
We got 99 Global Problems,
water is #1

Background

Climate Change and the Ocean

Greenhouse gases from human activity accumulate in the atmosphere, land and oceans. The various GHG stay in the atmosphere for hundreds of years after being released. This presentation focuses on carbon dioxide greenhouse gas.

Oceans regulate the amount of carbon dioxide in the atmosphere by storing large amounts of carbon dioxide, which increases ocean acidity.

https://www.epa.gov/climate-indicators/oceans

The ocean & health

Phytoplankton need energy from the sun and nutrients from the water. In the process of photosynthesis, phytoplankton **release oxygen into the water**. **Half of the world's oxygen** is produced via phytoplankton photosynthesis, the other half is produced via photosynthesis on land by trees and plants. The oceans are not taking in more carbon dioxide or letting off more oxygen. **Human activities** such as burning oil & coal to drive our cars and heat our homes **are increasing the amount of carbon dioxide released into the atmosphere.**

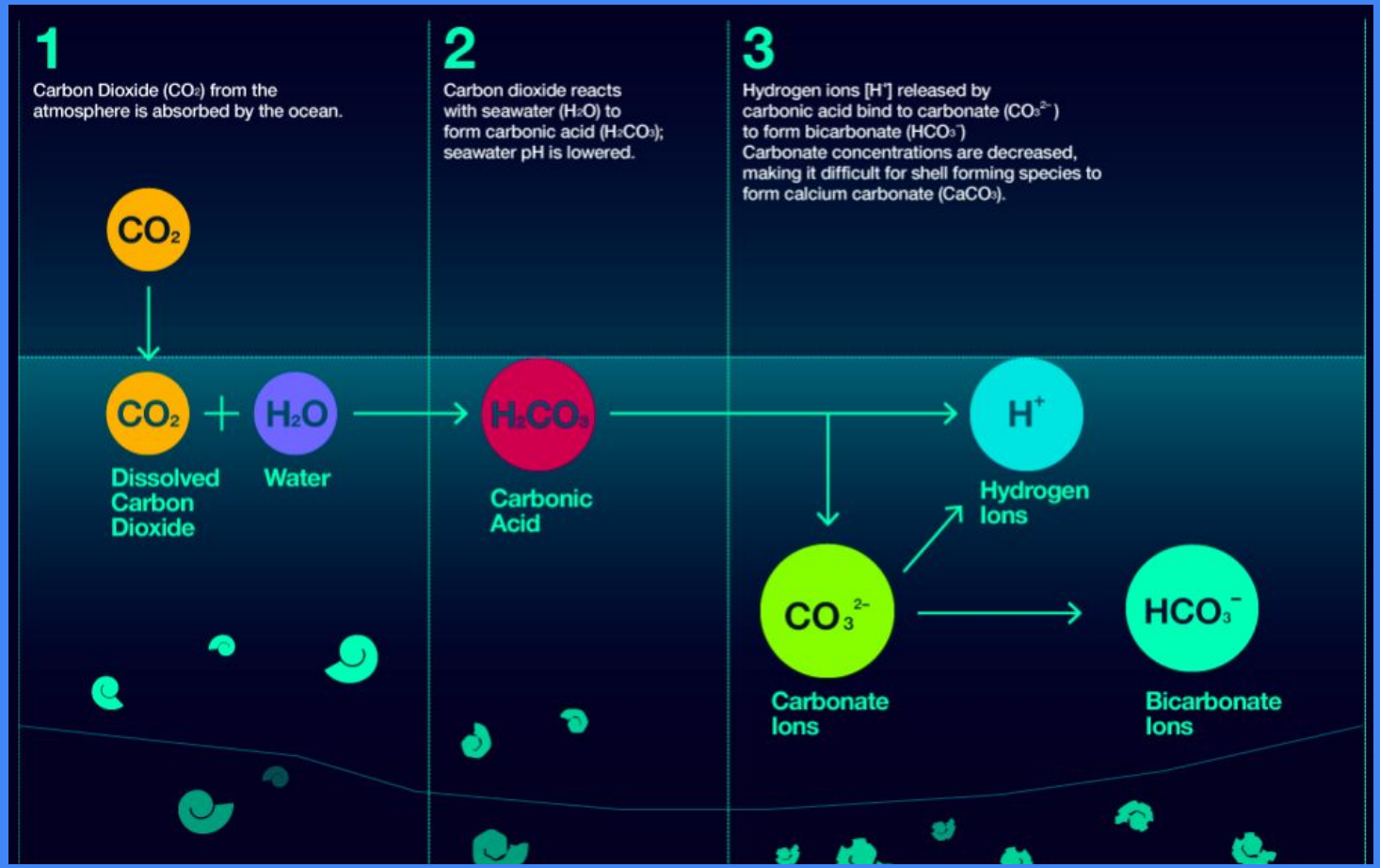
Ocean acidification affects phytoplankton survival has largely been tested in laboratory studies and needs further investigation into the ecological interactions caused by global climate change but so far some studies **show decrease in survival fitness** (Collins, Rost & Rynearson, 2014).

http://news.nationalgeographic.com/news/2004/06/0607_040607_phytoplankton_2.html

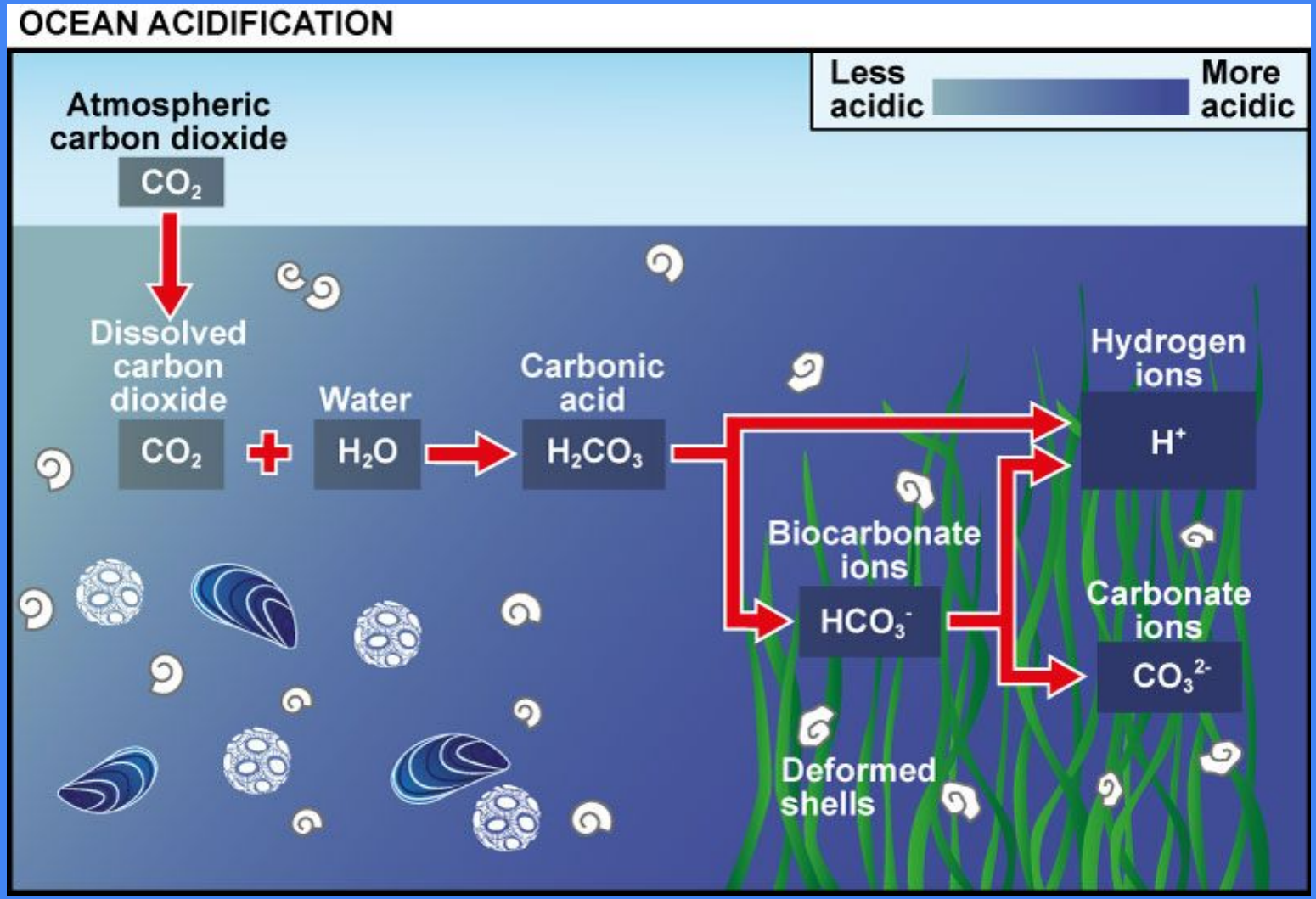
Ocean acidification

What ocean acidification is

Ocean acidification process



http://www.oceanhealthindex.org/methodology/components/ocean-acidification



http://www.oceanacidification.org.uk/Oarp/media/images/oa_800.jpg

Videos

https://www.youtube.com/watch?v=RnqJMInH5yM (1:36) Great Barrier Reef, Australian Government

