

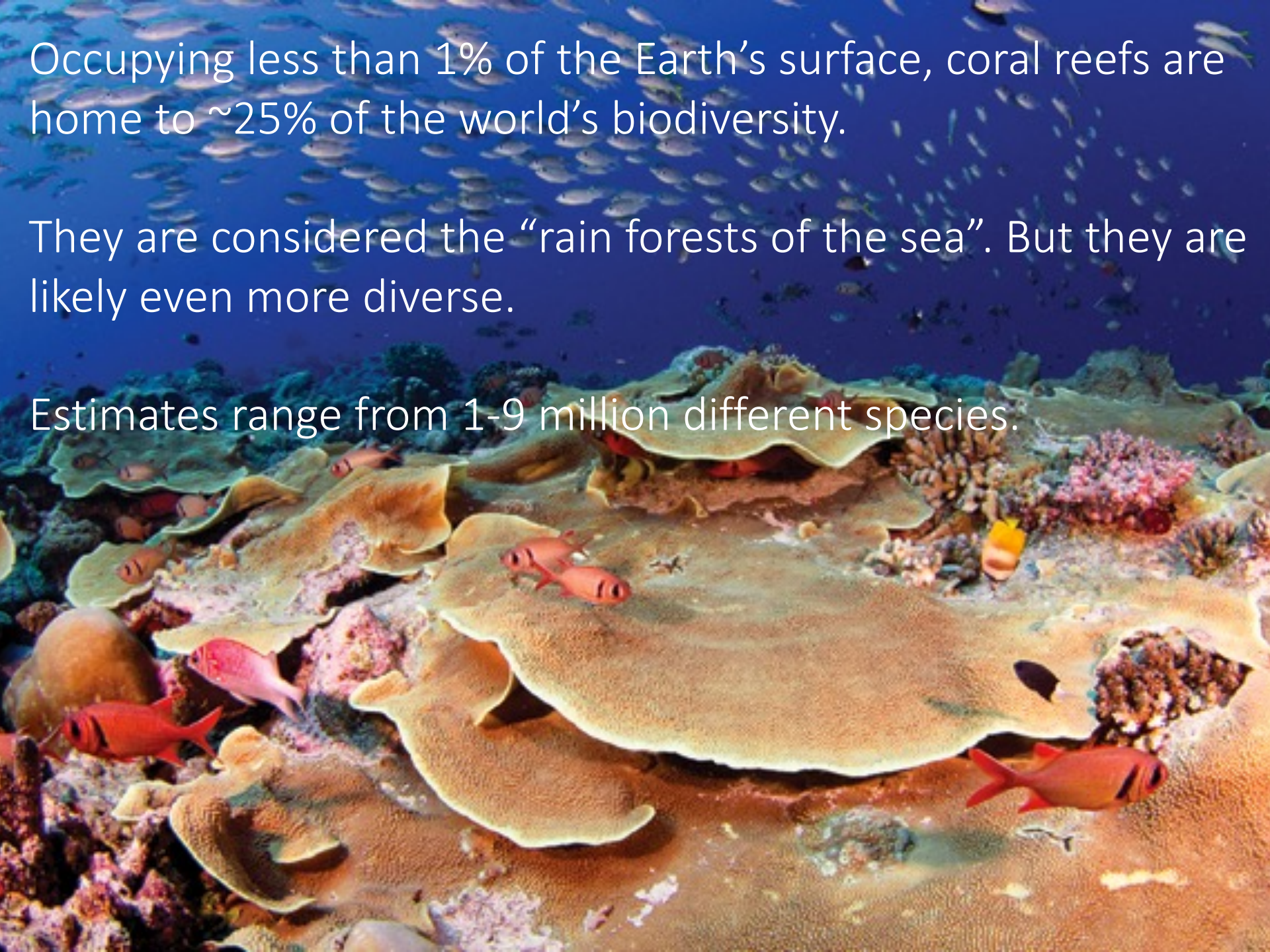
Opening Thought Question – 3/9

What is a coral reef?

Coral reefs: oceanographic influences and mutualisms that transform communities

Coral reefs: oceanographic influences and mutualisms transform communities

1. Coral reefs are incredibly biodiverse
2. How do corals survive and form reefs?
3. How do corals thrive in warm, shallow, clear water that is nutrient poor (i.e., oligotrophic)?
4. How resilient are coral reefs to stress?



