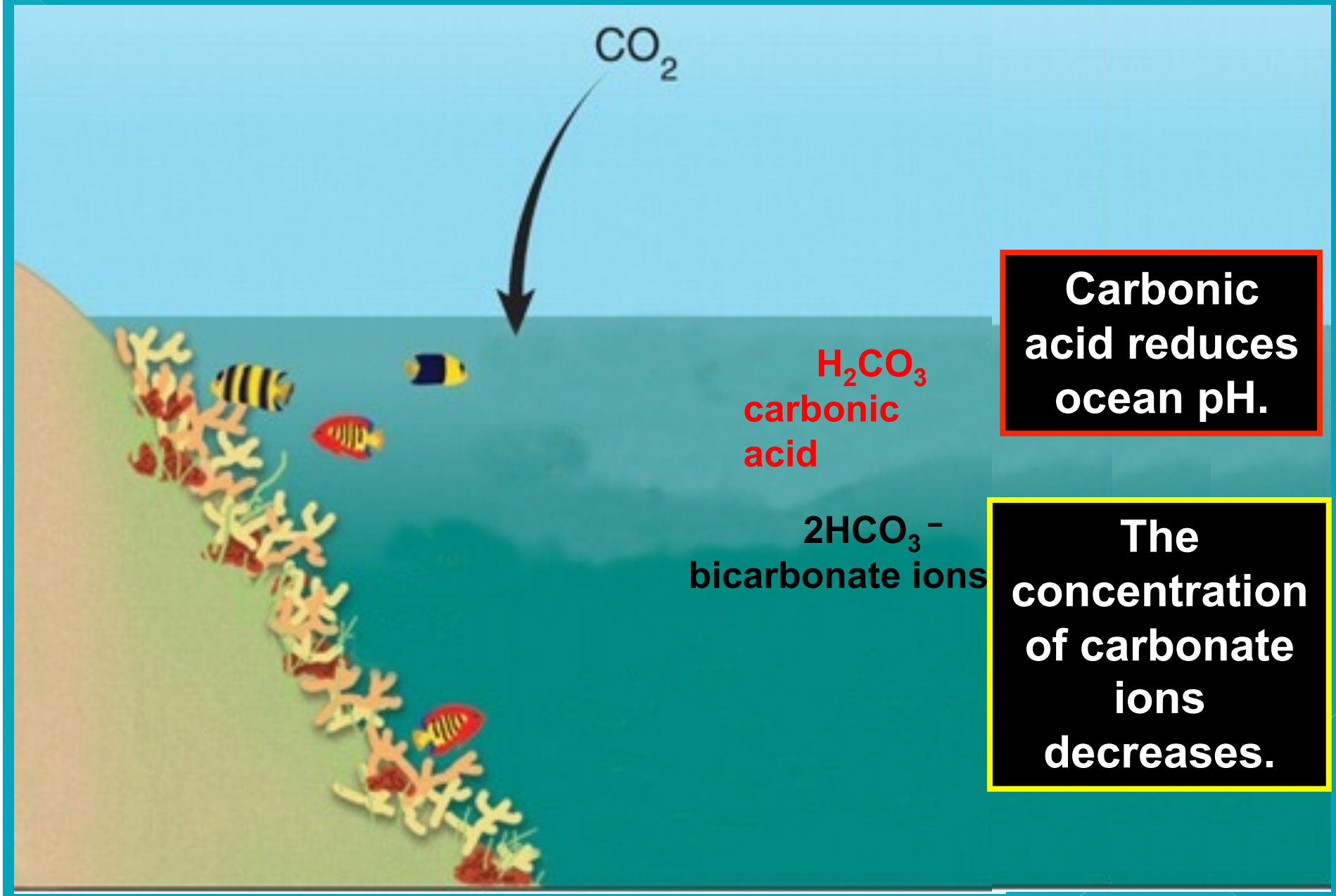
- Ocean acidification is caused by ocean's uptake of anthropogenic carbon dioxide (CO_2) from the atmosphere.
- Ocean acidification is decreasing the ability of many marine organisms to build their shells and skeletal structure.

Ocean Acidification vs. Climate Change

- Ocean acidification is **NOT** climate change.
  - When CO_2 dissolves in seawater, carbonic acid is formed. It is this chemical reaction that leads to ocean acidification. It is independent of the climate processes.
  - Reduction of global temperature and concentration of other greenhouse gases will not reduce ocean acidification.
- Both climate change and ocean acidification are caused by the release of anthropogenic CO_2

Carbon dioxide dissolves in the ocean, where it causes a potentially more serious problem → ocean acidification.





