

# **Coral Reefs and Climate Change - an ecosystem meets its match -**

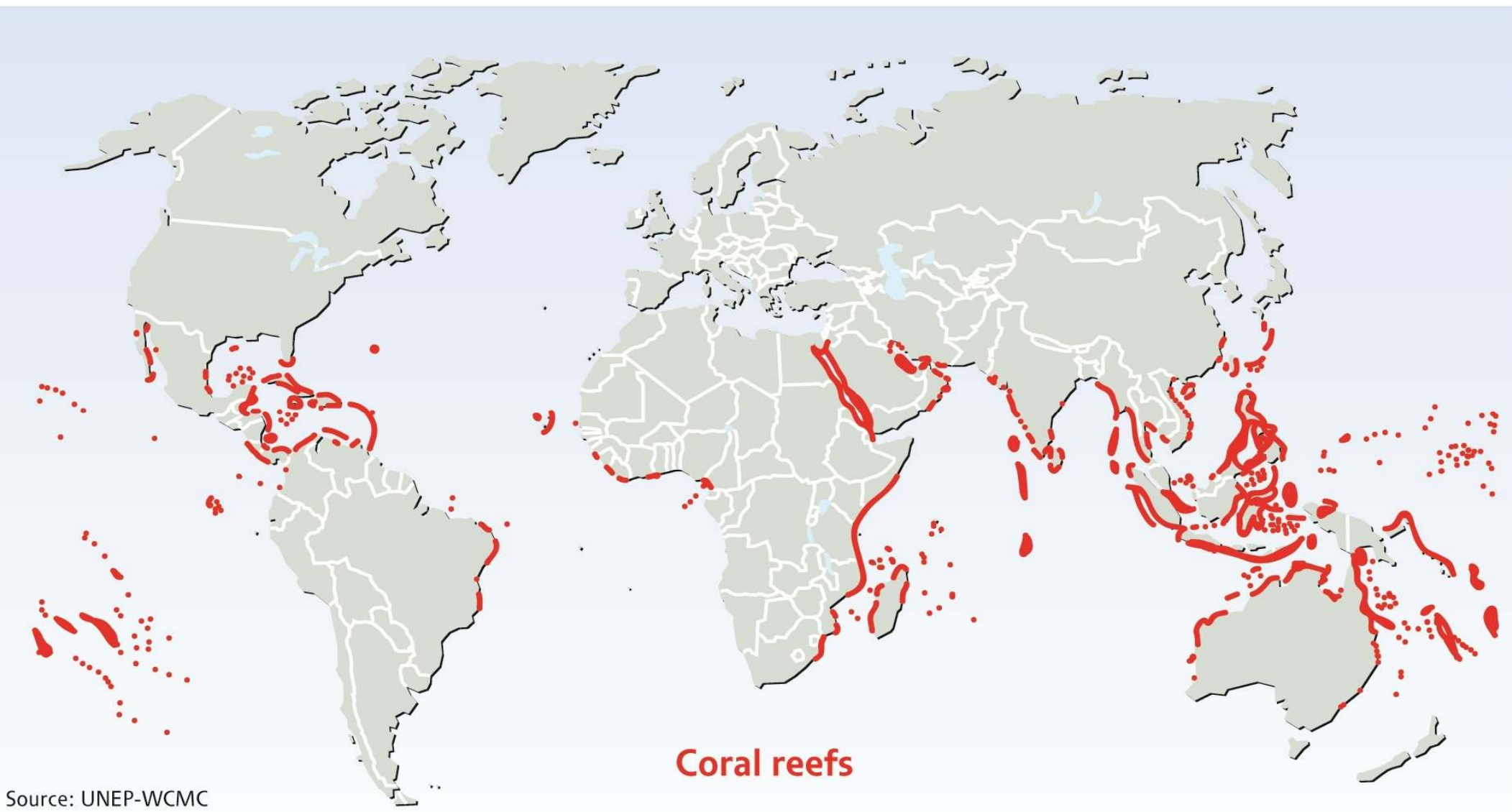
**THANKS TO:**

**John Katenzberger  
and everyone associated with the  
Aspen Global Change Institute**

**Thank YOU for coming!**

**Joanie Kleypas  
National Center for Atmospheric Research**

# Coral Reefs: Where they are



# Coral Reefs: What they are



ARC Center of Excellence for Coral Reef Studies

# Climate Change

**Pollution**



**Exploitation**



## Climate Change

Rising temperature

Ocean acidification

Ocean currents



## Pollution

Sediments

Nutrients

Toxins

## Exploitation

Overfishing

Rock extraction

Aquarium trade

Dynamite/cyanide

Tourism

## The CO<sub>2</sub> we put in the atmosphere

1.5 Pg C y<sup>-1</sup>



7.5 Pg C y<sup>-1</sup>



## Where it ends up

4.2 Pg y<sup>-1</sup>



2.6 Pg y<sup>-1</sup>



2.3 Pg y<sup>-1</sup>



46%

29%

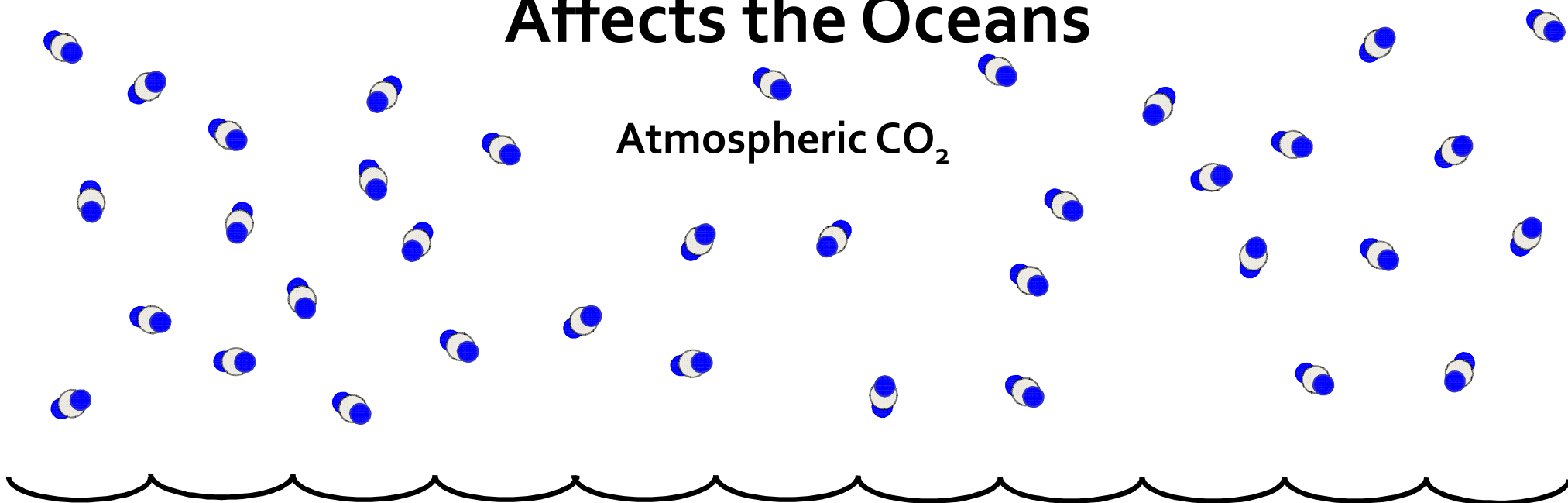
25%

Years 2000-2007

Canadell et al. 2007, PNAS (updated)