https://www.youtube.com/watch?v=aG3n1fAa7vk (3 min) Acid Test movie (NRDC)

https://www.youtube.com/watch?v=8m1X26Auw6Q (9:44) Ocean Acidification Ted Talk
https://www.youtube.com/watch?v=evfgbVjb688 (18:45) Rob Dunbar, threat of ocean acidification
https://www.youtube.com/watch?v=MQri6H0ebws (21:34) Shallin Busch ocean acidification
https://www.youtube.com/watch?v=GL7qJYKzcsk (12:12) demystifying ocean acidification & bio impact

The ecological drivers

This illustration shows the integrative effects of several drivers which determine ecological status (Blackford, 2010)

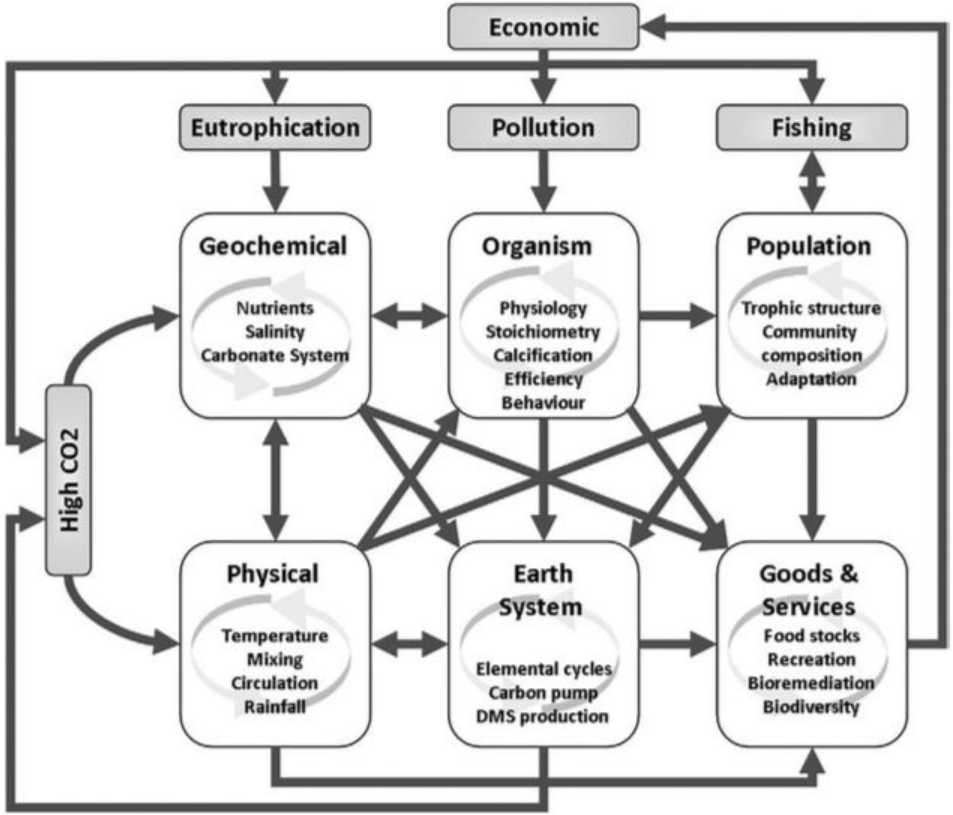
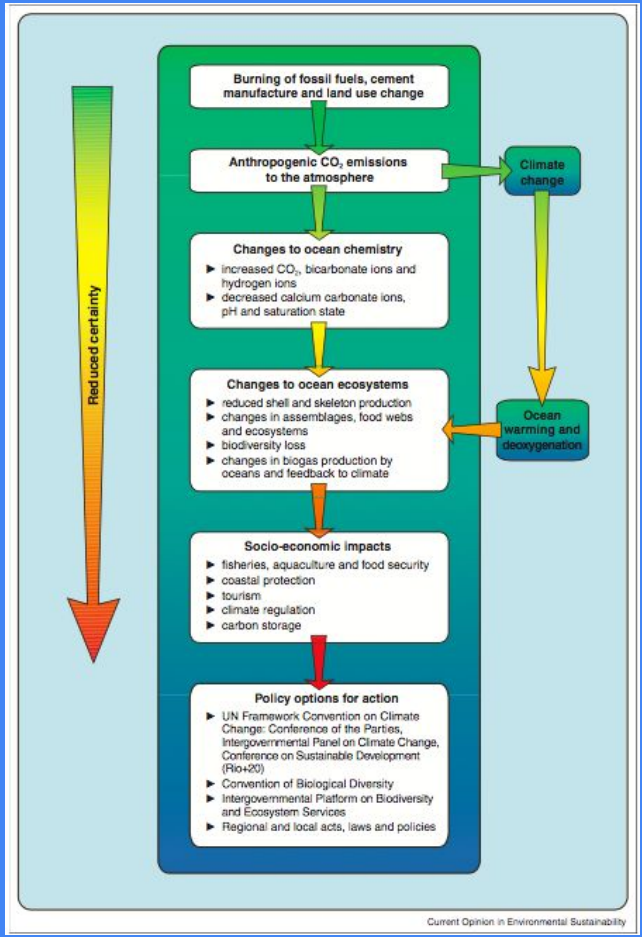


Fig. 1. An illustration of some of the drivers, impacts and scales of organisation relevant to predicting ecosystem response to high CO2. Drivers are indicated by the small shaded boxes and the scales of organisation – which could related to model foci – by the large boxes. Selected impacts are listed within each box, which are to a greater or lesser extent inter-related.



this shows the **direct cause of ocean acidification**, the **impacts** on ocean **chemistry and ecosystem**. The **socio-economic and the climate change** interaction through ocean warming and oxygen loss.

Note the decreasing certainty from chemistry, through life and social science.