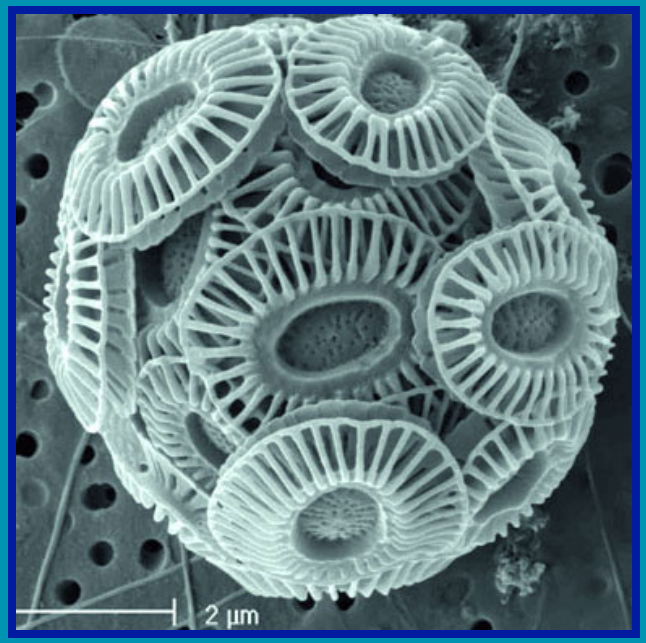
Carbonic acid reduces ocean pH.

The concentration of carbonate ions decreases.

What Does Ocean Acidification Mean for Organisms?

- The reduction in pH reduces the availability of carbonate ions
- Carbonate ions play an important role in shell formation for marine organisms (shells are made of calcium carbonate – our bones are made of calcium)
- CO_2 is corrosive to the shells and skeletons of marine organisms
- Some of the organisms affected:
  Corals, sea urchins, some marine plankton, marine snails, crabs

Ocean acidification poses a threat to shell-forming organisms like corals and calcifying plankton.



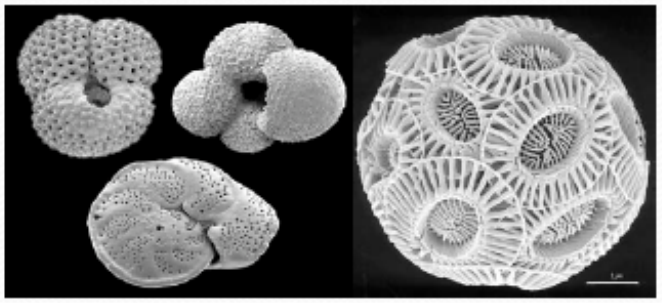
Aragonite and Calcite

Calcium carbonate occurs primarily in two forms in marine organisms: aragonite and calcite.

Aragonite

- Such as calcareous algae, coral reef.
- Aragonite more easily to dissolves when oceanic carbonate concentrations fall;

Calcite



- Such as Foraminifera and coccolithophorids.
- Calcite are more resistant to ocean acidification.

Organisms with aragonite structures will be most severely impacted by ocean acidification compared to calcite.

- CO_2 is corrosive to the shells and skeletons of many marine organisms

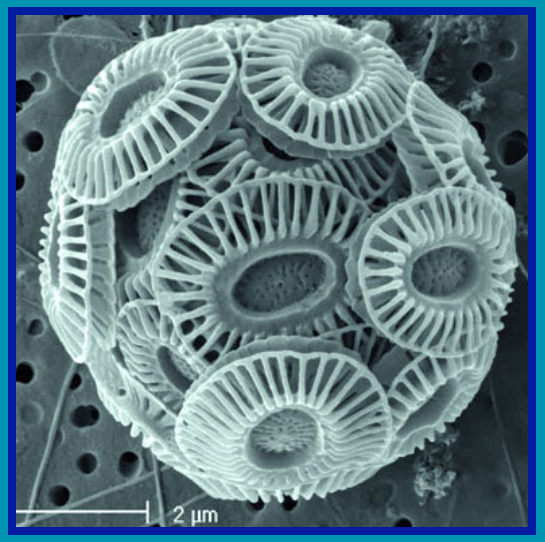
Corals

Calcareous plankton

As the ocean acidifies, organisms such as corals, snails, and calcifying plankton will not be able to make their shells and grow.