# Rising Atmospheric CO<sub>2</sub> Affects the Oceans

Atmospheric CO<sub>2</sub>

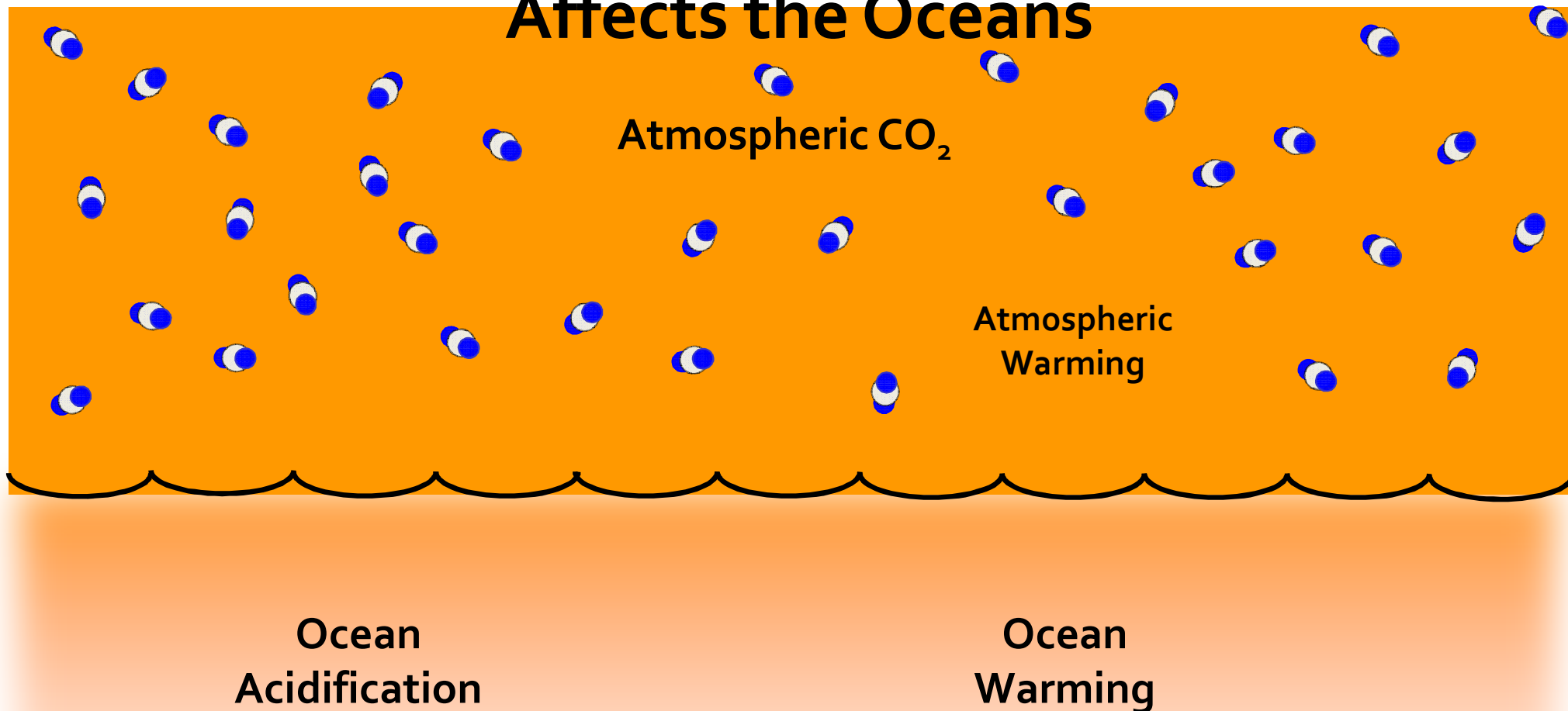


**Henry's Law:** At a constant temperature, the amount of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid.



Under Pressure by Queen and David Bowie

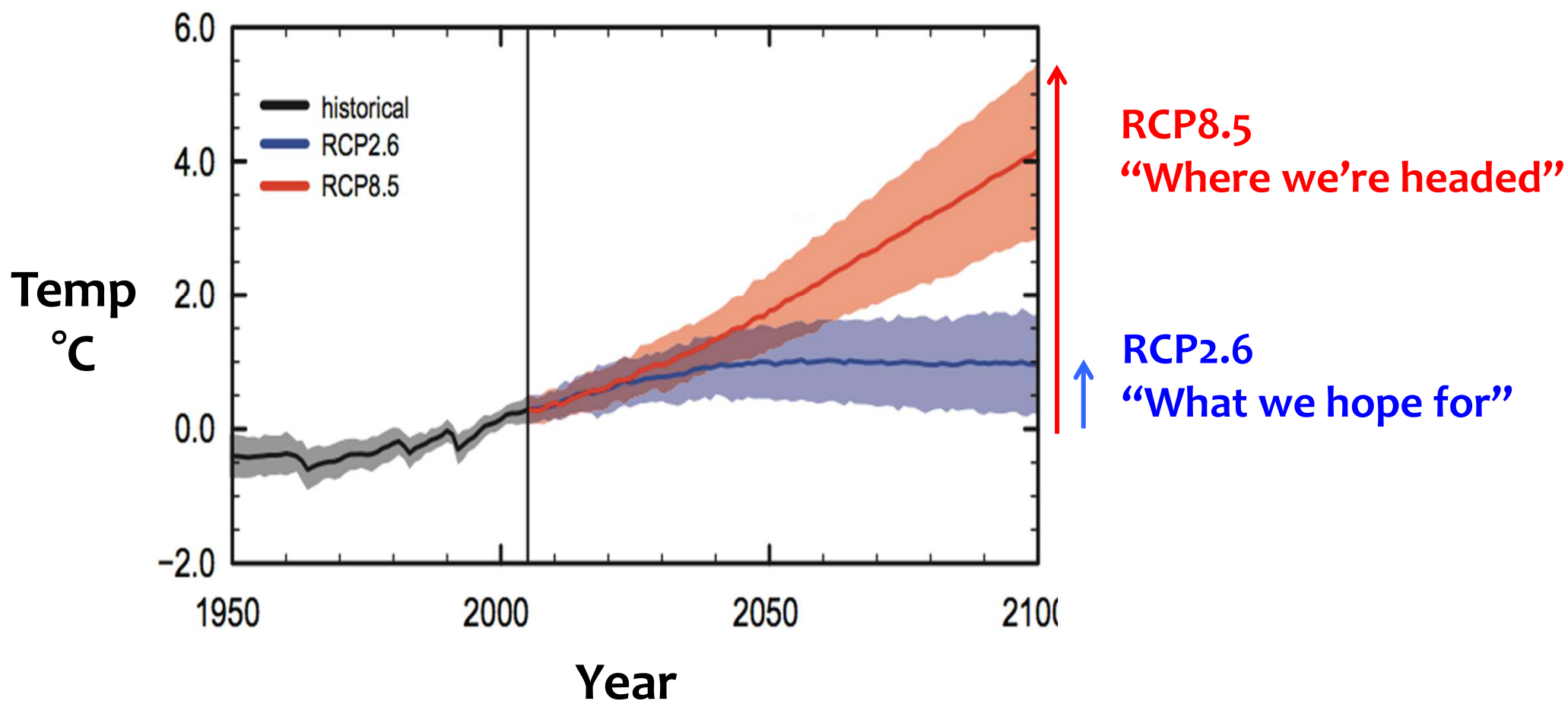
# Rising Atmospheric CO<sub>2</sub> Affects the Oceans