burning fossil fuels

anthropogenic CO_2 emissions to the atmosphere

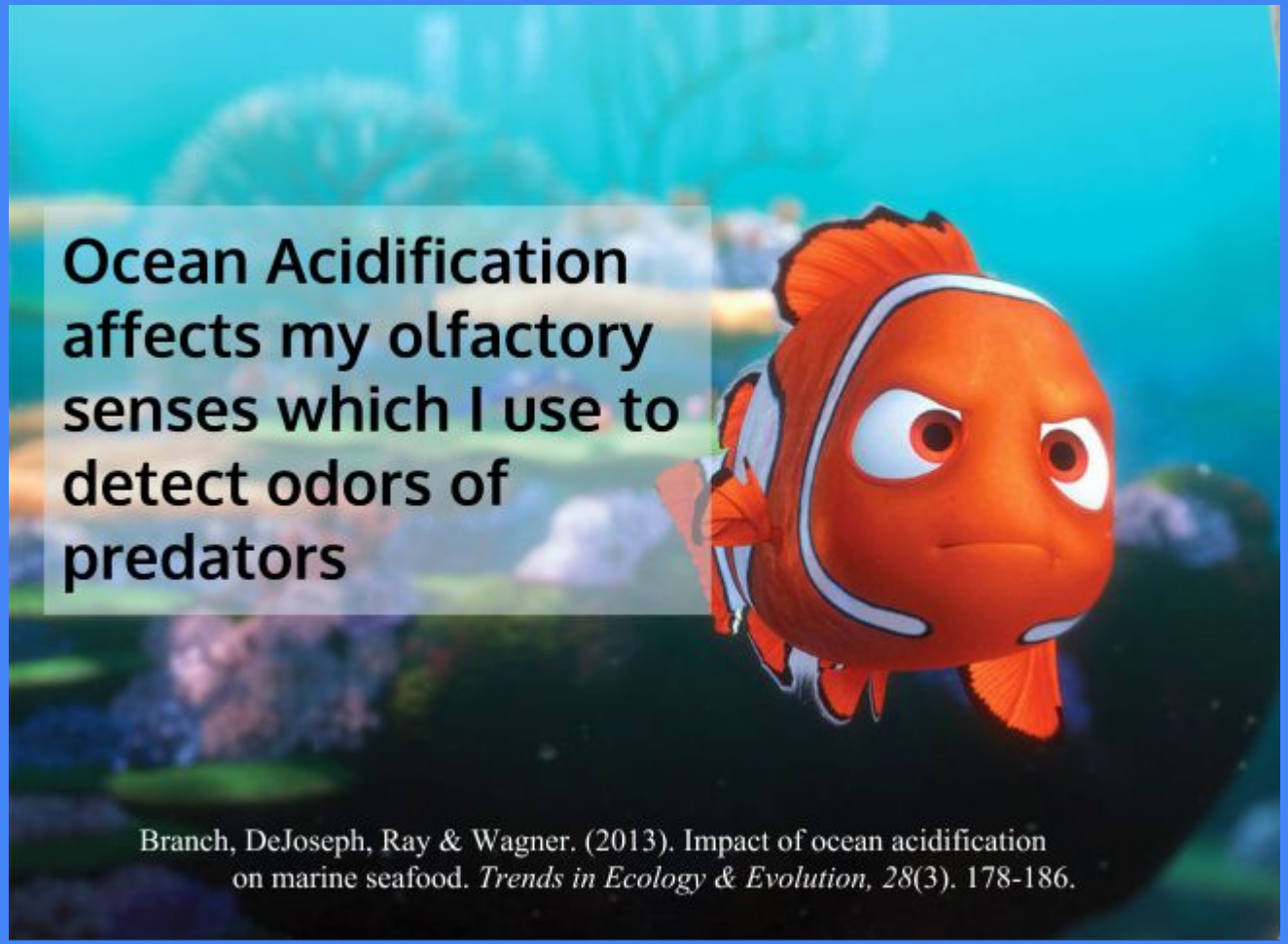
changes to ocean chemistry

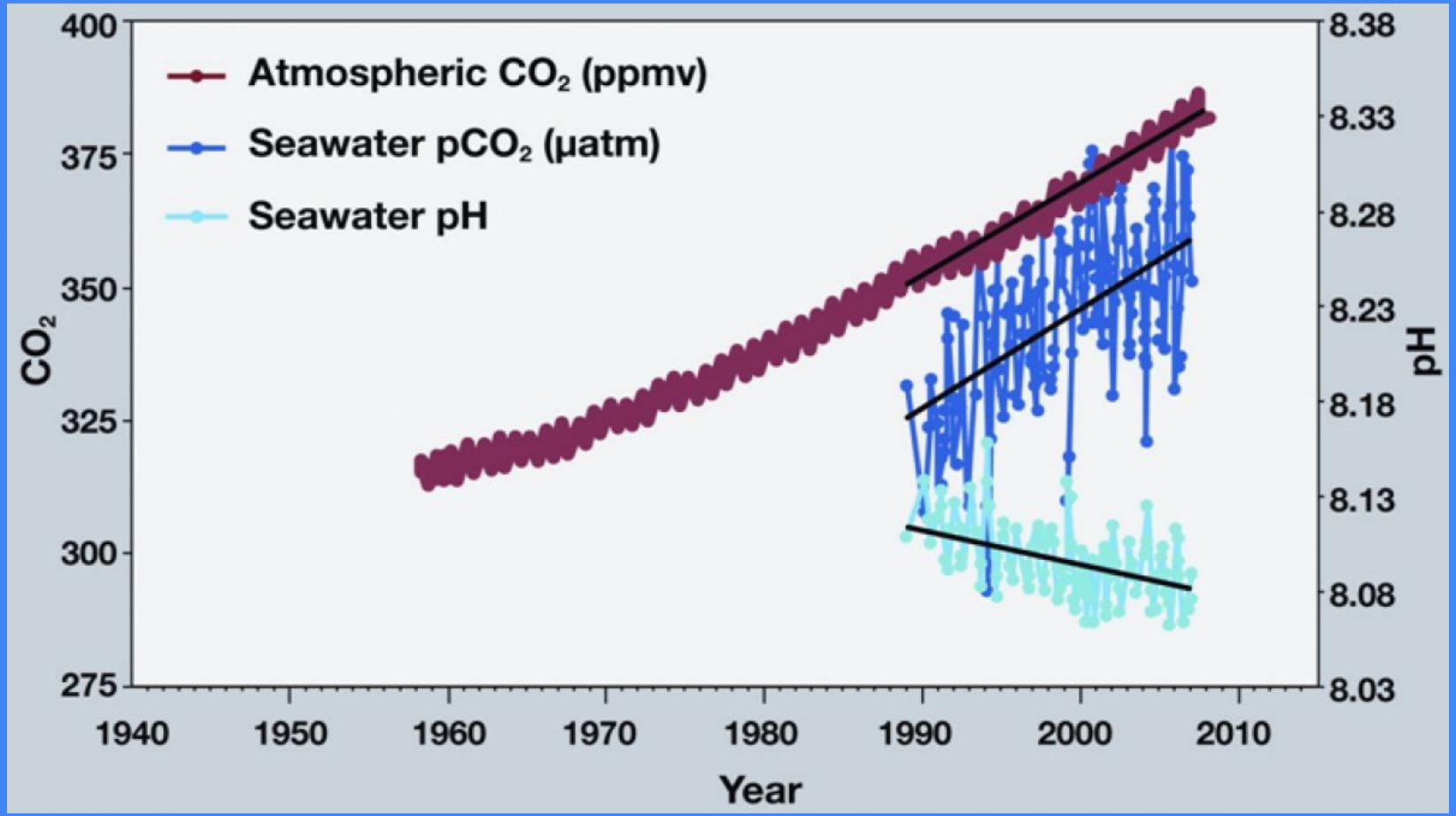
changes to ocean ecosystems

socioeconomic impacts

policy options for action

(Turley & Gattuso, 2012)


Ocean Acidification affects my olfactory senses which I use to detect odors of predators
Branch, DeJoseph, Ray & Wagner. (2013). Impact of ocean acidification on marine seafood. *Trends in Ecology & Evolution, 28*(3). 178-186.



Source: http://ocean.si.edu/ocean-acidification

dead zone

a dead zone is hypoxic (water with low levels of dissolved oxygen) or anoxic (water that does not contain dissolved oxygen) areas without enough dissolved oxygen to support most aquatic life. Dead zones can form after waters become stratified in the summer and surface and bottom waters do not mix.

Less oxygen dissolved in the water is often referred to as a “dead zone” because most aquatic life either dies.