Zooplankton (Pterapod)

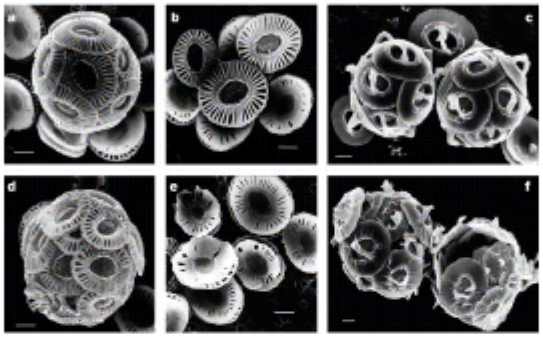
Coral



Phytoplankton (Coccolithophore)

Local species that will not be able to make their shells and grow

Ecosystem impact of ocean acidification

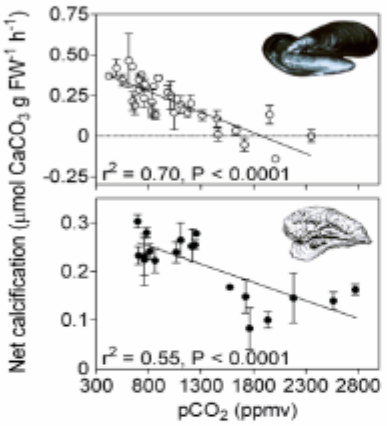


Normal CO_2
300 ppm

High CO_2
780-850 ppm

(Riebesellet al. 2000)

Malformed coccoliths and incomplete coccospheres increased in relative numbers with increasing CO_2 concentrations.



(Gazeau et al. 2007)

At pCO_2 740 ppm:

- 25% decrease in calcification for mussels
- 10% decrease in calcification for oysters

(NOAA Alaska Fisheries Science Center: R. Foy, S. Persselin)

t experiments (2006-07): pH decrease negatively affects growth and survival of blue king crab.

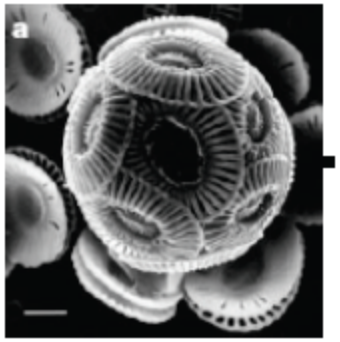
Affects of Lower pH

- Corals decrease the production of their reef-building skeleton
- Reduction in ability of marine algae and zooplankton to maintain protective shells
- Reduction in survival of certain larvae

Coccolithophore (single-celled algae)

pCO_2 280-380 ppmv

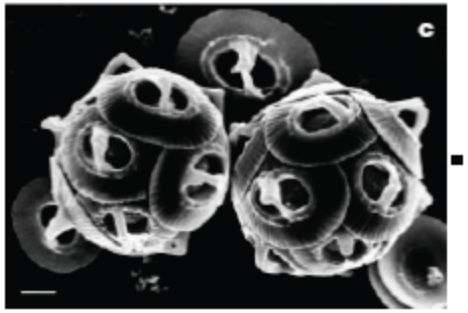
pCO_2 780-850 ppmv

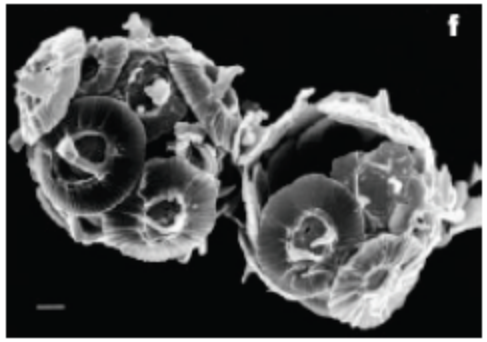


Calcification decreased

- 9 to 18%

Emiliania huxleyi





- 45%

Gephyrocapsa oceanica

Malformed liths at high CO_2

Manipulation of CO_2 system by addition of HCl or NaOH

Riebesell et al.(2000); Zondervan et al.(2001)