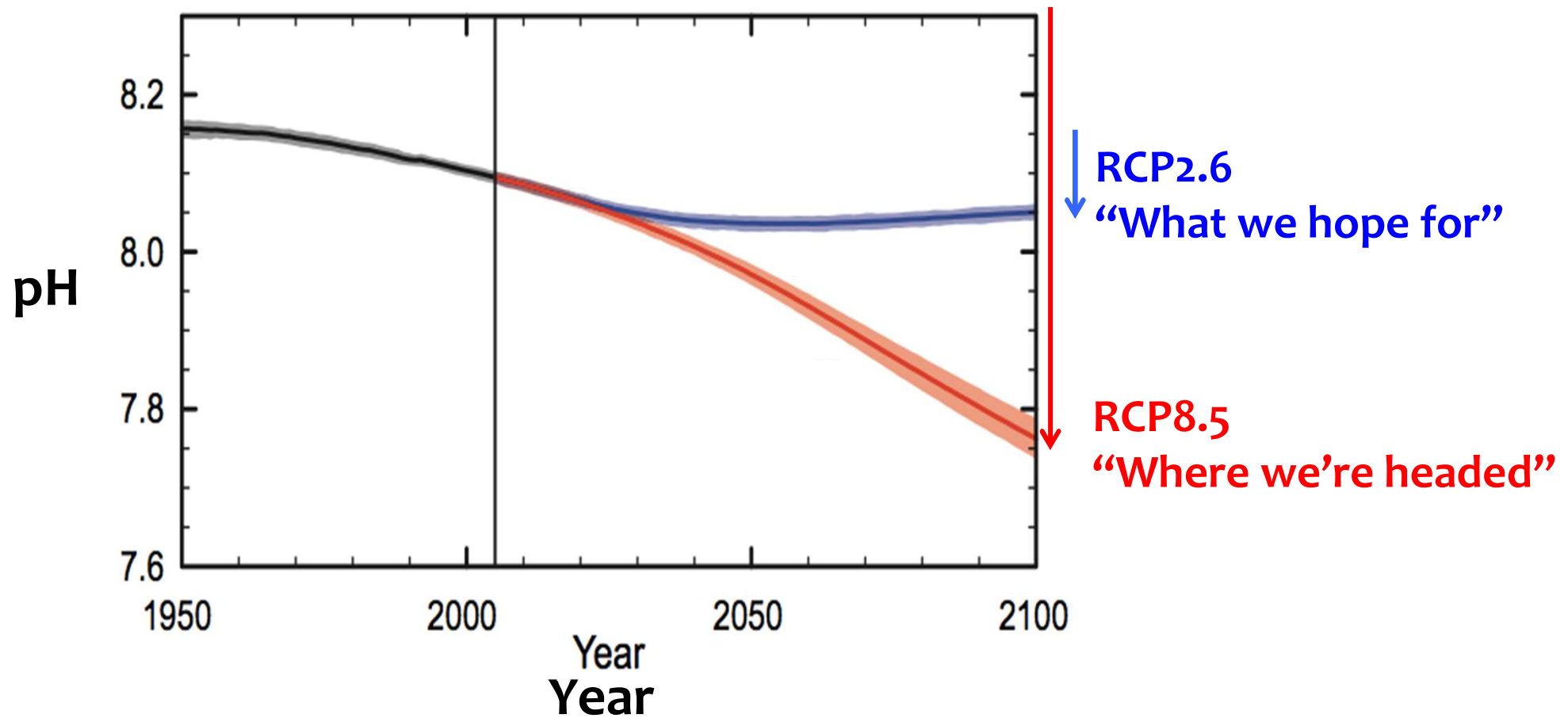
# Rising Temperature

## Change in average surface temperature

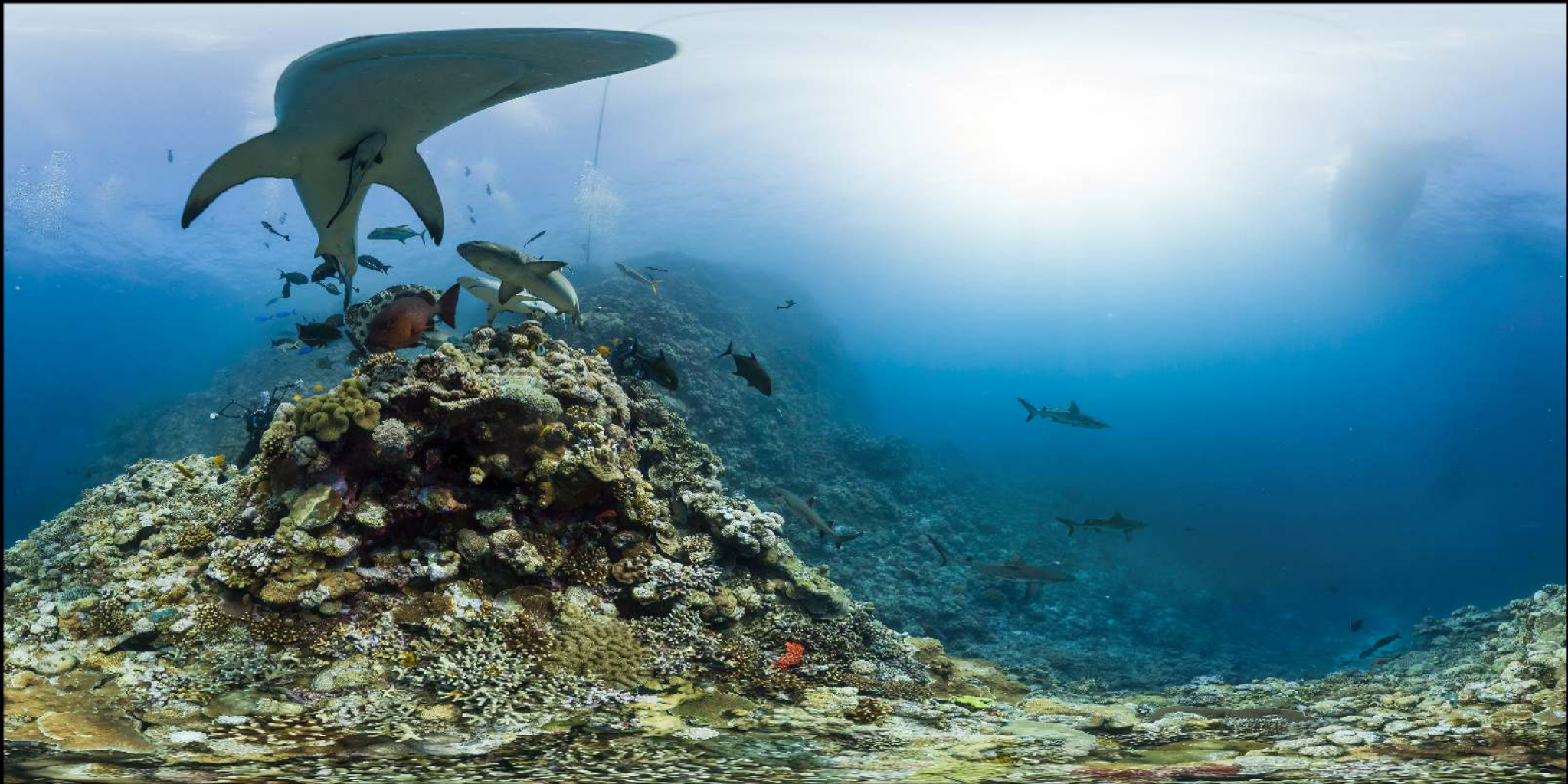


# Ocean Acidification

## Average pH of the ocean surface



# Coral Bleaching



© Underwater Earth



# Coral Bleaching

corals expel symbiotic algae that live and photosynthesize within their tissues



*Images courtesy Ray Berkelmans*

- Coral bleaching has increased in frequency and severity since the mid 20<sup>th</sup> Century
- During the 1997-1998 El Niño, ~30% of reefs worldwide experienced bleaching
- Some think that for most reefs, bleaching frequency will exceed capacity to recover by the middle of the 21<sup>st</sup> Century



# Thermal Stress

## Degree Heating Week (DHW)

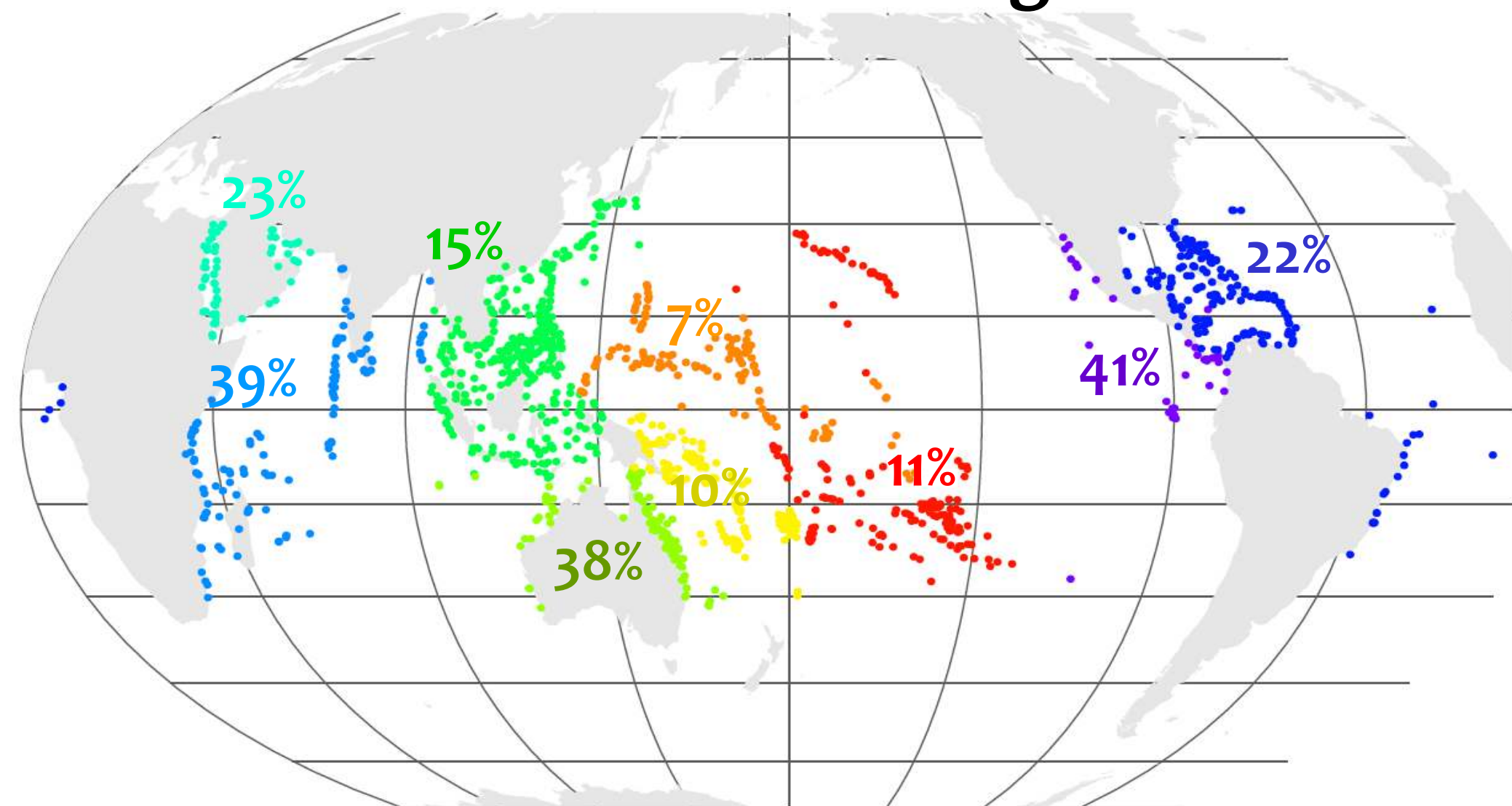
- Cumulative thermal stress over a rolling 12-week period for a given location
- Accumulation of excess heat when SST  $\geq 1^{\circ}\text{C}$  of climatological maximum SST

	$^{\circ}\text{C}$ above max	DHW
Week 1	1.0	1.0
Week 2	2.0	3.0
Week 3	0.8	3.0
Week 4	1.2	4.2
...	...	...
Week 12	0.0	4.2





# % of Reefs That Have Experienced Severe Bleaching



# Ocean Acidification



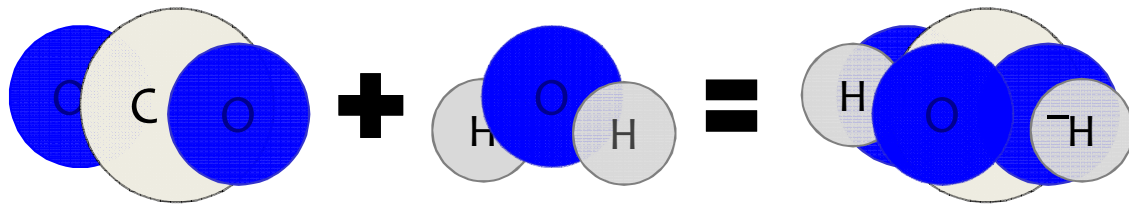
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> CATLIN SEAVIEW SURVEY - North Horn, Osprey Reef

Photo: Catlin Seaview Survey



# Cartoon Chemistry



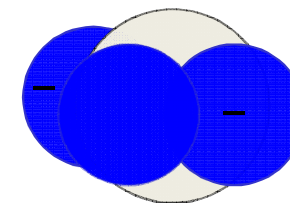
Carbon  
Dioxide

Water

Bicarbonate

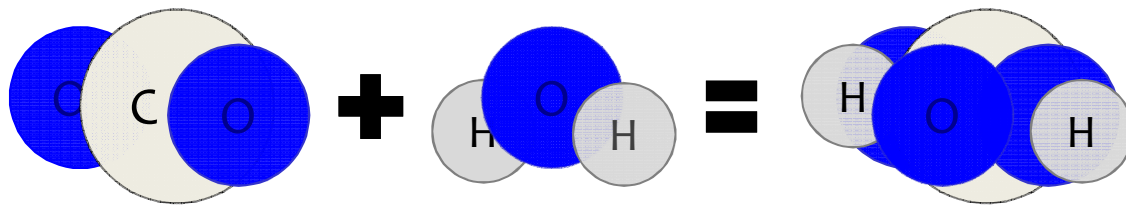
+

pH  $\square$

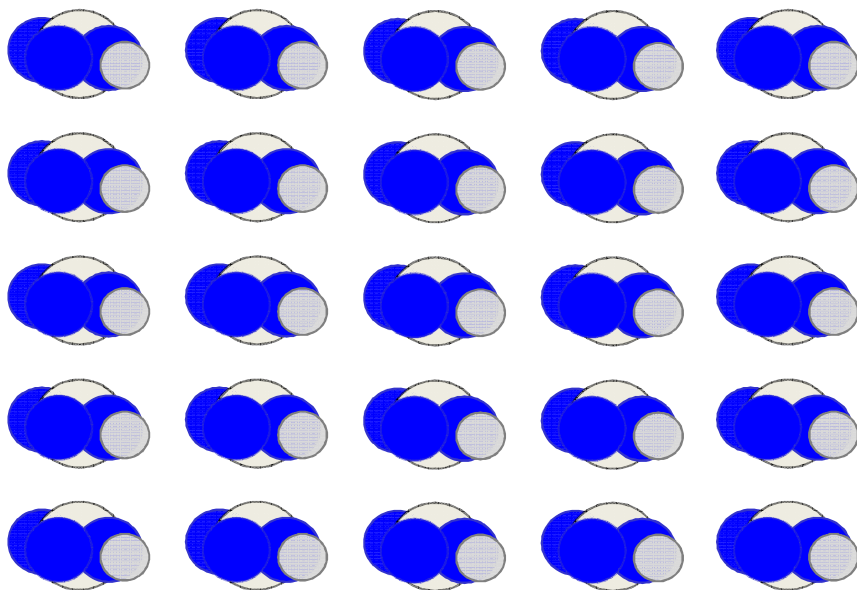


Bicarbonate

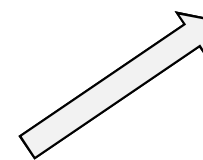
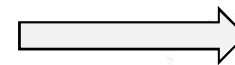
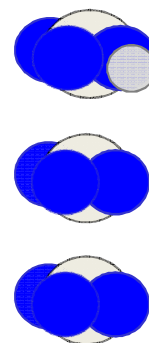
# Cartoon Chemistry