Dead zones occur in many areas throughout North America, particularly along the East Coast, the Gulf of Mexico and the Great Lakes.

http://www.miseagrant.umich.edu/lessons/lessons/by-broad-concept/physical-science/dead-zones/

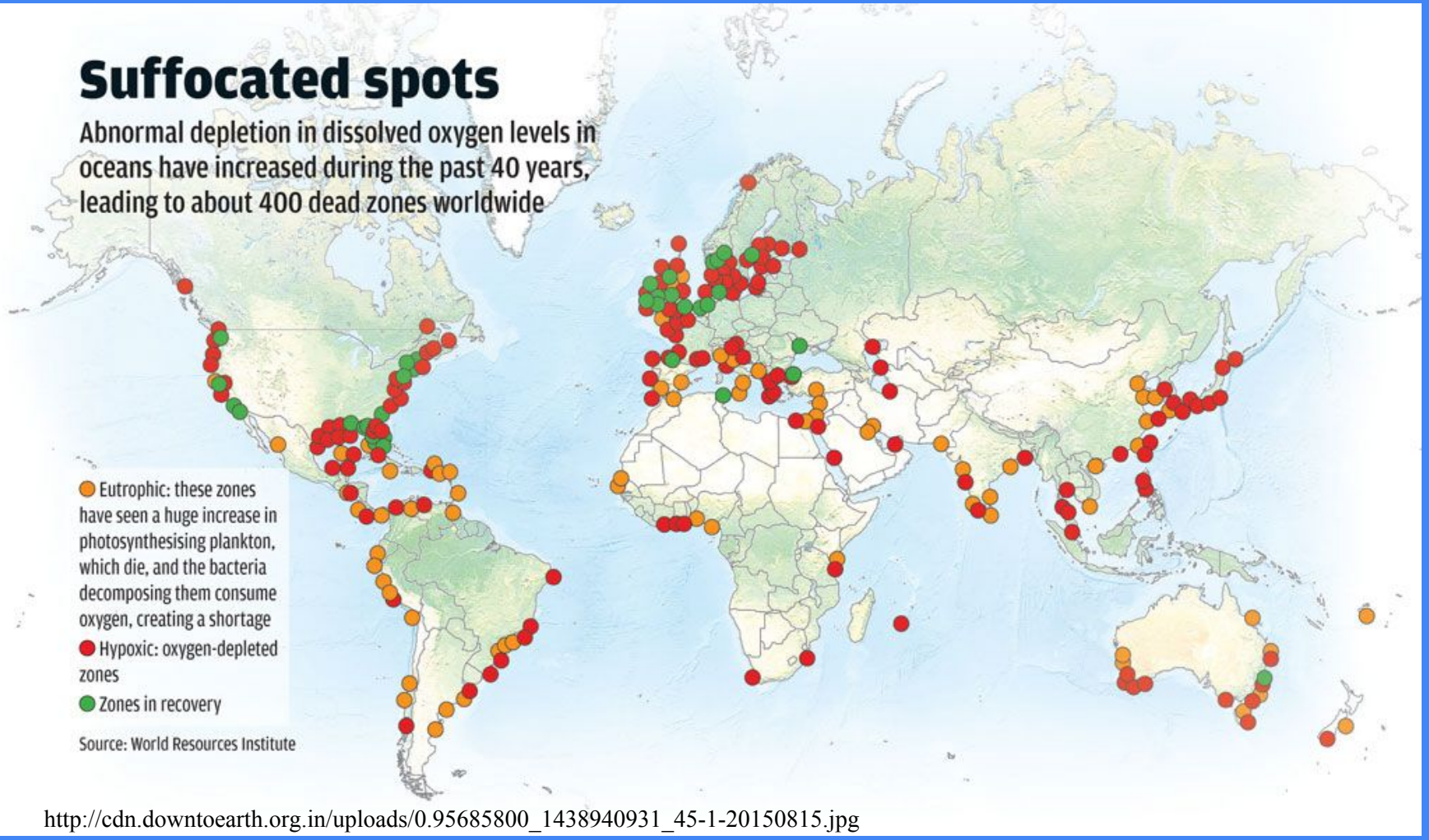
Dead zones

There are many factors that combine to create dead zones, but **excess nutrients** entering the water is a primary cause of dead zones in the Great Lakes. These are considered human-influenced and can be linked particularly to excess nutrients that run off land or wastewater that can overflow into rivers and lakes.

The nutrients from these **sources can stimulate algae growth**, more than the lake would naturally support, which then sinks and decomposes in the water. The **decomposition process consumes oxygen** and there is none to replace it because of the temperature and water density gradient during the summer. The dissolved oxygen supply available for aquatic life is depleted until the lake “turns over” or the stratified layers of water mix.

Invasive species like zebra and quagga mussels are also thought to **contribute** to the development of dead zones, specifically in Lake Erie. The mussels filter out nutrients and green algae early in the year and release fecal pellets (excess nutrients) late into the summer. They also reject the blue green algae, which contributes to harmful algal blooms (which in turn can contribute to dead zones).

http://www.miseagrant.umich.edu/lessons/lessons/by-broad-concept/physical-science/dead-zones/



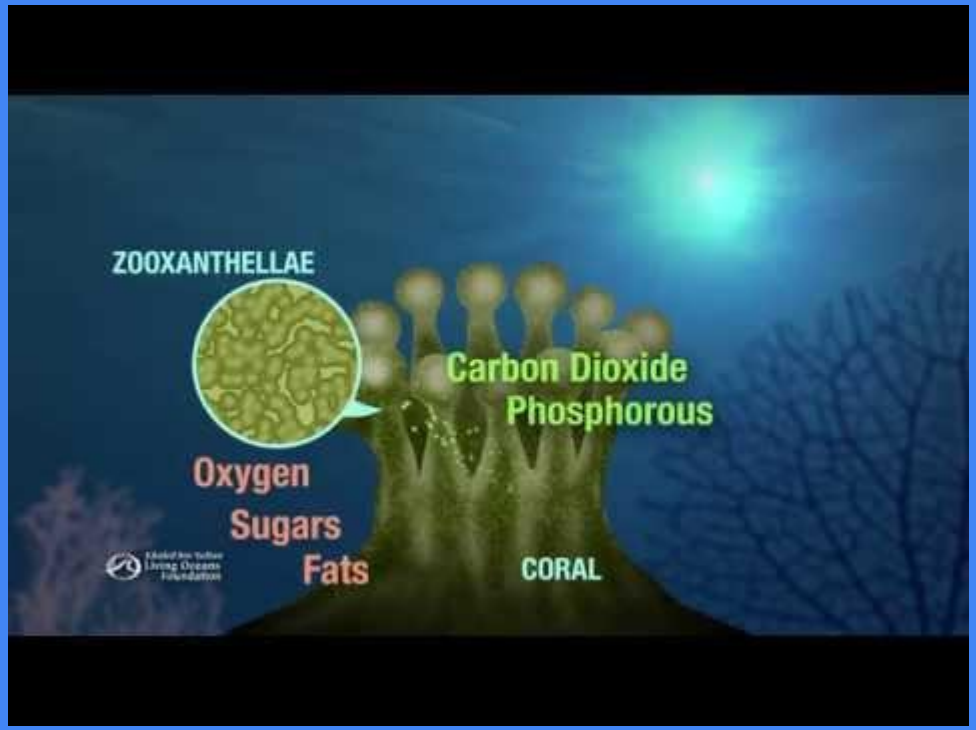
http://cdn.downtoearth.org.in/uploads/0.95685800_1438940931_45-1-20150815.jpg

Ocean acidification and coral reefs

What is a coral Reef?

(Mortillaro, 2016)

What is a Coral Reef?



Why are Coral Reefs Important?

→ Biodiversity. “Rainforest of Ocean”

→ 25% of fish species live in coral reefs

→ Half a billion people depend on coral reefs

→ Revenue, tourism, fishery

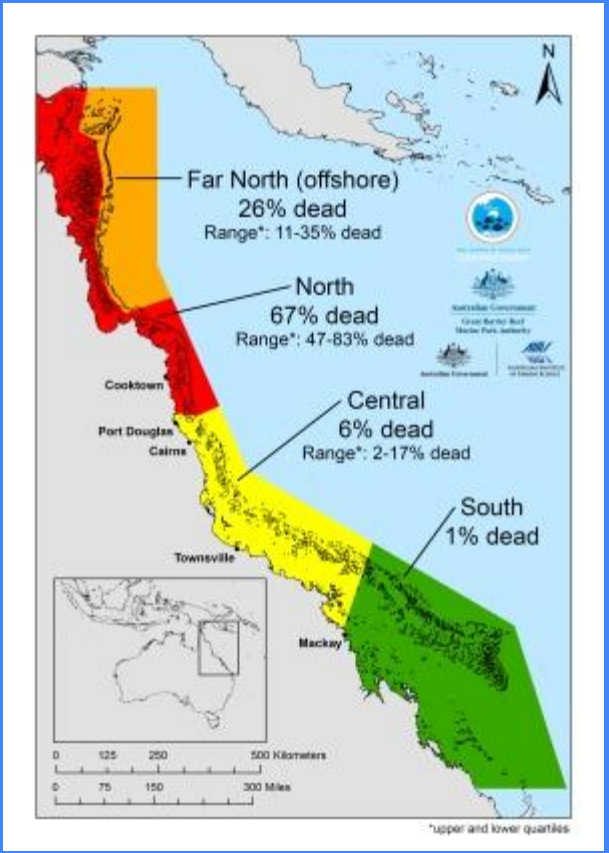
→ Protection from storms and waves

→ Economic advantage ($170 billion)

(CHU, 2011)

Great Barrier Reef

(Mortillaro, 2016)



Temperature and Coral Reefs

Impacts of ocean acidification on the Reef

- About half of this anthropogenic CO2 is in the upper 10 per cent of oceans (less than 1000 metres depth) due to slow ocean mixing processes.
- Because of increased CO2 in water, carbonate ion used to make carbonic acid.
- More dissolved carbon dioxide in the ocean, the less free carbonate ions available for making calcium carbonate.
- Reefs are disintegrating faster then regenerating.
- From a current pH of 8.2 (alkaline), it is predicted that the ocean's pH could fall to about 7.8 (still slightly alkaline) by 2100.