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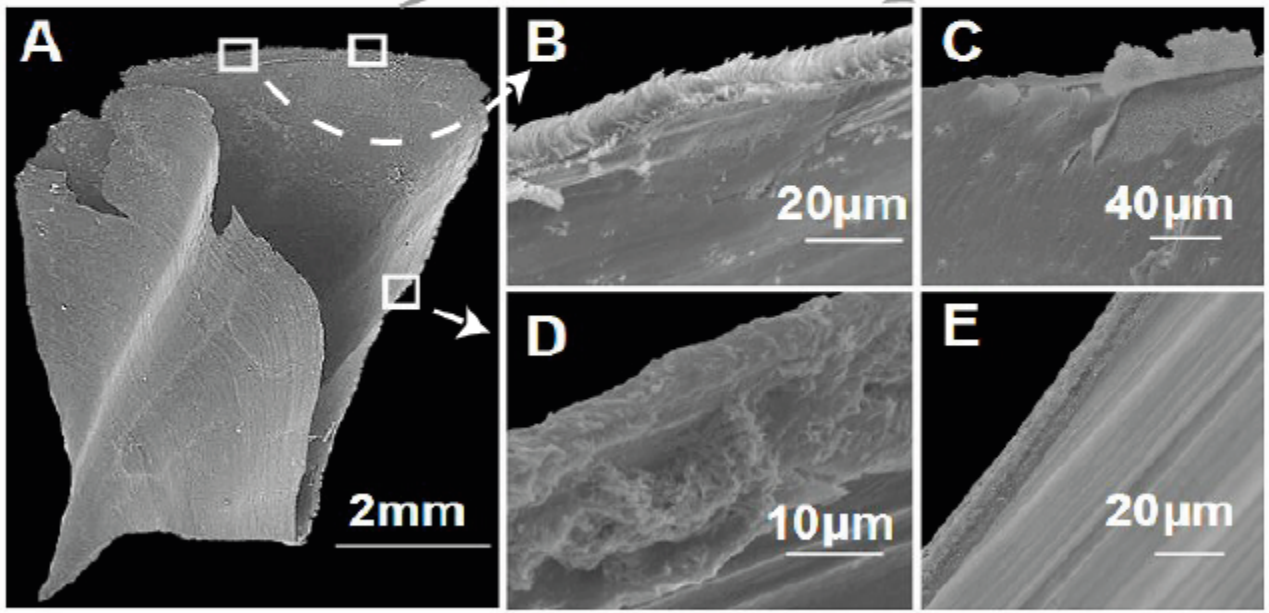
Shelled Pteropods (planktonic snails)

Respiratory CO_2 forced Ω_A <1
Shells of live animals start to dissolve within 48 hours

Whole shell:
Clio pyramidata

Arag. rods exposed

Prismatic layer (1 μm) peels back



Aperture (~7 μm): advanced dissolution

Normal shell: no dissolution

Orr et al. (2005)

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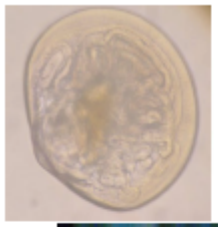
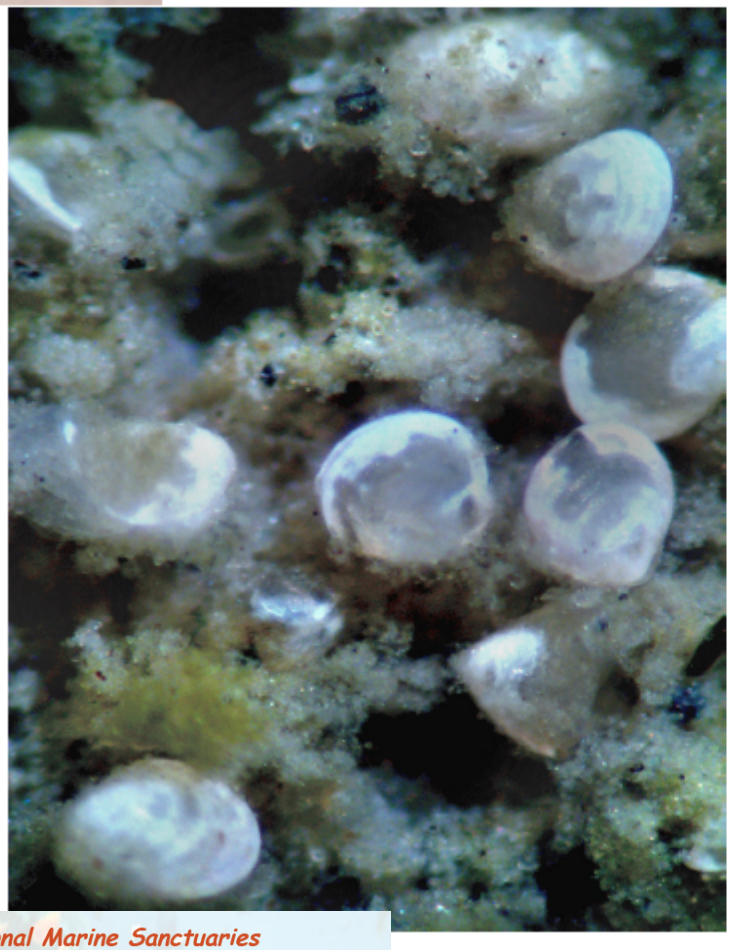
February 2009