Bicarbonate



Carbonate



Calcium



# The pH scale

$$\text{pH} = -\log_{10} [\text{H}^+]$$

$$[\text{H}^+] = 0.001$$

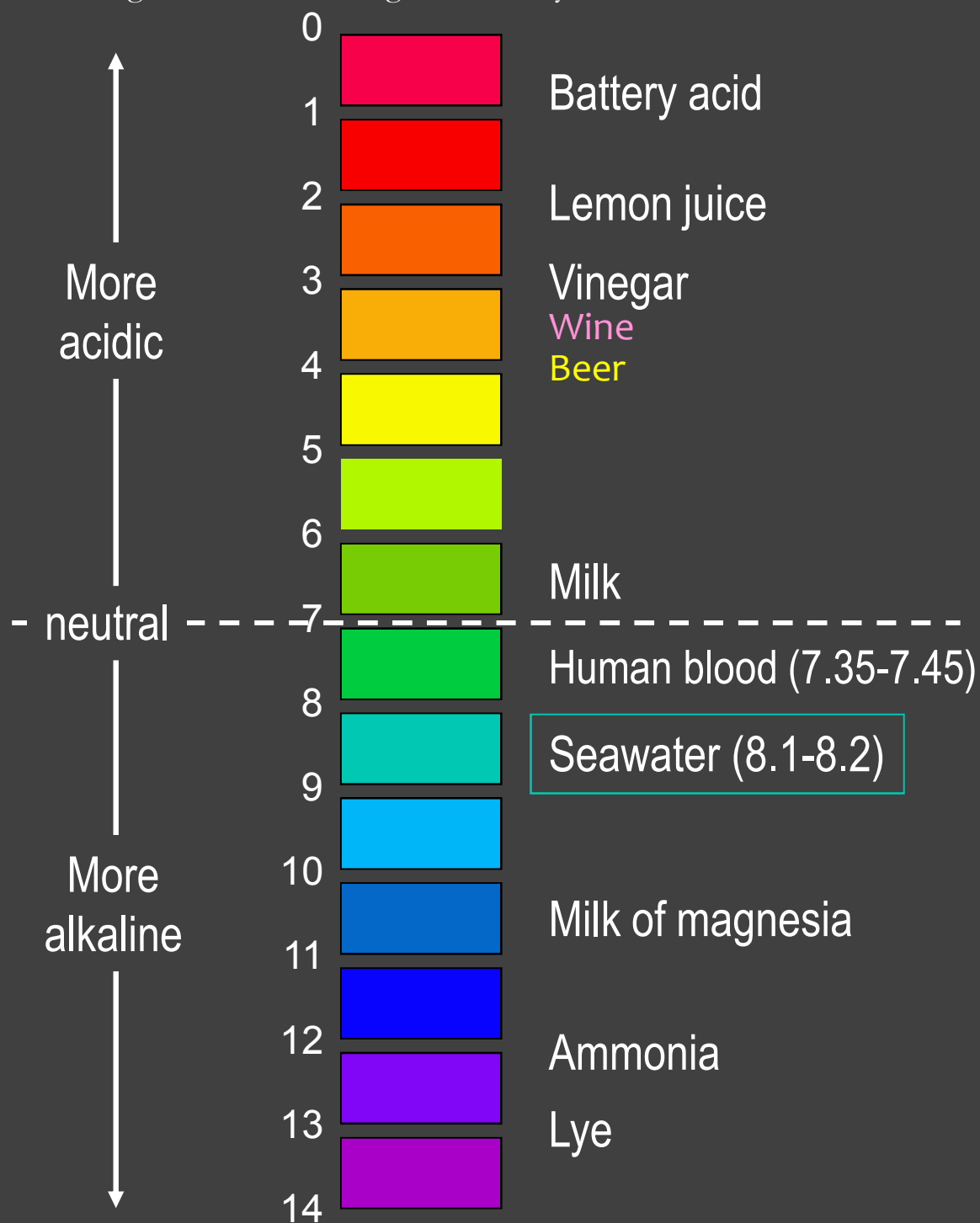
$$\text{pH} = 3$$

$$[\text{H}^+] = 0.000001$$

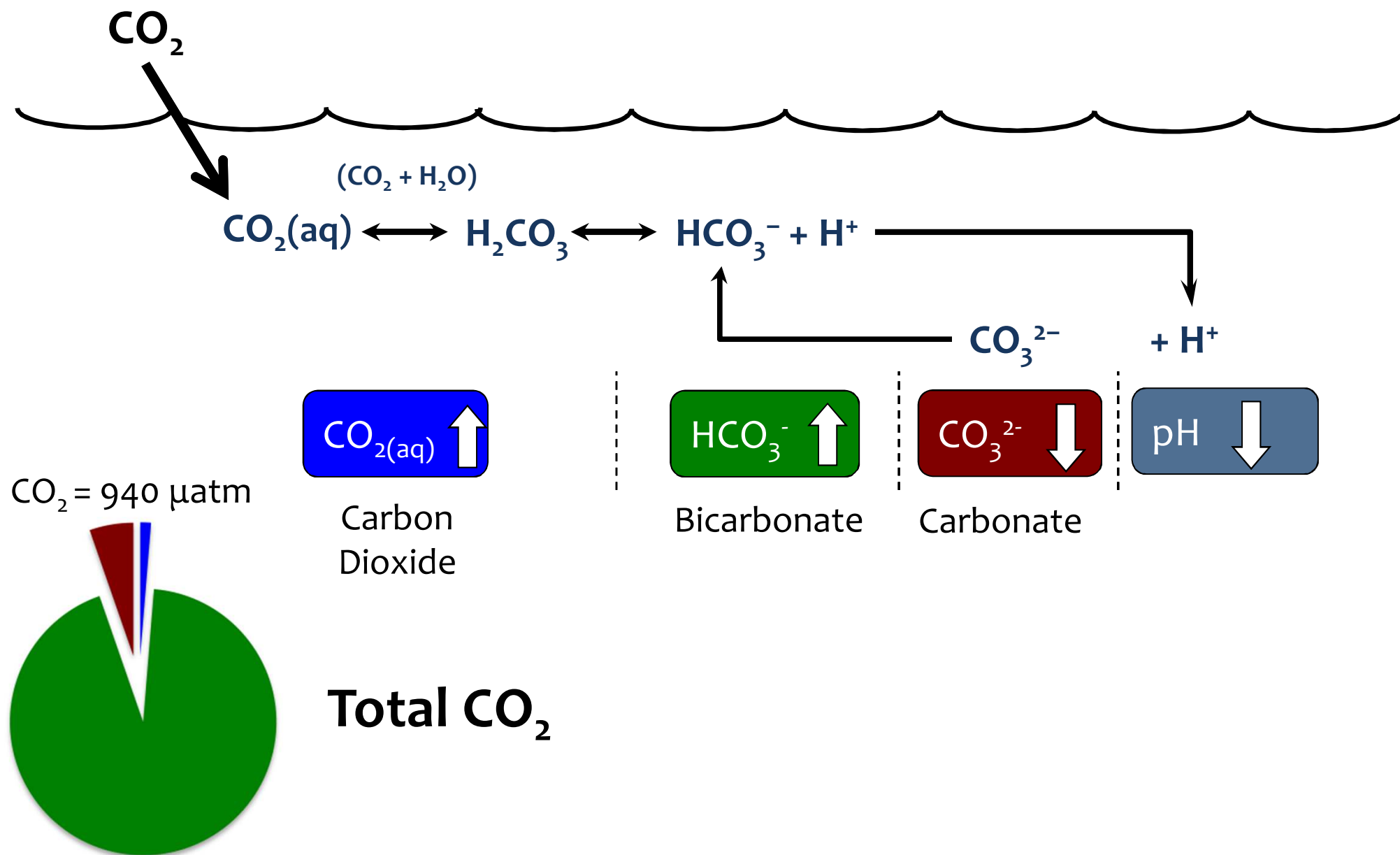
$$\text{pH} = 6$$

$$[\text{H}^+] = 0.000000001$$

$$\text{pH} = 9$$

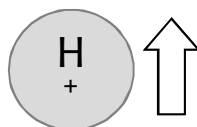
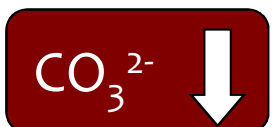
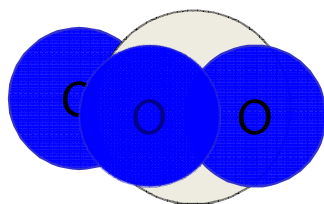
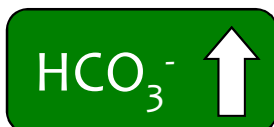
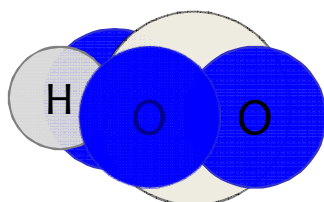
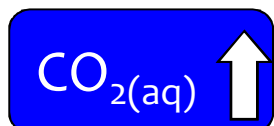
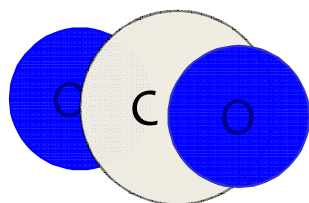


# The Chemistry





# A suite of chemical shifts



# Effects on Coral Reef Builders





# Theme song for Ocean Acidification

Bad to the bone.