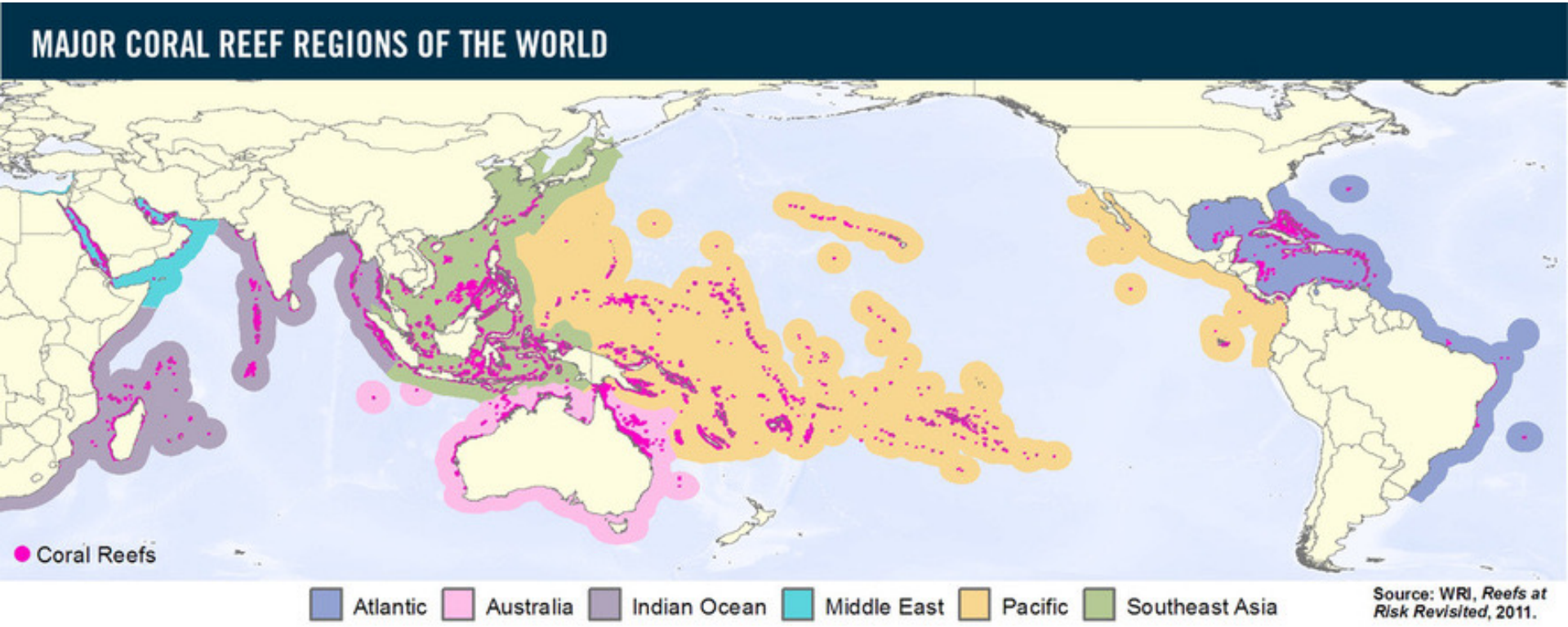
Occupying less than 1% of the Earth's surface, coral reefs are home to ~25% of the world's biodiversity.

They are considered the "rain forests of the sea". But they are likely even more diverse.

Estimates range from 1-9 million different species.

Coral Paradox ("Darwin's Paradox")

Corals thrive in warm, shallow, clear water that is nutrient poor. How?