Bivalve juvenile stages can also be sensitive to carbonate chemistry



Hard shell clam *Mercenaria*

- Common in soft bottom habitats

Used newly settled clams

- Size 0.3 mm
- Massive dissolution within 24 hours in undersaturated water; shell gone within 2 weeks
- Dissolution is source of mortality in estuaries & coastal habitats

Green et al., 2004

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Scorecard of Biological Impacts

Physiological process	Major group	# species studied	Response to increasing CO_2			
			↘	↗	—	∩
Calcification						
	Coccolithophores	4	2	1	1	1
	Planktonic Foraminifera	2	2	-	-	-
	Molluscs	4	4	-	-	-
	Echinoderms	2	2	-	-	-
	Tropical Corals	11	11	-	-	-
	Coralline Red Algae	1	1	-	-	-
Photosynthesis[1]						
	Coccolithophores[2]	2	-	2	2	-
	Prokaryotes	2	-	1	1	-
	Seagrasses	5	-	5	-	-
Nitrogen Fixation						
	Cyanobacteria	1	-	1	-	-
Reproduction						
	Molluscs	4	4	-	-	-
	Echinoderms	1	1	-	-	-

1) Strong interactive effects with nutrient and trace metals availability, light, and temperature
2) Under nutrient replete conditions

Figure from Doney et al. (2009)

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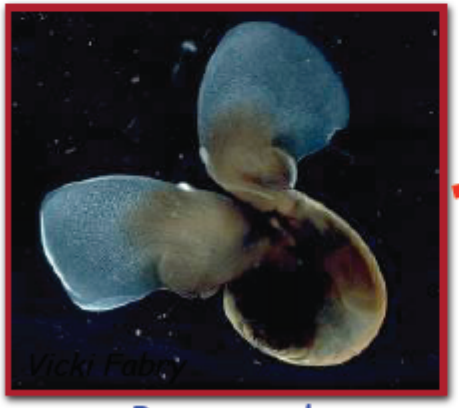
Why Are These Affects Significant?

- Coral reefs are less resilient to bleaching, disease, and death
- The rate of reef building is decreased
- The base of the food web (algae and zooplankton) is reduced creating a ripple affect along the food web
- The economy will be negatively affected
  - Fisheries (i.e. shellfish, sea urchins) may decline
  - Tourism may decline
  - Affect on bio-tech and pharmaceuticals

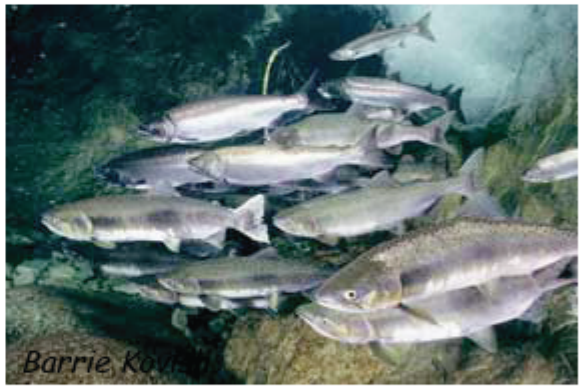
Potential Effects on Open Ocean Food Webs