Bad to the bone.

Bad to the bone.

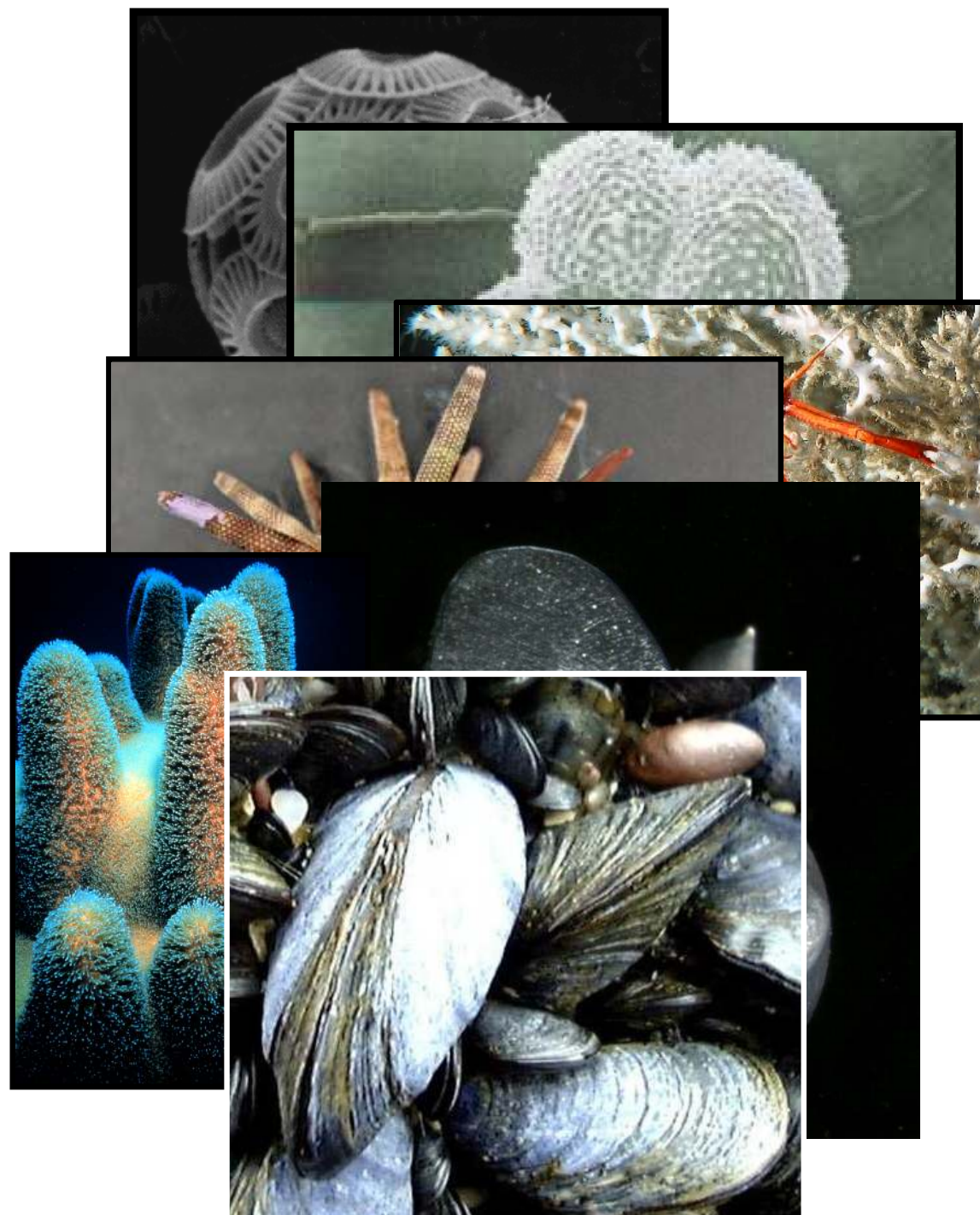
B-b-b-b-b-bad.

B-b-b-b-b-bad.

B-b-b-b-b-bad.

Bad to the bone.

*“Bad to the Bone”*  
George Thorogood



# Ocean Acidification Impacts Marine Ecosystems

## “Champagne Sites”

CO<sub>2</sub> bubbles up naturally due to underlying volcanism

Ecosystems show big changes



Italy



Papua-New Guinea



# A window into the future of coral reefs?

**pH 8.05: Today**

**pH 7.95: ~ year 2050**

**pH 7.8: ~ year 2100**



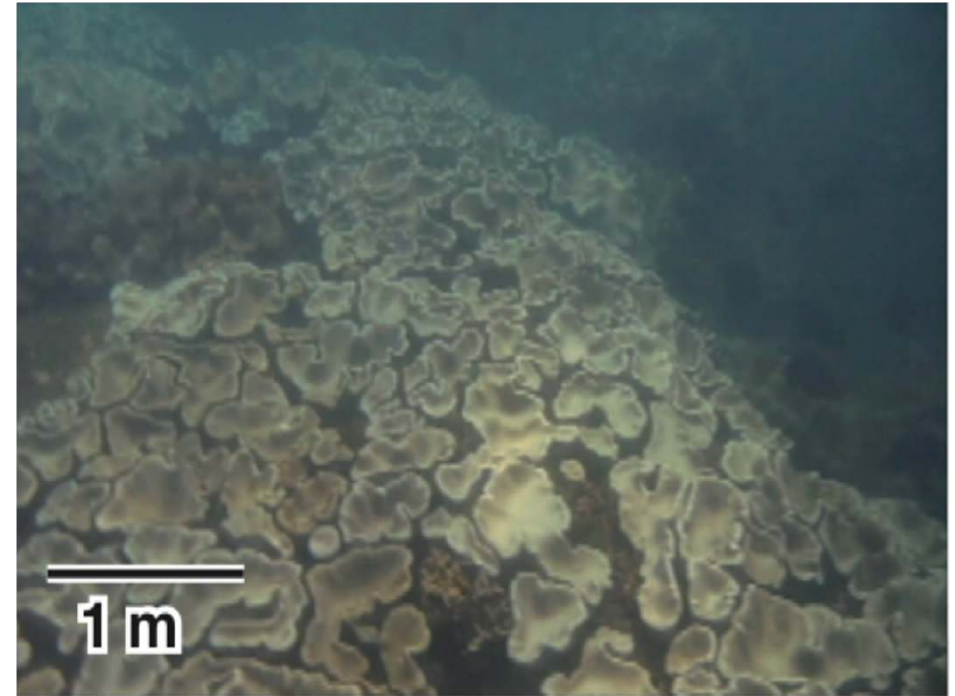
**Biodiversity decreases**  
**Coral recruitment decreases**  
**Reef erosion increases**