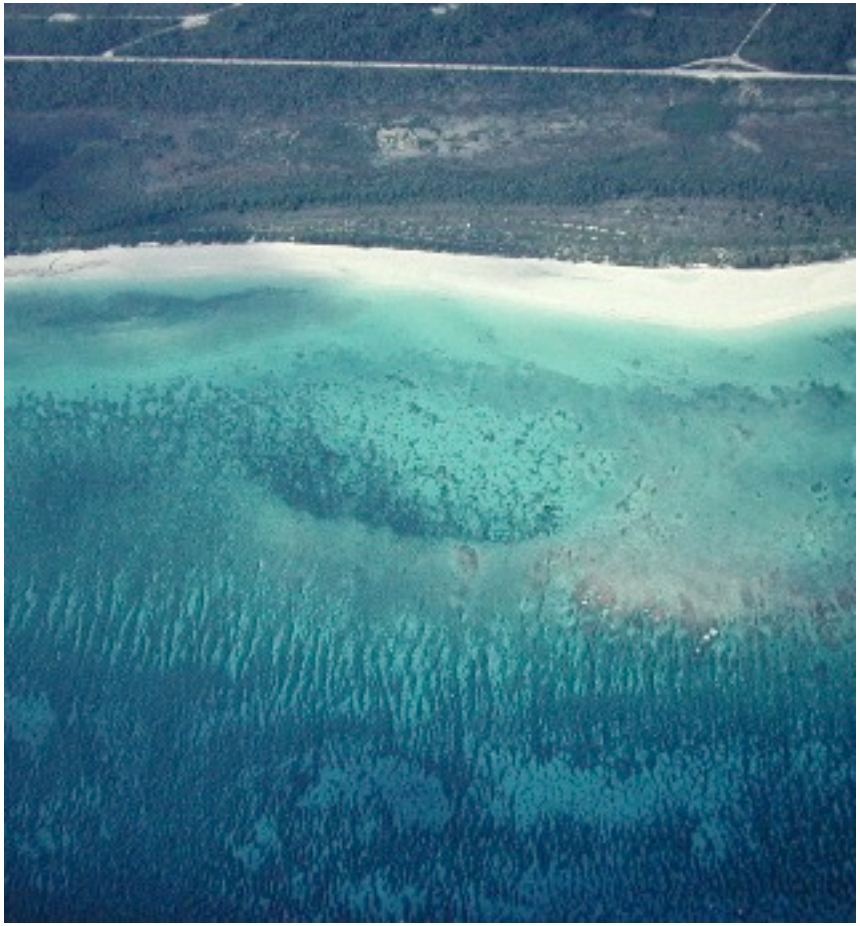
Possible because of:

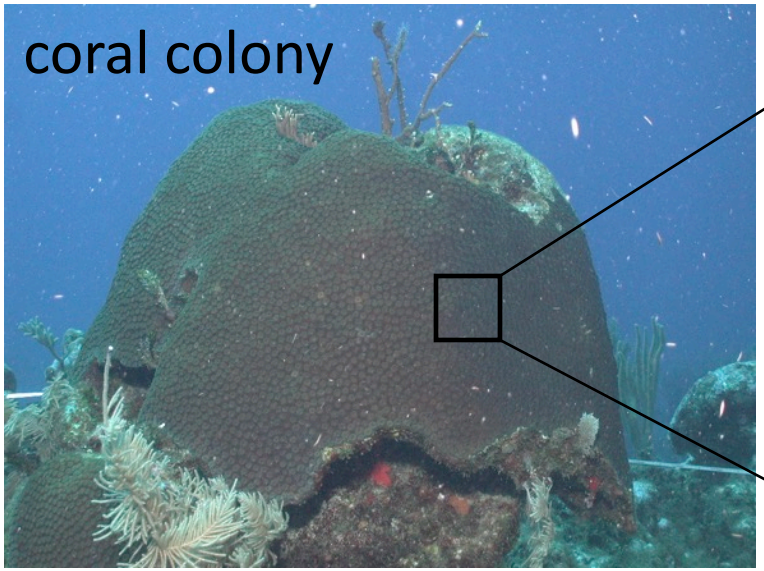
- symbionts
- key herbivores that reduce algal biomass
- positive feedback loop from reef building corals keeps phytoplankton and nutrients within system

What is a coral reef? How is it made?

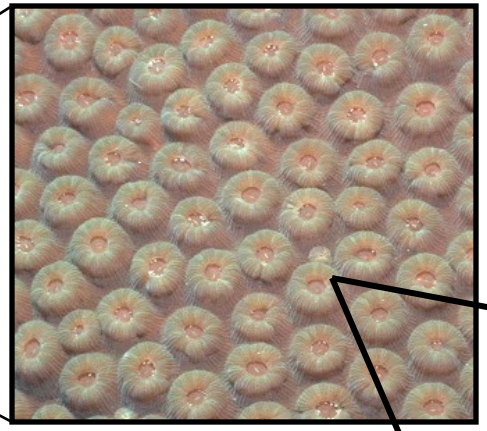
A coral reef is a biogenic structure built over 1000's of years by tiny coral polyps that make up coral colonies.

Scleractinian (reef-building) corals secrete $CaCO_3$ to build an external skeleton.