Coccolithophores

Copepods



Pteropods



Pacific Salmon

National Marine Sanctuaries

Ocean Acidification: The Other CO_2 Problem

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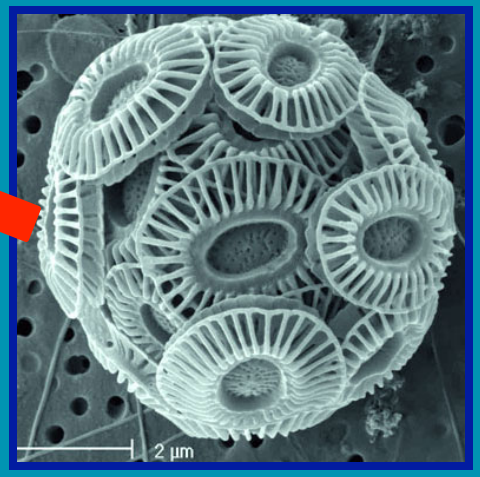
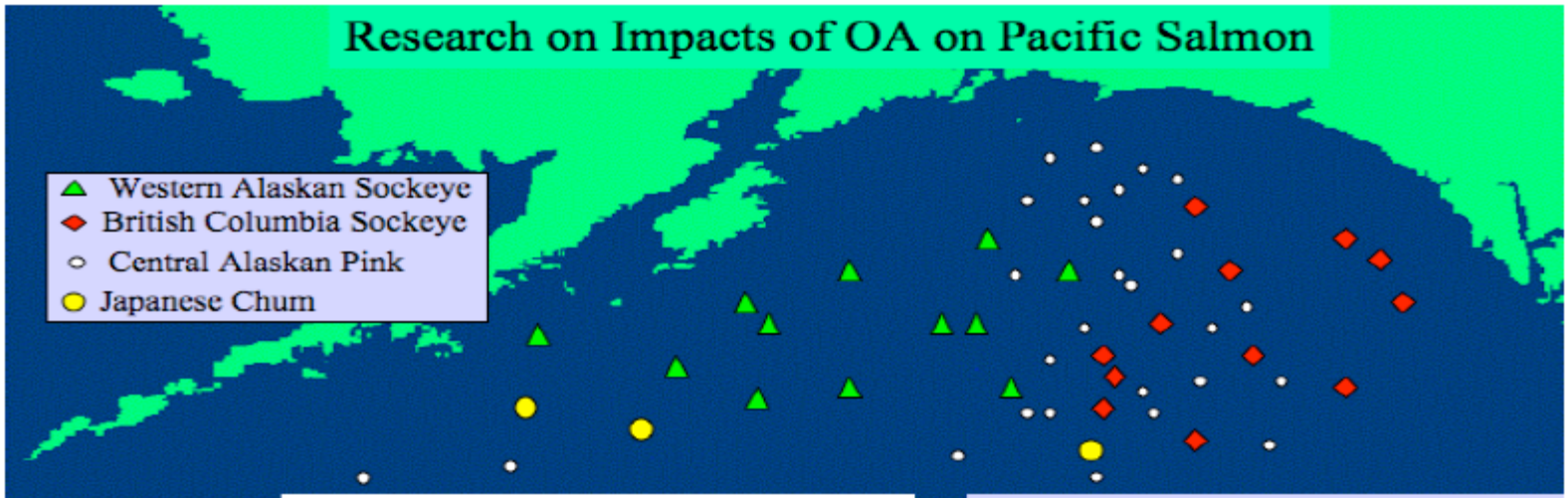
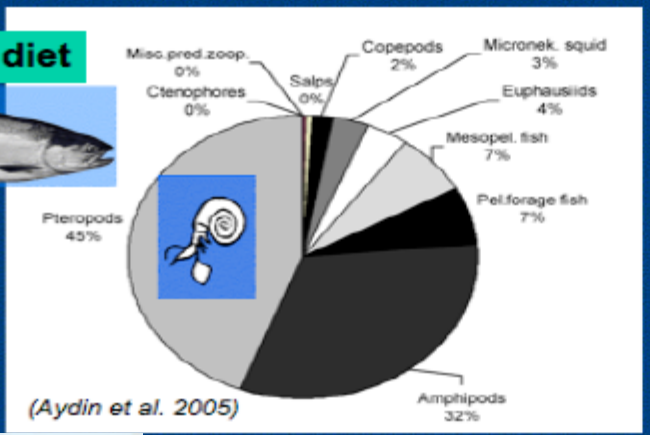

2 µm

What we know about the biological impacts of ocean acidification *...on marine fish*

Research on Impacts of OA on Pacific Salmon



Pink salmon diet



(Aydin et al. 2005)

Predicted effect of climate change on pink salmon growth:

- 10% increase in water temperature leads to 3% drop in mature salmon body weight (physiological effect).
- 10% decrease in pteropod production leads to 20% drop in mature salmon body weight (prey limitation).

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February 2009

http://www.noaanews.noaa.gov

Socio-economic Impact of Ocean Acidification

Ocean acidification may trigger a chain reaction of impacts through the marine food web that will threaten

- Coastal and marine commercial fishing that generates upwards of $34B per year.
- Food security for millions of the world's poorest people.
- Job security. As example, the seafood industry supported nearly 100,000 jobs in New York State alone.
- Tourism that generates billions of dollars annually.