# A window into the future of coral reefs

Today



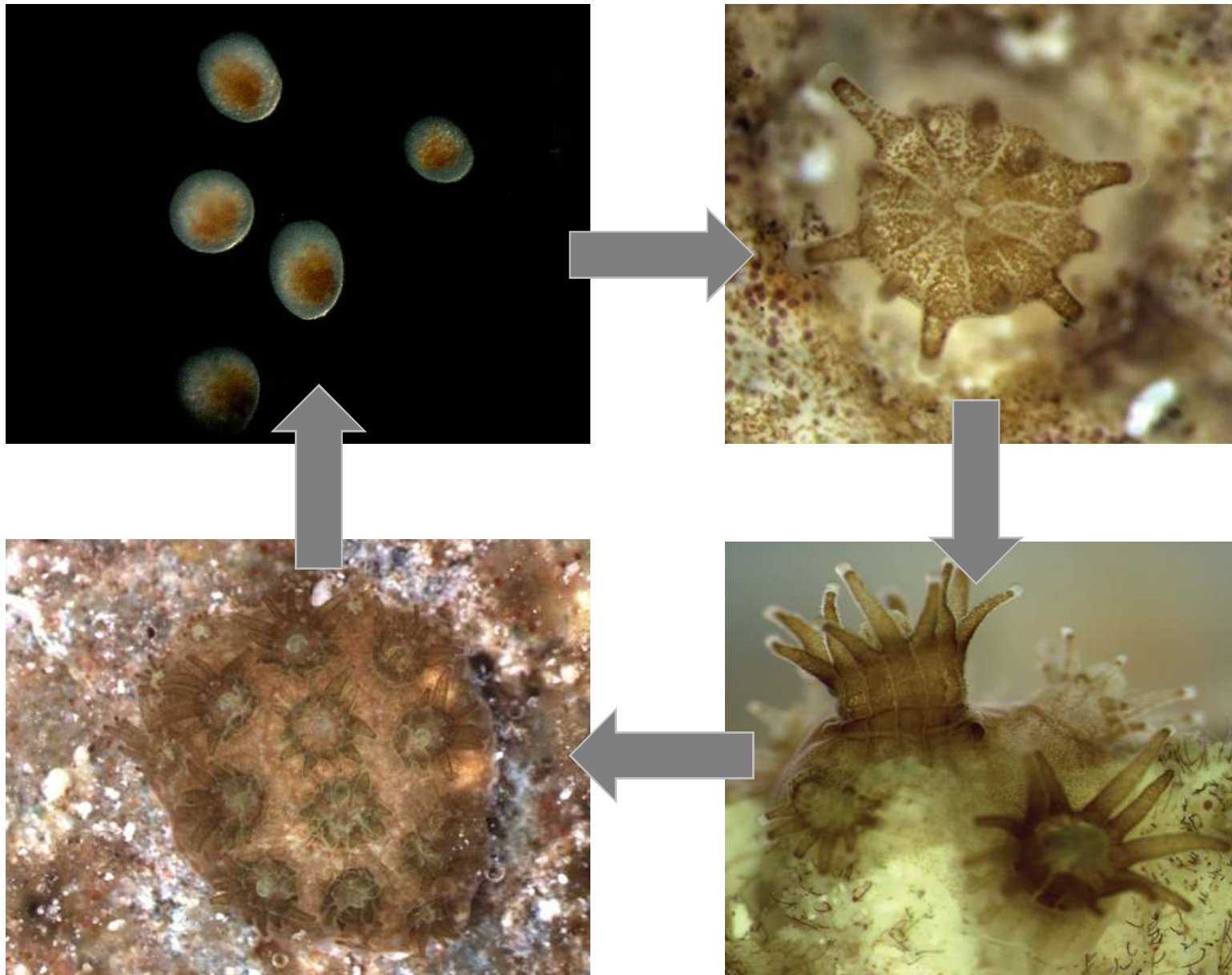
year 2100



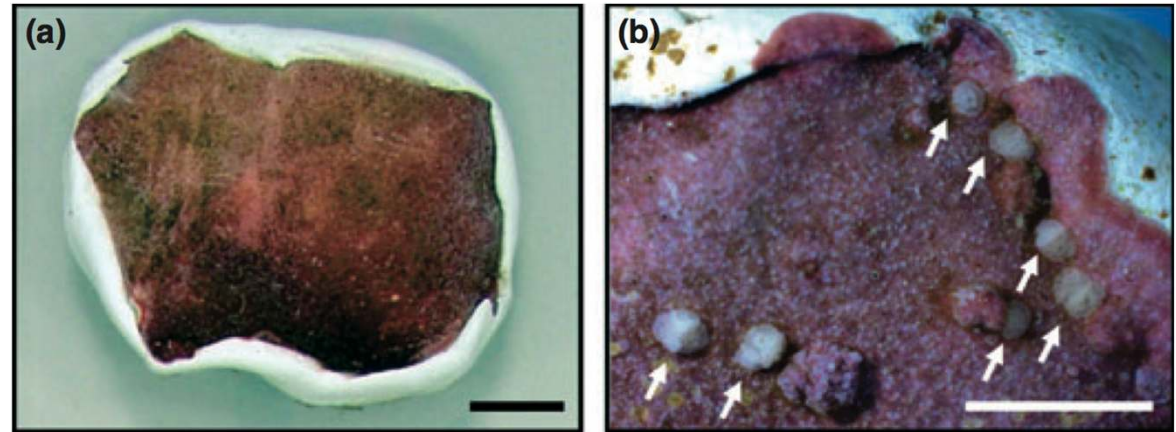
Biodiversity decreases  
Coral recruitment decreases  
Reef erosion increases



# Coral Life Cycle



# Reduced settlement on coralline algae



Coral larvae are not affected

The algae don't produce the  
compounds that trigger the corals to  
settle



# Reduced survival of recruits after settlement

With ocean acidification – the  
young corals are more fragile

Fish become bulls in a china  
closet



# Bioerosion of Reefs will increase in the future

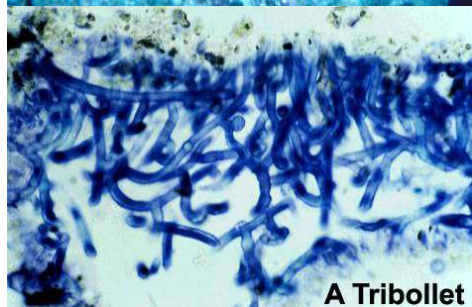
←  
**Grazers**



**Macroborers** →



**Microborers**



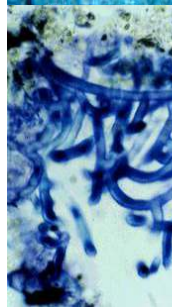
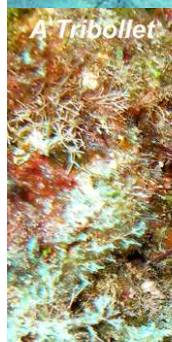
A Tribollet

Sponge: *Cliona orientalis*  
Coral: *Porites*



From 400 to 800 ppm  
30% increase in bioerosion rates

# Bioerosion of Reefs will increase in the future



Coral reefs will not only grow  
more slowly,

They will also erode away more  
quickly



# Coral Reefs and Climate Change

## Has this ecosystem met its match ?

ABC News  
NewsRadio Now Playing: ABC

Beijing 2008 Coverage of the Beijing Olympic Games ▶

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Hot tags: australia, government-and-politics, law-crime-and-justice, sport, states-and-territories, s

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### Barrier Reef could be gone within 30 years: study

### Death knell for Great Barrier Reef?

Report estimates most coral will die by 2050

AP Associated Press

updated 8:23 a.m. MT, Mon., Feb. 25

SYDNEY, Australia - A new study says rising ocean temperatures will kill coral on the Great Barrier Reef.



We Report.  
You Decide.

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### Study: Rising Carbon Dioxide in Oceans Threatens Coral Reefs

The New York Times

Environment

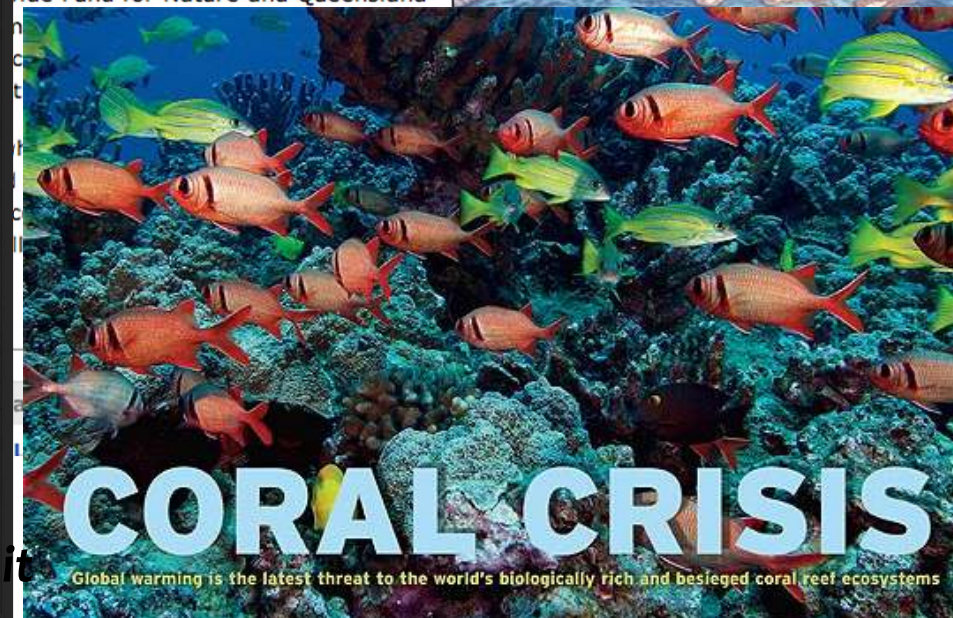
Before They Vanish

1 of 11



R.E.M. It's the end of the world as we know it

Queensland University of Technology said the Pacific Ocean is warming too fast for the survival of the Great Barrier Reef.



Global warming is the latest threat to the world's biologically rich and besieged coral reef ecosystems



# Coral Reefs and Climate Change

Has this ecosystem met its match ?

All we are saying...