Acidification and Coral Reefs

http://www.slate.com/content/dam/slate/articles/health_and_science/science/2015/11/151125_SCI_Catlin-Seaview-Survey-American-Samoa-6.jpg.CROP.original-original.jpg

http://voices.nationalgeographic.com/files/2015/12/XL-Catlin-Seaview-Survey-American-Samoa-5-600x400.jpg

Impact of ocean acidification on marine ecosystems

(Turley & Gattuso, 2012)

Table 1

Summary of the knowns and unknown. The recommendations of Mastrandrea *et al.* [47] were used for the levels of evidence ('limited', 'medium', or 'robust'), agreement among the expert coauthors ('low', 'medium', or 'high') and confidence ('very low', 'low', 'medium', 'high', and 'very high'). Question marks indicate that the effect is unknown. From Gattuso *et al.* [3••]

Statement	Level of evidence	Level of agreement	Level of confidence
Chemical aspects			
Ocean acidification occurred in the past	Robust	High	Very high
Ocean acidification is in progress	Robust	High	Very high
Ocean acidification will continue at a rate never encountered in the past 55 Myr	Robust	High	Very high
Future ocean acidification depends on emission pathways	Robust	High	Very high
The legacy of historical fossil fuel emissions on ocean acidification will be felt for centuries	Robust	High	Very high
Biological and biogeochemical responses			
Ocean acidification will adversely affect calcification	Medium	High	High
Ocean acidification will stimulate primary production	Medium	High	High
Ocean acidification will stimulate nitrogen fixation	Medium	High	Medium
Some species or strains are tolerant	Robust	High	Very high
Some taxonomic groups will be able to adapt	Low	Medium	?
Ocean acidification will change the composition of communities	Robust	Medium	High
Ocean acidification will impact food webs and higher trophic levels	Limited	High	?
Ocean acidification will have biogeochemical consequences at the global scale	Medium	High	Medium
Policy and socio-economic aspects			
There will be socio-economic consequences	Limited	Medium	?
An ocean acidification threshold that must not be exceeded can be defined	Limited	High	?

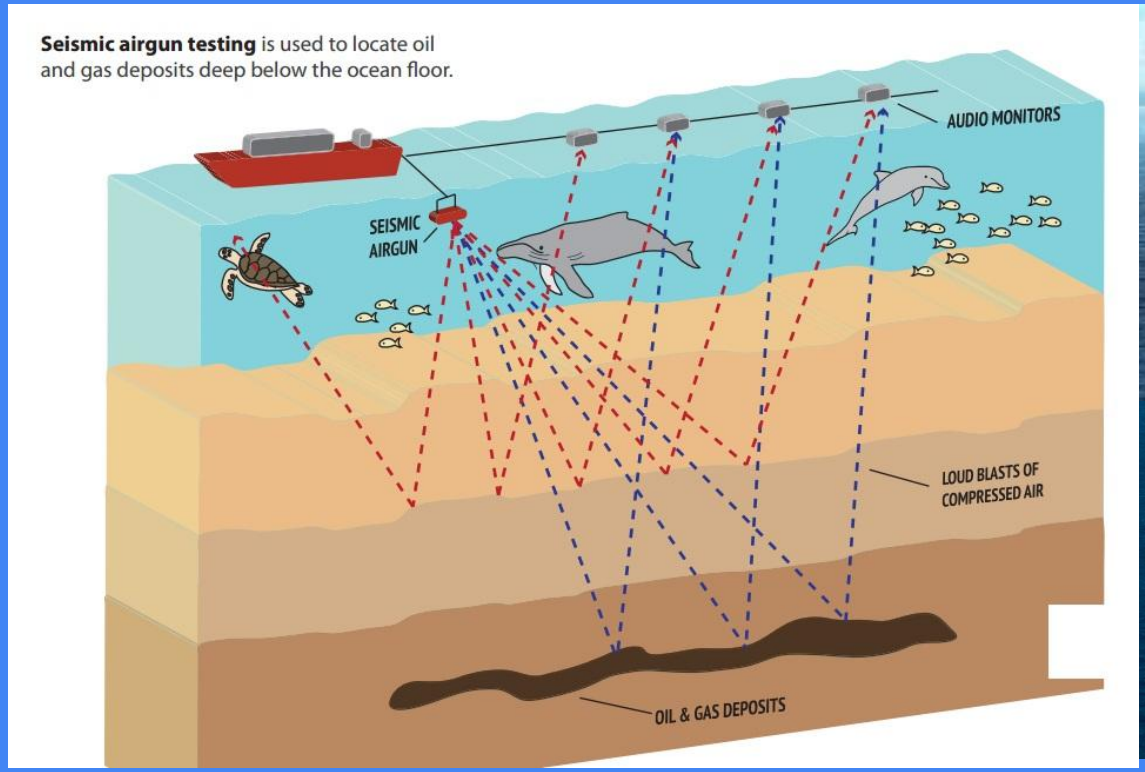
More acidic oceans = noisier oceans?

Abiotic Natural Sounds

Biotic noise

http://www.divestvincent.com/Critters/PistolShrimp.html

Anthropogenic sources of sound



(Peng, Zhou & Liu, 2015)