What Does the Future Hold?

If trends continue:

- Atmospheric CO_2 levels could reach 500ppm, possibly 800ppm by the end of the century

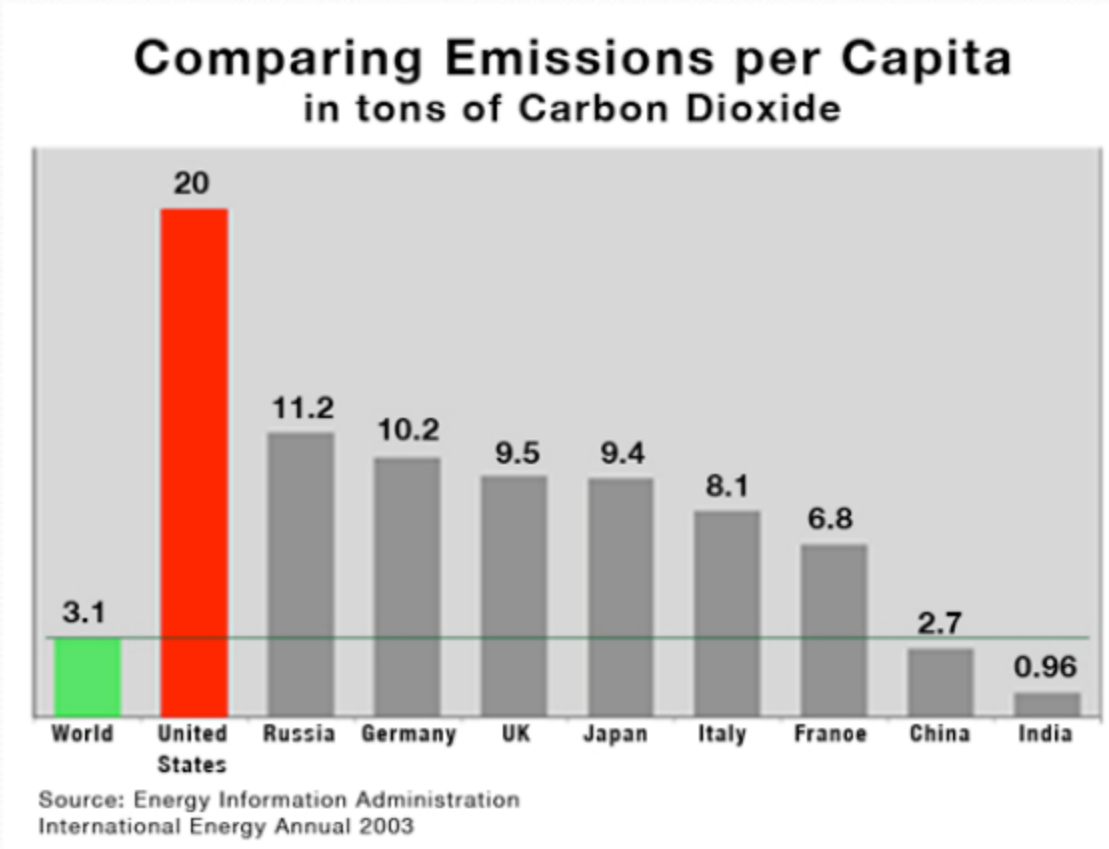
- That would decrease surface water pH by .3 units by 2100

- The pH scale is logarithmic so a change in 1 pH unit equals a 10-fold change in acidity, so while .3 units sounds small it is really a large change

How It Affects Us

- Plankton: The base of the food chain; Phytoplankton also produces majority (~70%) of the oxygen
- Sea Urchins: Important local fishery
- Crabs: fishery
- Lobster: fishery
- Coral reefs: provide habitat that increases biodiversity