... is give REEFS a chance

**John Lennon: *Give Peace a Chance***

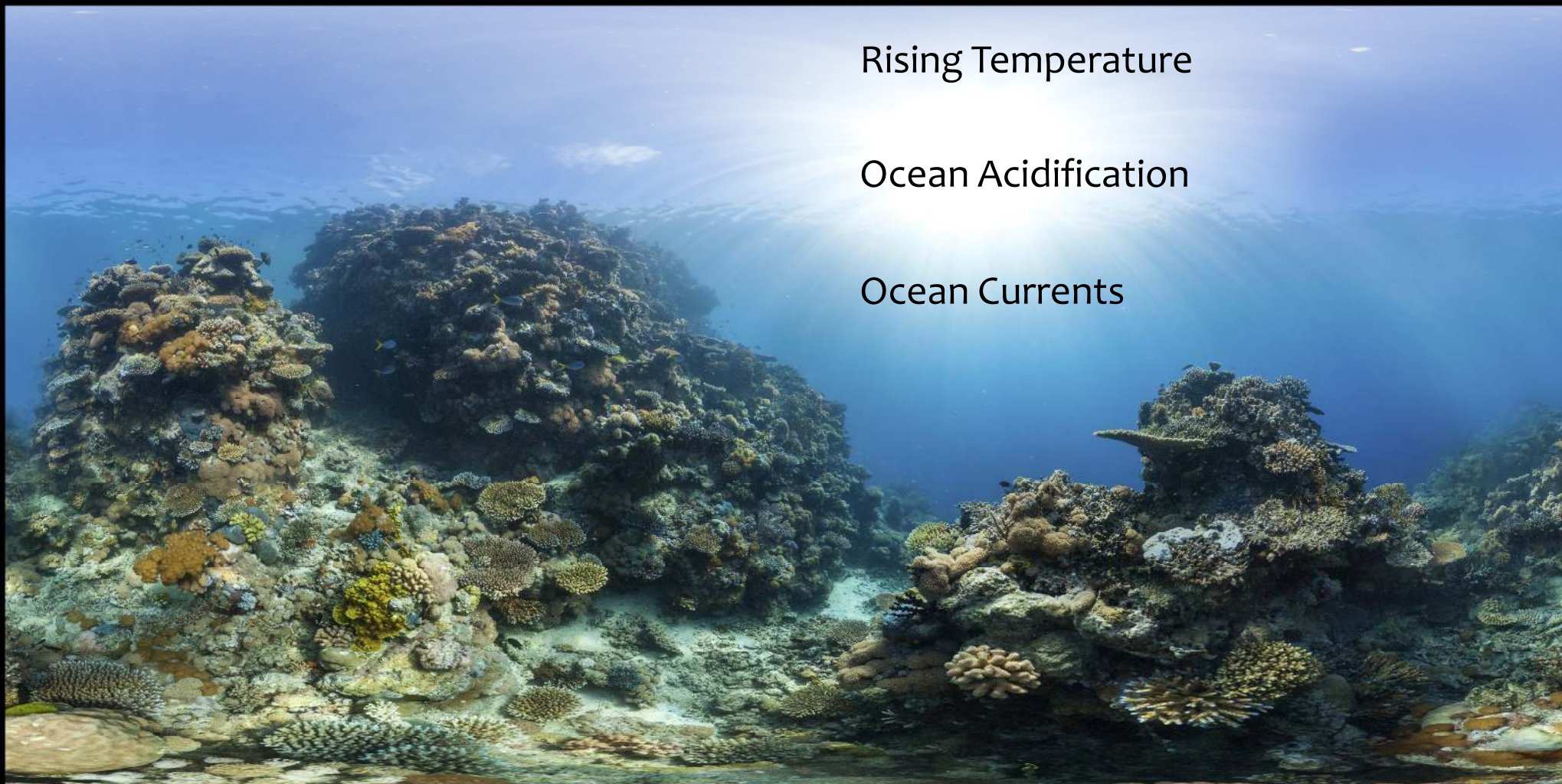
# Planning for the Future

- work with The Nature Conservancy -

Rising Temperature

Ocean Acidification

Ocean Currents



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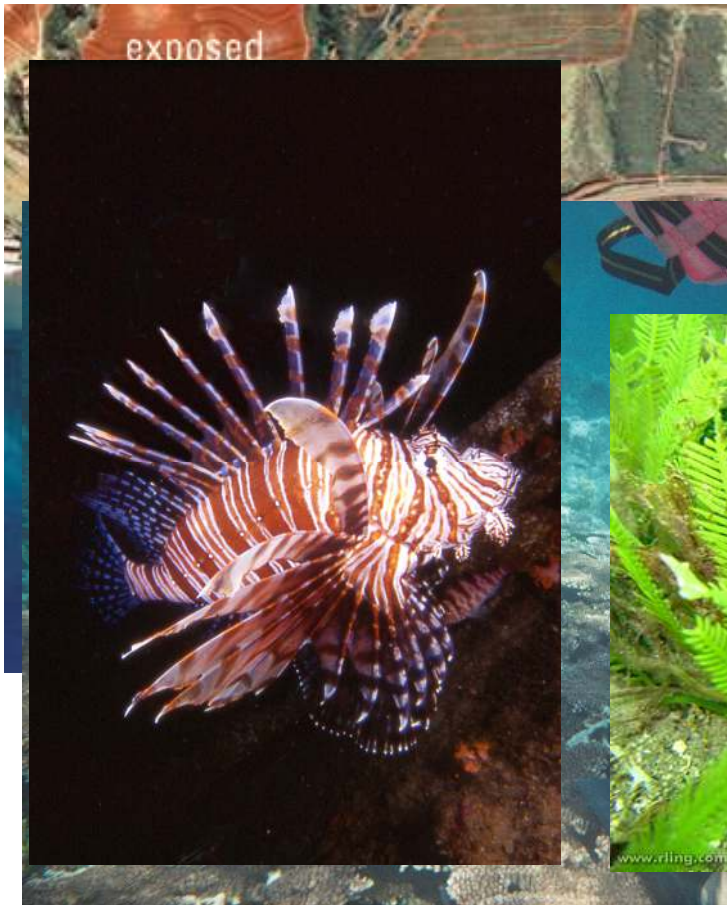
> CATLIN SEAVIEW SURVEY - Wilson Reef