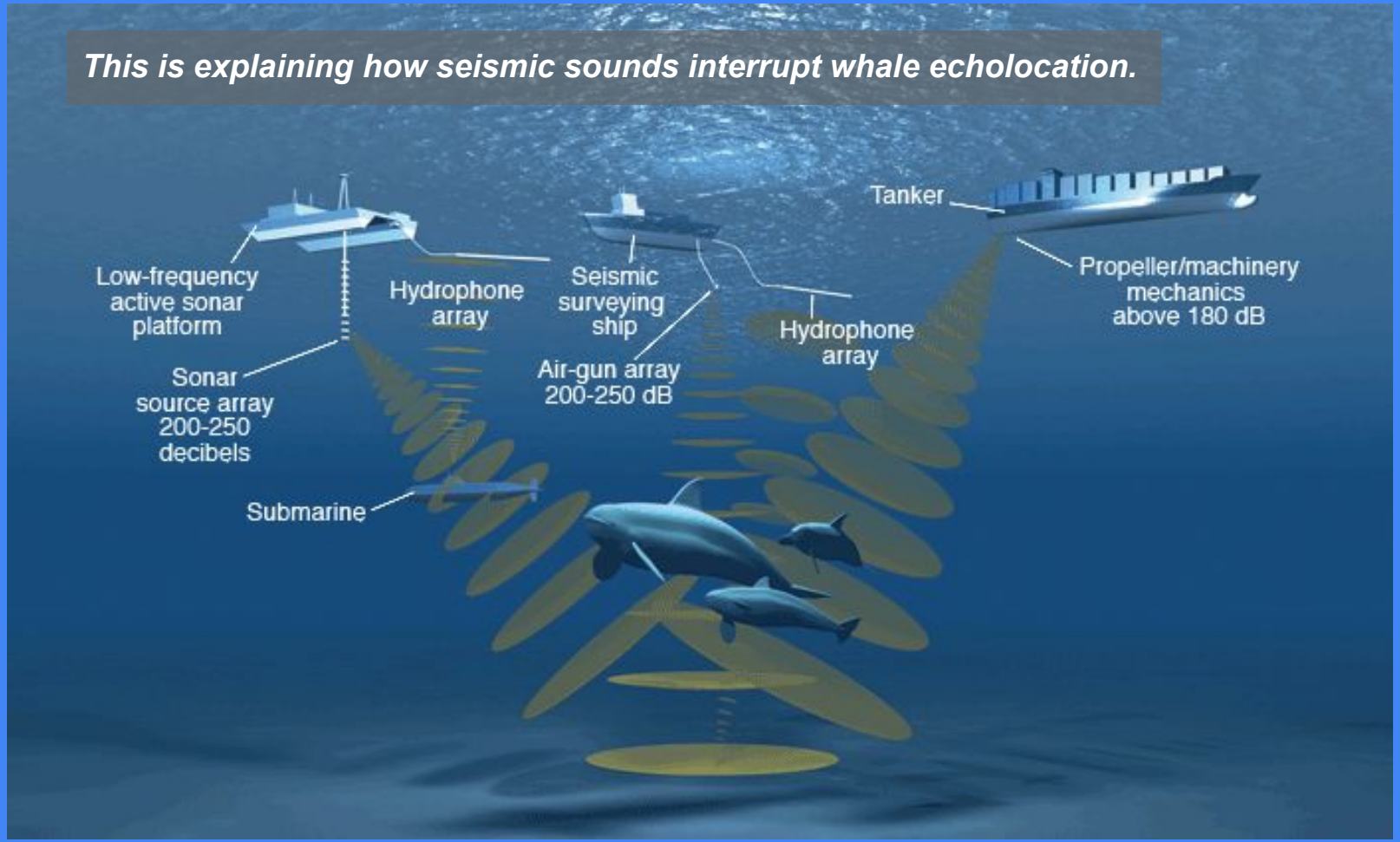
As ocean acidification increases, noise management will become increasingly important.

Factors to modify:

- Level of sound
- Location of sounds
- Duplication of sounds (seismic testing)

Seismic testing ship

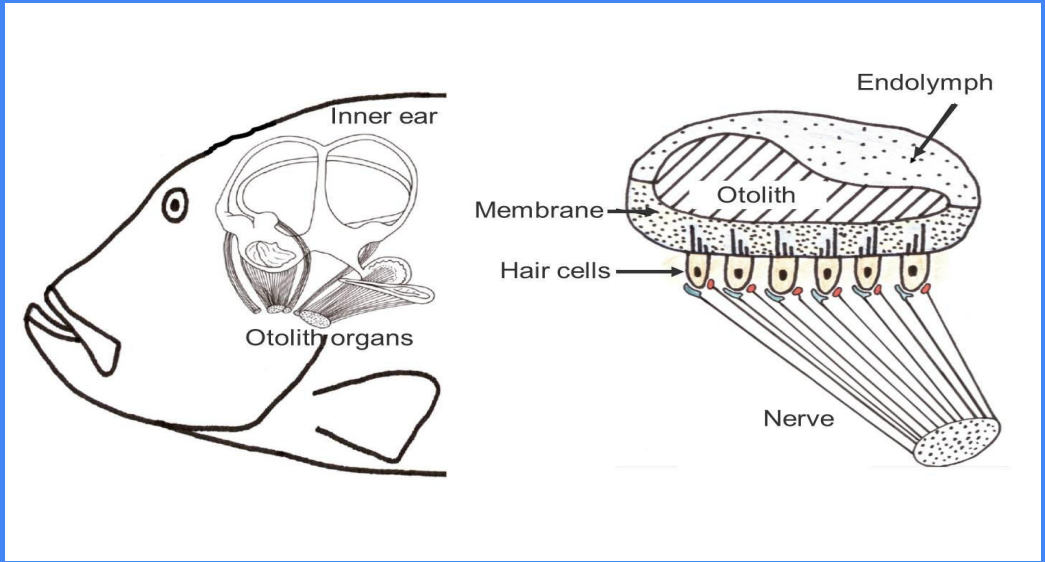
This is explaining how seismic sounds interrupt whale echolocation.



Boat noise can change schooling behaviour

Sara, et al., 2007

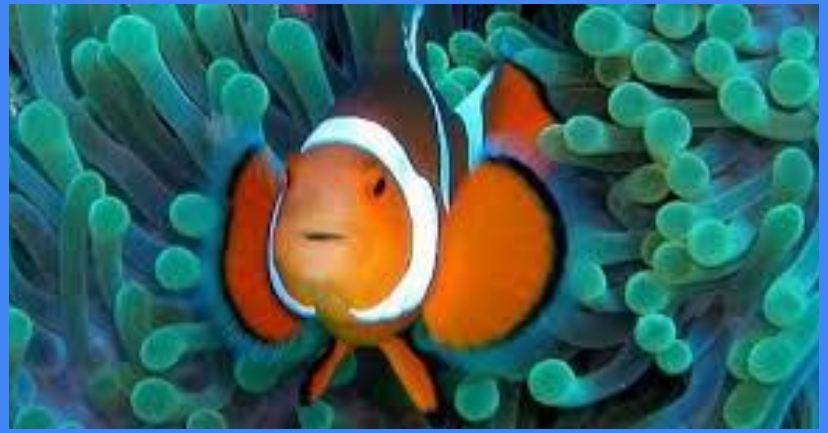
Noise may result in auditory system damage



(McCauley, Fetwell & Popper, 2003)

Excessive anthropogenic noise impacts embryo development

- Sea hares have higher rate of development failures
  (Nedelec, et al., 2014)



- Clownfish heart rates increased with exposure to noise
  (Simpson, et al., 2015)

Noise from boats aggravated me

and make me act AGGRESSIVELY towards my school

Ocean acidification and changes to marine life

Ocean acidity effect on marine life

https://www.youtube.com/watch?v=NXa3U-nmGYc
15 effects of climate change and ocean acidification on Australian marine fish (16:42)

https://www.youtube.com/watch?v=GL7qJYKzcsk&t=4s
Demystifying ocean acidification and biodiversity impacts (12:12)

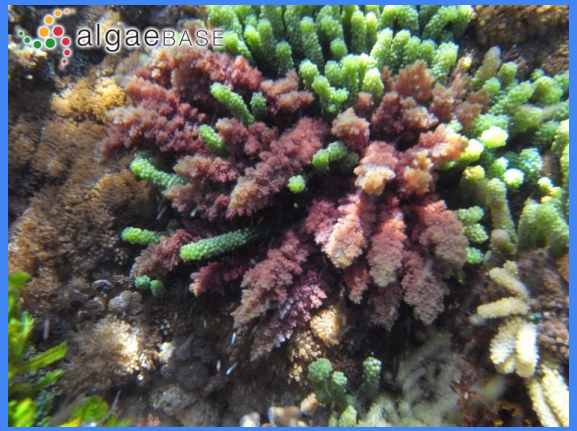
Ocean acidification and invasive species

Reference Video:
https://www.youtube.com/watch?v=xvlHH0y2hwE

Image source :http://www.freshvista.com/wp-content/uploads/2014/01/Invasive-illo.jpg

“Winners” of Ocean Acidification

‘Nuisance’ species likely to preferentially benefit from ocean acidification



ALGAE/SEAWEED

JELLYFISH

INVASIVE MOLLUSCS

Image sources: http://img.algaebase.org/images/AC100CF00290f29FEDWSo1BB702C/jfYcCQLHZewe.jpg, https://www.fws.gov/midwest/endangered/images/mussels/higginseye/HigginsEyeWithZebraMusselsByUSFWS.jpg, http://i2.wp.com/oceanbites.org/wp-content/uploads/2015/11/Untitled4.jpg?resize=432%2C304

“Losers” of Ocean Acidification

‘Nuisance’ species likely to decline or be negatively impacted from ocean acidification

Echinoderms-Sea Urchins

Invasive Crustaceans

Invasive Fish-Lionfish

Image sources: http://soer.justice.tas.gov.au/2009/image/898/cem/id898-p-Centrostephanus2-l.jpg, http://www.rinse-europe.eu/assets/images/__rte/another-shellfish-invaisve-species---chinese-mitten-crab---ron-offermans.jpg, http://passportcaribbean.com/wp-content/uploads/2012/06/lionfish5-1100x786.jpg

The socioeconomic impact

US food production and economic revenue

Table 1. Annual catch and revenue of different taxa during 2002–2006[a]

Broad taxonomic group	Subgroups	Catch (10^6 t)	% catch	2000 US$ (10^9)	% revenue
Fishes	Bony fishes	56	68	65	73
	Sharks, rays, etc.	1	1	2	2
	Unknown	13	16	–	–
Molluscs	Squids and octopuses	4	5	6	7
	Scallops, mussels, and oysters	2	2	5	6
	All other molluscs	1	1	–	–
Crustaceans	Prawns and shrimps	3	4	9	10
	Crabs and lobsters	1	2	2	2
	All other crustaceans	1	1	–	–
Total fishes		69	85	67	75
Total molluscs		7	8	11	12
Total crustaceans		5	7	11	12
Total other invertebrates		<1	<1	–	–
Overall total		81	100	89	100

[a]Sources: Sea Around Us Project (www.seaaroundus.org), FAO [94], Sumaila *et al.* [95].