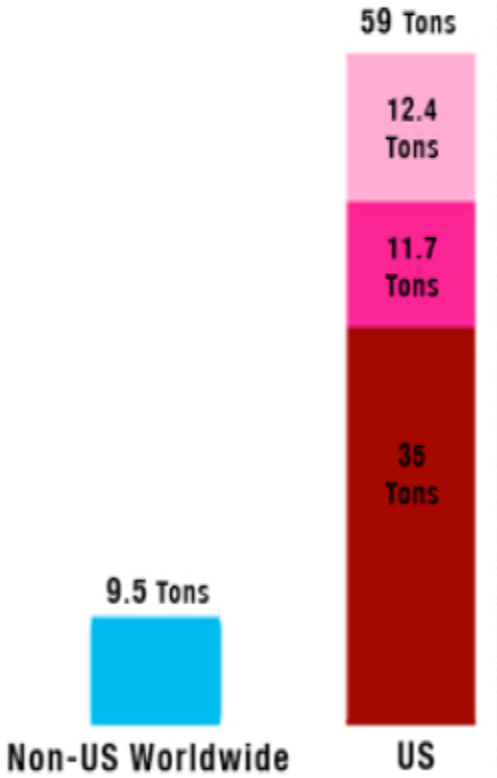
Carbon dioxide emissions in the world



Where can we reduce carbon dioxide emission

Emissions for an average American household with an income of $43,000 per year

- **Direct Carbon Dioxide Emissions (24 tons):**
  - Household Operations (12.4 tons),
    - Heating our houses (47%)
    - Lighting and appliances (24%)
    - Hot water (17%)
    - Air-conditioning (6%)
    - Refrigerations (5%)
  - Driving (11.7 tons).
- **Indirect Carbon Dioxide Emissions (35 tons).**
  - When we buy a new product that has substantial embodied energy in it from its manufacture, packaging and delivery.
  - When we visit an air-conditioned store,
  - When we eat an avocado in New York that was grown in California,
  - When we stay in a hotel on vacation, or
  - When we work in a heated office building.



What can you change in your daily life to help decrease the rate of ocean acidification?

Transportation

- Carpool
- Use public transportation
- Ride your bike
- Walk

Energy

- Use less
- Use “clean” energy

Goods (fossil fuels are used to produce goods)

- Use less
- Buy in bulk (less packaging)
- Buy locally (large ships and trains are used to transport goods)

The Experiment

- Choose a material to test
- Create a hypothesis about what you think will happen to your material
- Place material in both regular tap water and vinegar and/or carbonated water
- Record observations every 30 minutes for 3 hours

Abalone Shell in Vinegar

Fig A: At the start

Fig B: After 1 hour

Fig C: After 2 hours

Fig D: After 3 hours

Fig E: After 4 hours

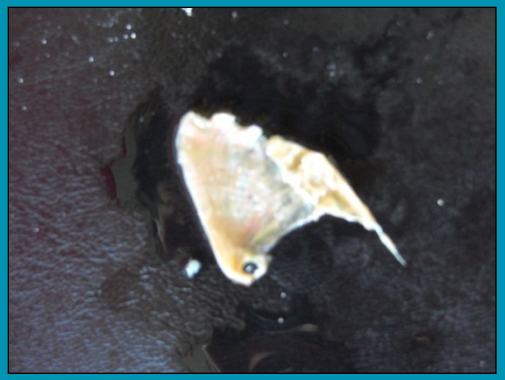


Fig F: After 5 hours

Abalone in Vinegar after 11 Hours

Piece of Coral in Vinegar

Fig. A: At start

Fig. B: After 1 hour

Fig .C: After 2 hours

Figs. D & E: After 3 hours

Fig. F: After 4 hours

Fig. G: After 5 hours

Pieces of Coral after 11 hours
Left: Carbonated water
Right: Vinegar

Key Words

***Ocean acidification*:** the ongoing decrease of the pH of the ocean

Corrosive: Harmful, destructive, eating away at

Dissolve: to break up, to liquefy, to disintegrate

Argonite: a more unstable calcium carbonate mineral used to form coral skeletons and bivalve

Calcite*:* calcium carbonate mineral used to form coccolithophores, and foraminiferans

***Pteropod*:** small mollusc

Foraminifera: marine protozoan having a concentric shell

Coccolithophore:

***Calcareous*:** containing calcium carbonate

Mollusc: snails

***Echinoderm*:** phylum of marine organisms with radiating sections and a calcareous skeleton

Socio-economic: pertaining to the interaction of social and economic factors

Ocean Acidification Resources

NOAA
http://www.pmel.noaa.gov/co2/OA/
Ocean Acidification Network
http://ioc3.unesco.org/oanet/index.html
National Resources Defense Council
http://www.nrdc.org/oceans/acidification/default.asp
Channel Islands National Marine Sanctuary
http://channelislands.noaa.gov/sac/pdf/CWG_OAR_final.pdf
Gulf of the Farallones National Marine Sanctuary
http://farallones.noaa.gov/pdfs/manage/OceanAcidification_021209.pdf

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