Photo: Catlin Seaview Survey



# Eliminate other stresses on reefs

~~Deleterious fishing~~

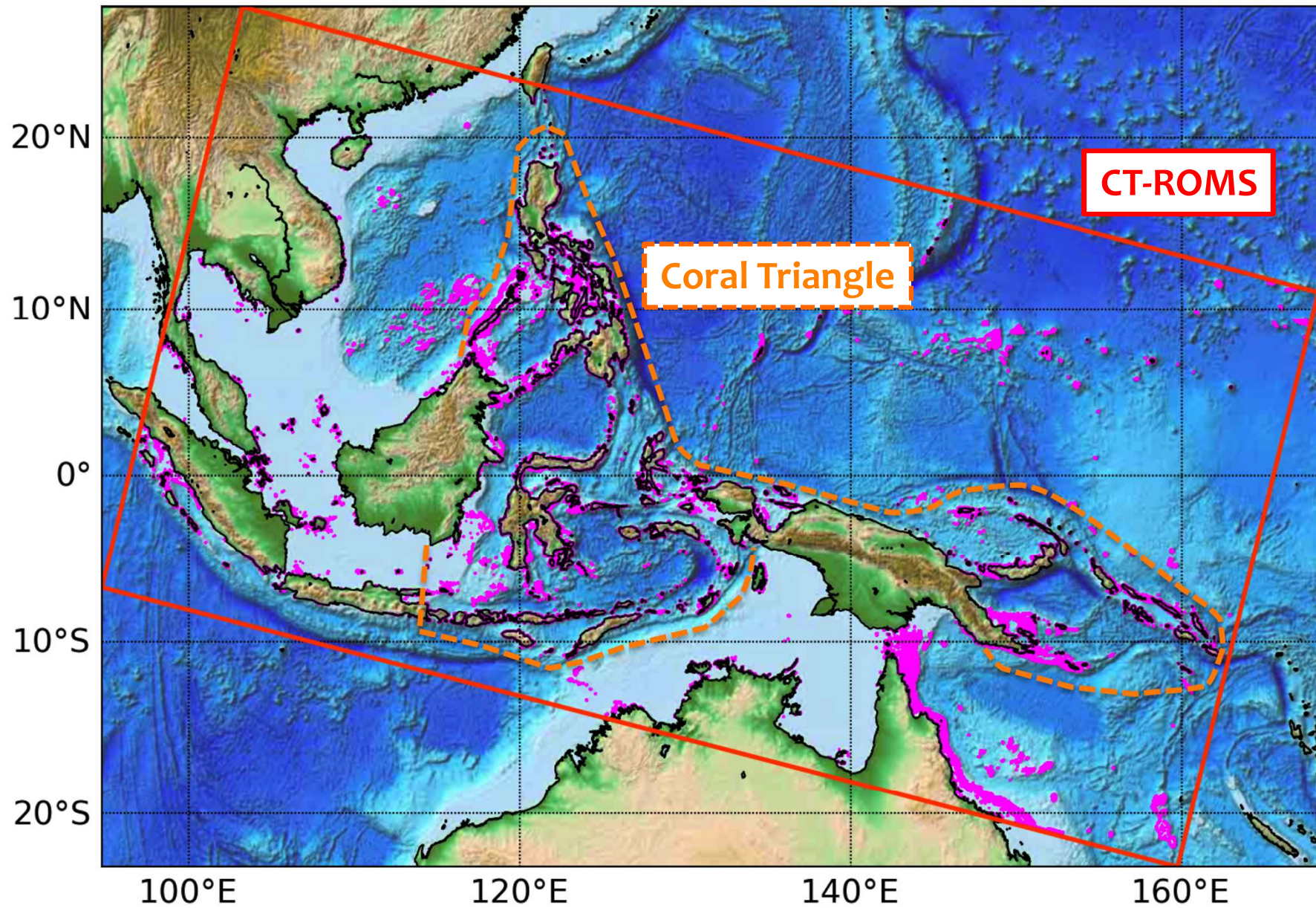


People damage





# The Coral Triangle



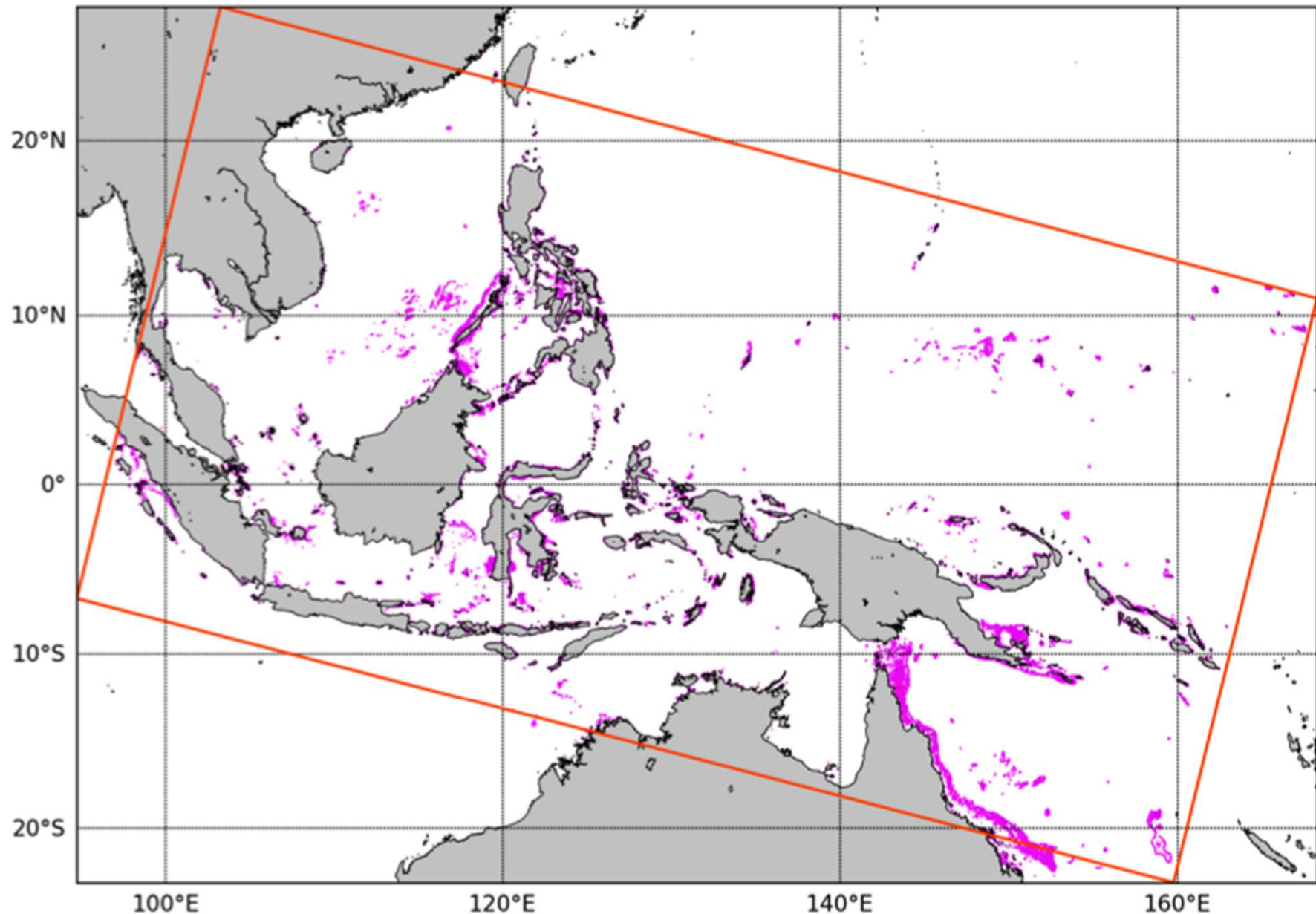


# Highest Marine Biodiversity of anywhere



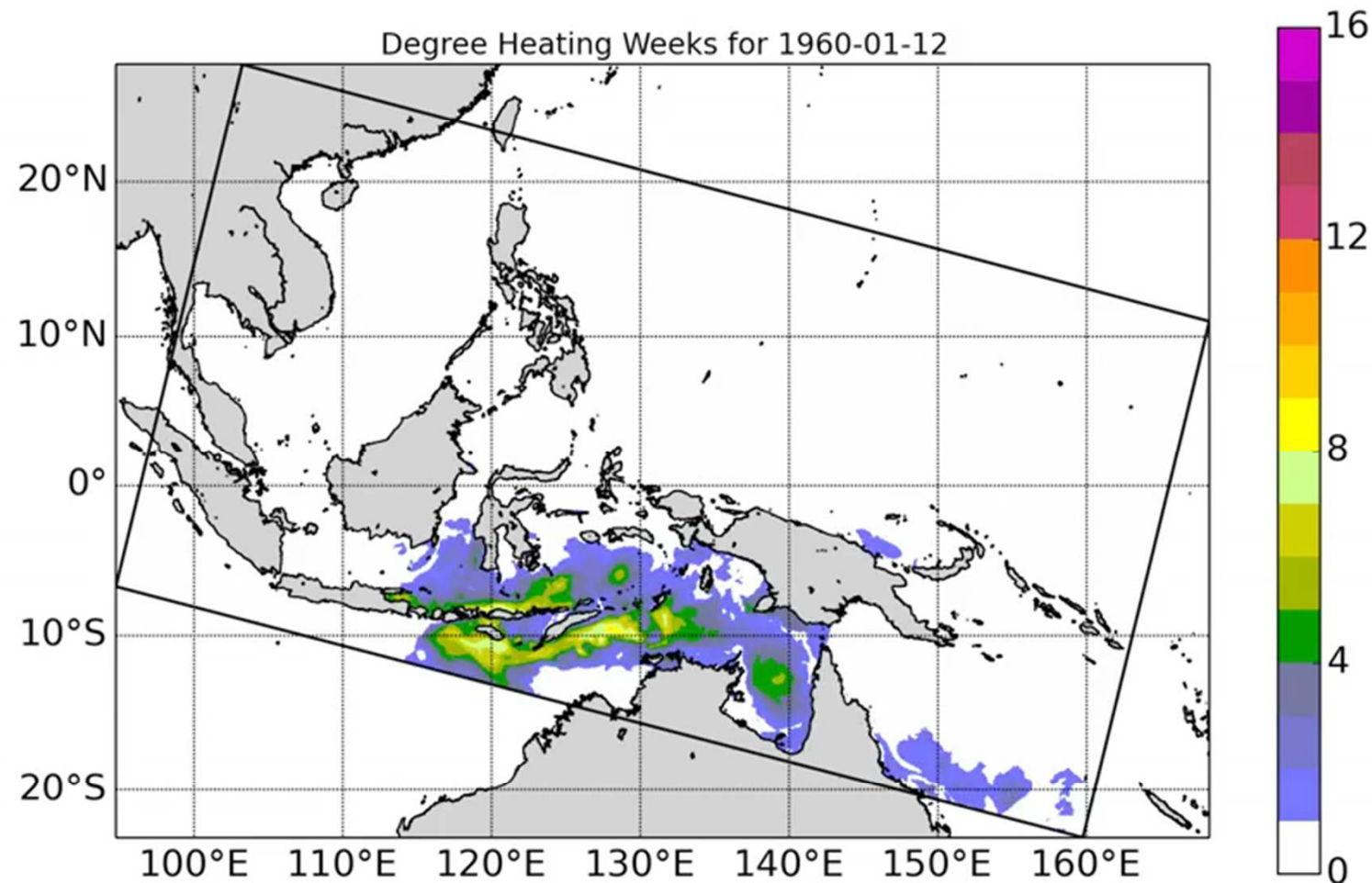
Photos from Rod Salm, TNC

# Region of Greatest Marine Biodiversity





# Heat Stress



# Coral Life Cycle



© Underwater Earth

> CATLIN SEAVIEW SURVEY - Heron Bommie - Heron Island

Photo: Catlin Seaview Survey



# Coral Spawning Events



Video: NOAA Flower Garden Banks



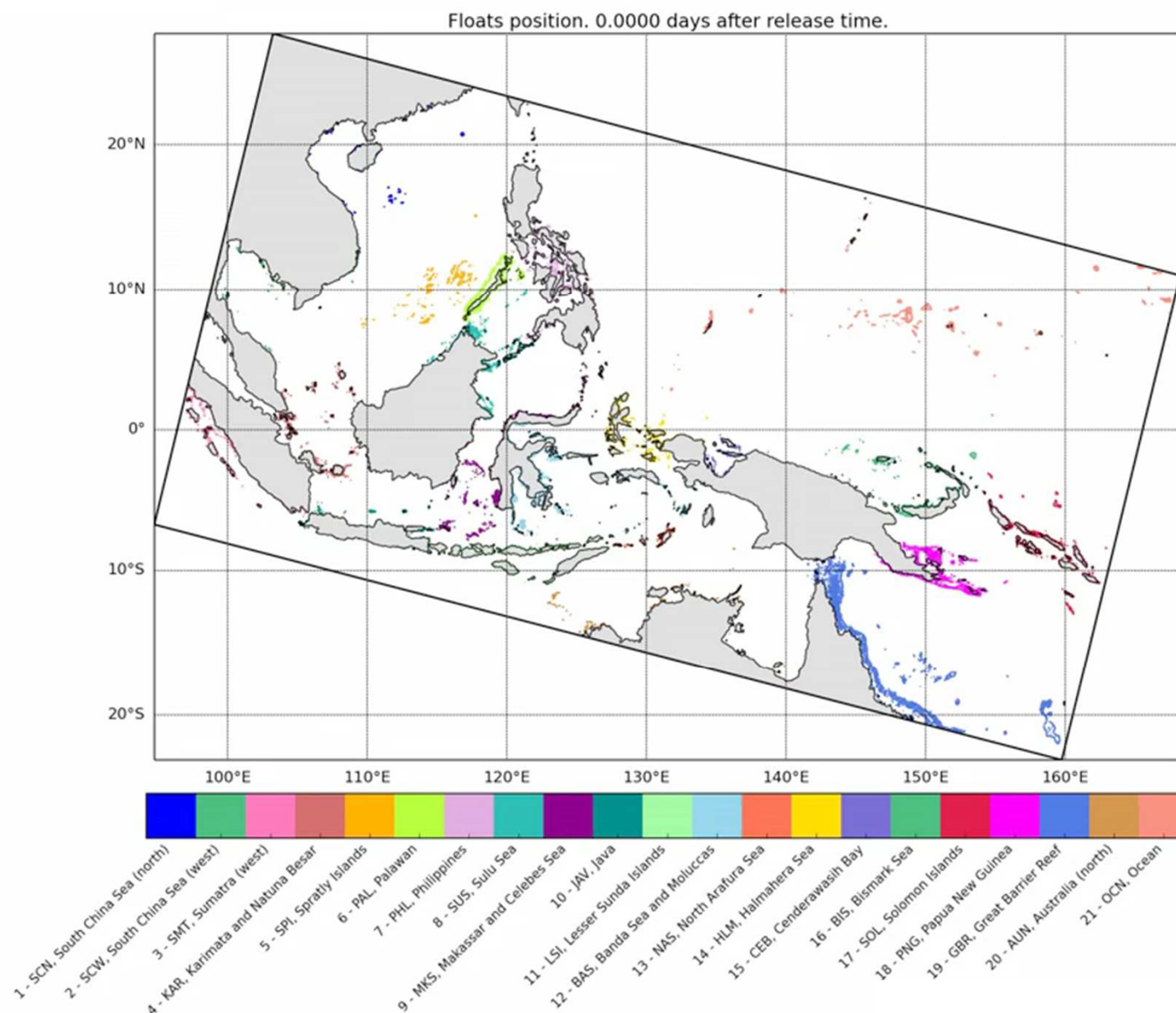
Photo: Bette Willis

# Coral Connectivity

## Holding it all together

Recovery depends on how well “connected” coral communities are in terms of the transport of larvae from one reef to another

If one reef gets hit, will it be reseeded with larvae from a healthy reef?



Lyrics: “Stir it up”  
Bob Marley



# Reef Restoration





# Have reefs met their match?

**Coral reefs are definitely challenged by climate change**

1. **Warming** will continue to cause bleaching events, but there are signs of some adaptation to heat stress
2. **Ocean acidification** will impact the ability of coral reefs to recover, AND will attack the reef structure

**There is a lot we can do to lessen the challenge**

1. **Cleaning up the other stresses**
2. **Better conservation planning** including reefs' ability to reseed
3. **Creative ways to grow better corals**

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**YOU**

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