(Branch, DeJoseph, Ray & Wagner, 2013)

The economic value of the US fishing industry by region and by type of catch

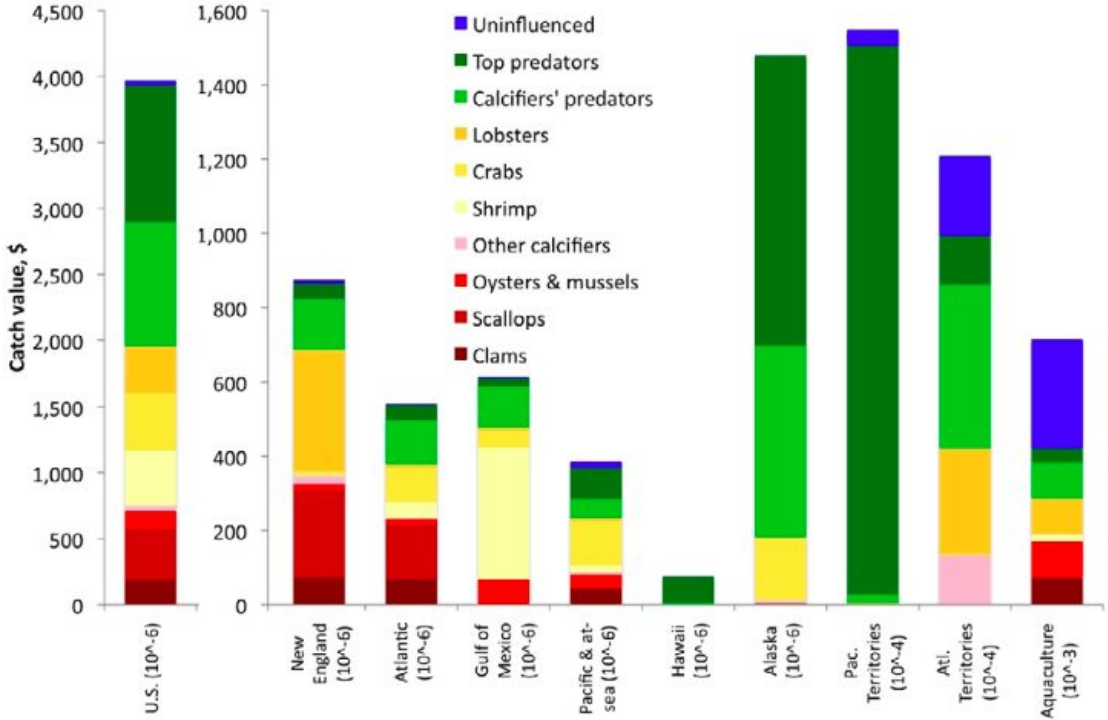


Figure 2. US commercial fishing ex-vessel revenue for 2007 (NMFS statistics, accessed October 2008). Reds indicate organisms containing primarily aragonite, yellows indicate those using primarily calcite, greens indicate predators, and blue indicates species not directly influenced by ocean acidification. (NMFS statistics and Andrews *et al* 2008.)

Table 2. Revenues from US recreational (2000, Steinback *et al* 2004) and commercial (2007, Andrews *et al* 2008) fishing.

Recreational	
Total economic impact[a]	$ 42 868 million
Jobs supported	349 119
Commercial	
Domestic ex-vessel revenue	$ 3765 million
+Harvest outside US	$ 159 million
+Aquaculture	$ 1244 million
Primary sales	$ 5168 million
Retail sales	$ 68 390 million
GNP contribution	$ 34 159 million

[a] Economic impact encompasses jobs, revenue, and income. Numbers exclude Texas, Alaska, and Hawaii; see Steinback *et al* (2004) for details. (Cooley & Doney, 2009)

The **economic benefits** from commercial fishing, recreational fishing via spending on permits, equipment and travel is significant. Fishing also supports industries, creates jobs, profits, tax revenue, and business revenues.

(Cooley & Doney, 2009)

Future predictions

Future predictions of ocean pH levels which will cause changes to last over a few hundred years

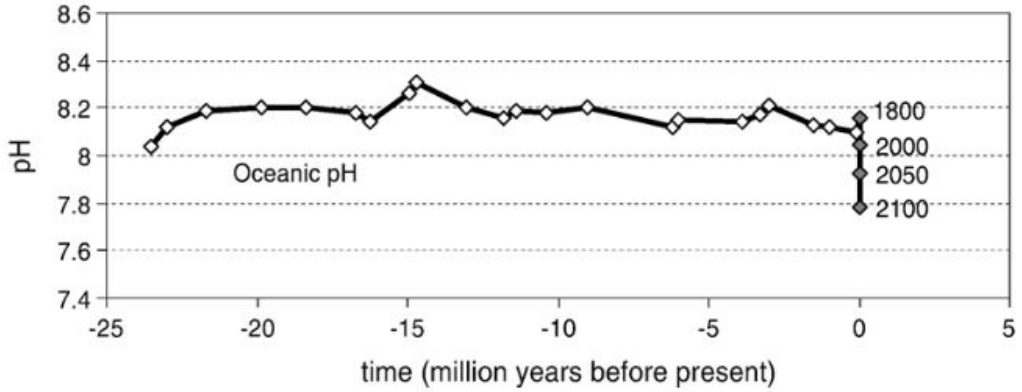


Fig. 1. Past (white diamonds, data from Pearson and Palmer, 2000) and contemporary variability of marine pH (grey diamonds with dates). Future predictions are model derived values based on IPCC mean scenarios. (Blackford & Gilbert, 2007)

Projected increase in anthropogenic CO_2 emissions

A decrease of average pH by 0.2-0.3 units (7.9-7.8) reduces calcite and aragonite by ~25% which impacts carbonate formations (shells & skeletons)

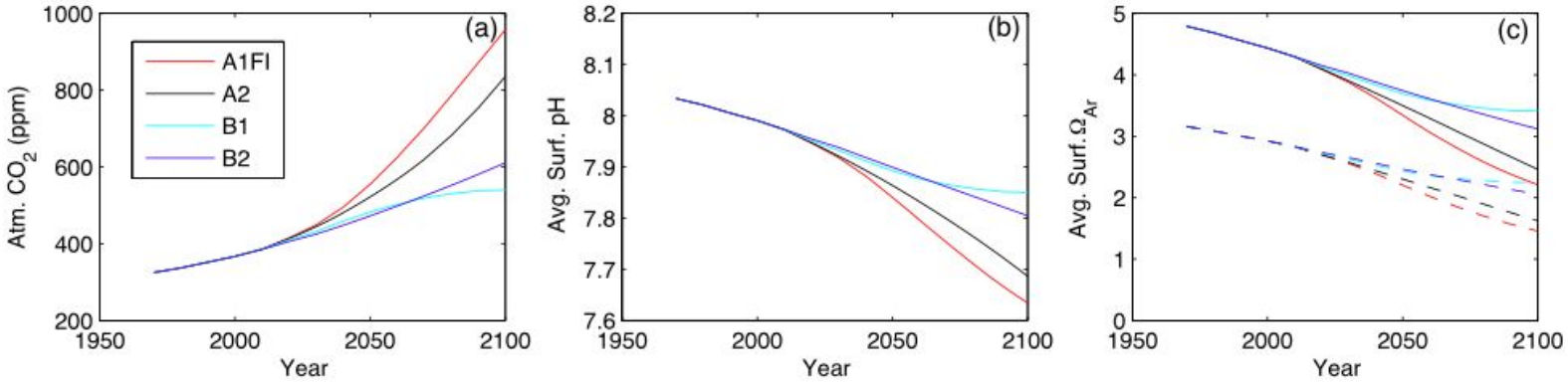


Figure 1. (a) Atmospheric CO_2 anticipated for a variety of scenarios from the Intergovernmental Panel on Climate Change's (IPCC's) Special Report on Emissions Scenarios (SRES): pathways B1, B2, A2, and intensive fossil-fuel dependence pathway A1FI, calculated with the Bern-CC model reference case (IPCC 2001). Surface ocean (b) pH and (c) calcium carbonate saturation state Ω (for calcite, solid; for aragonite, dashed) for each scenario calculated assuming constant temperature, salinity, and total alkalinity.

(Cooley & Doney, 2009)

Policies and interventions

Potential actions against ocean acidification

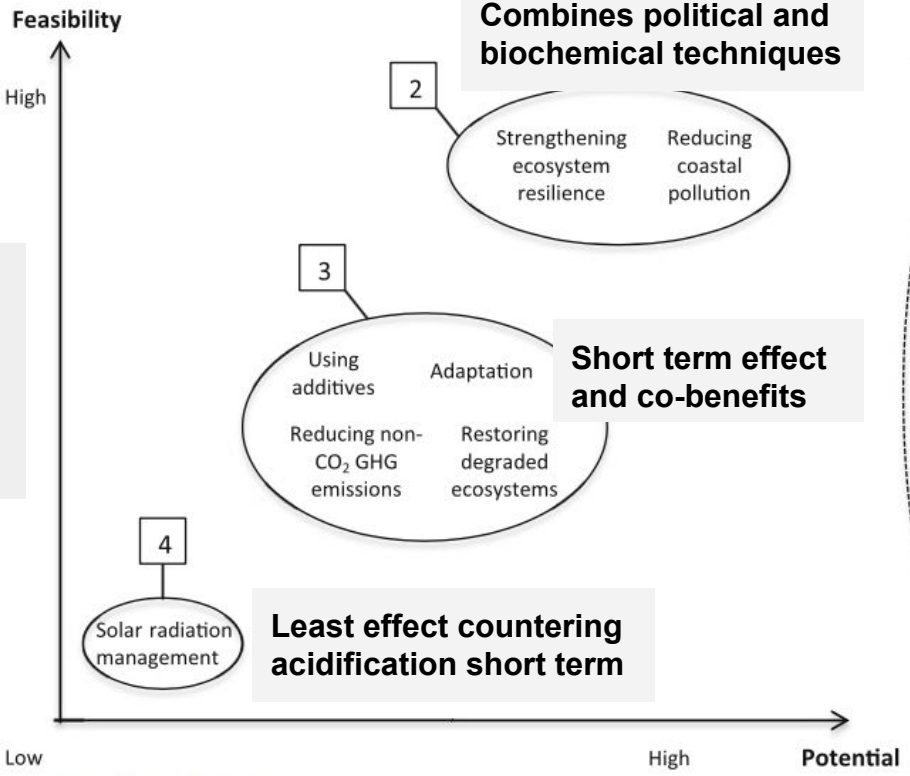


Fig. 1 Comparing potential and feasibility of options

(Billie, Biastoch & Harrould-Kolieb, 2013)

Seaweed & Kelp trap CO_2 and can help reduce ocean acidification

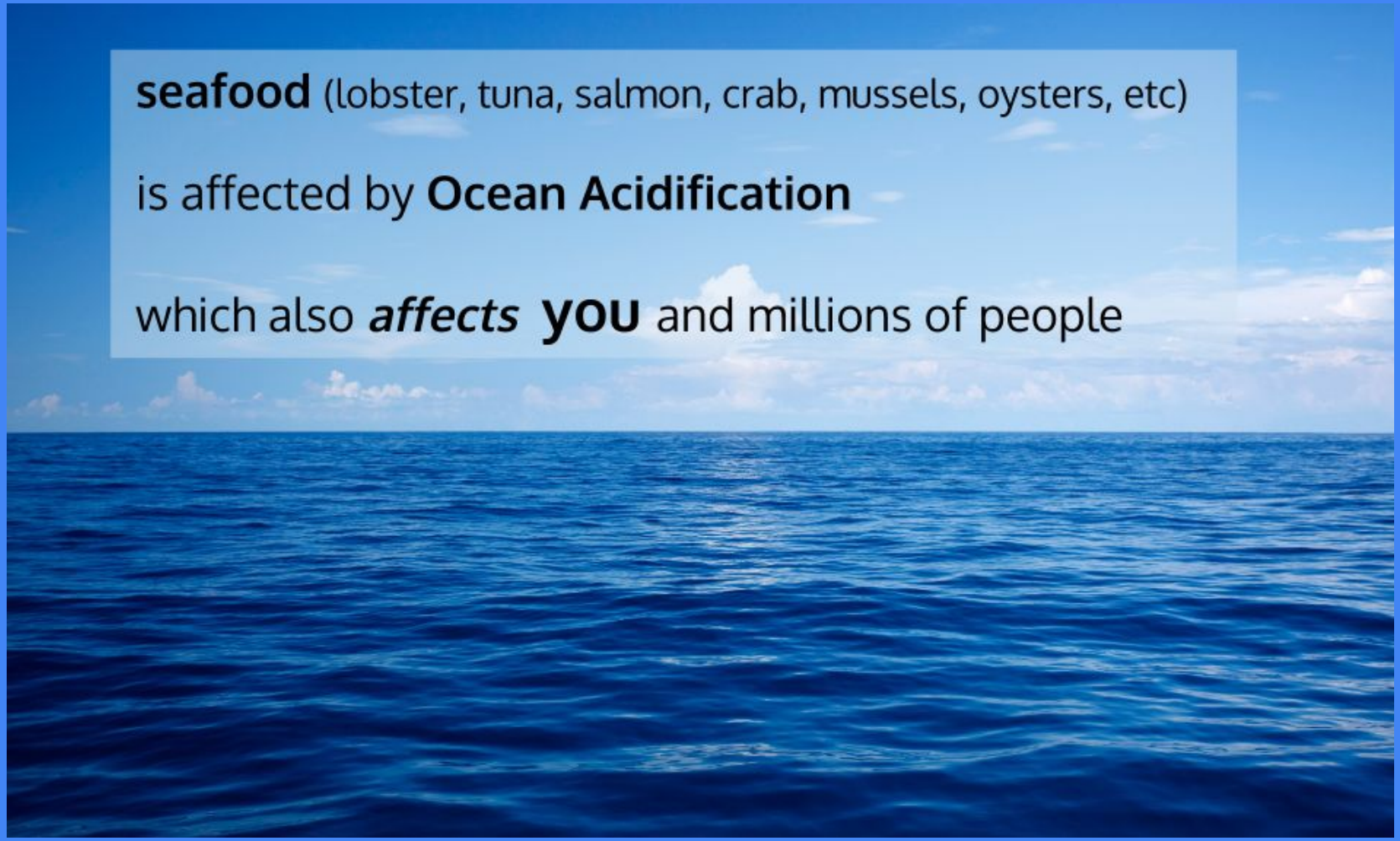
seaweed

kelp

6. ensure availability & **sustainable management of water & sanitation** for all
13. take urgent care to **combat climate change** and its impacts
14. **conserve the oceans** and marine resources for sustainable development
15. protect, restore and **promote sustainable use of terrestrial ecosystems** by sustainably managing forests, combating desertification and halt land degradation and **halt biodiversity loss**

conclusion

So what does Ocean Acidification mean?


seafood (lobster, tuna, salmon, crab, mussels, oysters, etc)
is affected by **Ocean Acidification**
which also ***affects*** **YOU** and millions of people

References

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