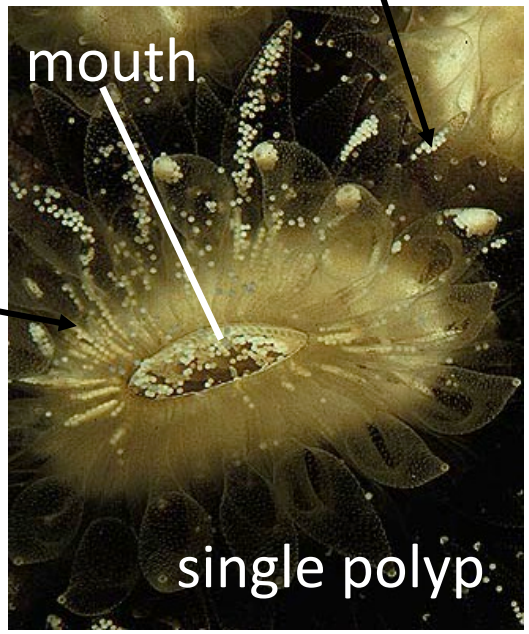




coral polyps



zooxanthellae



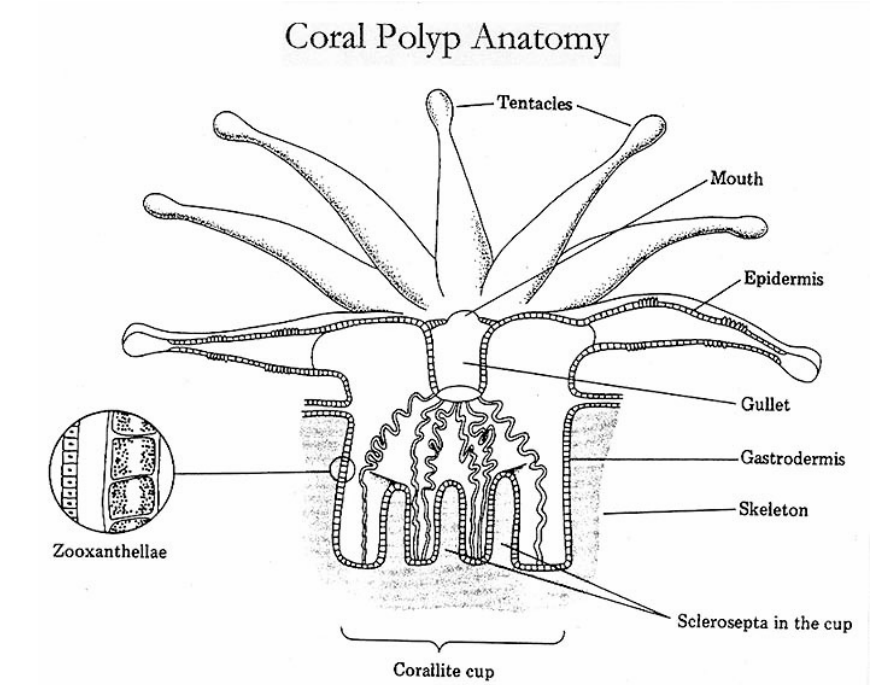
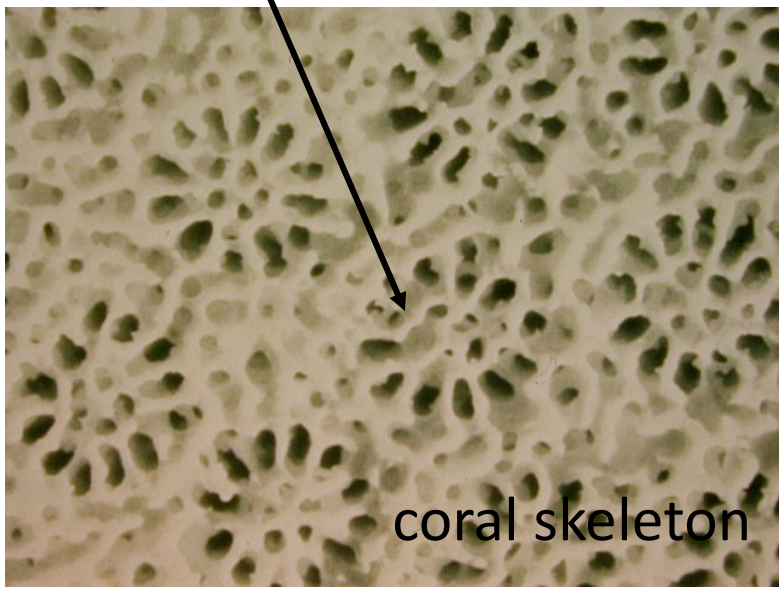
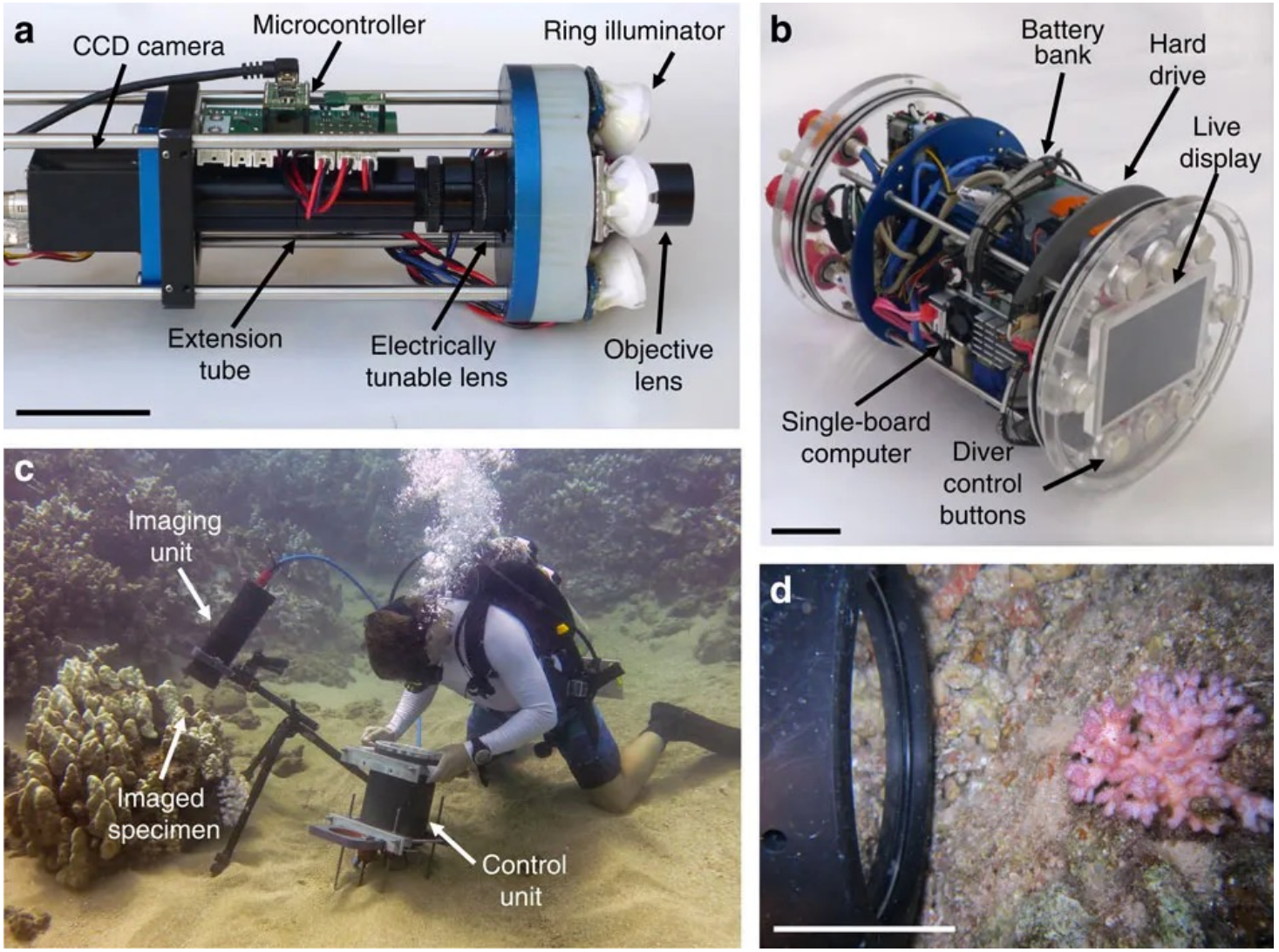


Figure 9.3 Anatomy of a coral polyp.



How do corals make a living?



https://jaffeweb.ucsd.edu/2016/07/benthic-underwater-microscope-work-published-in-nature-communications/

Mullen et al. 2016 Nature Communications

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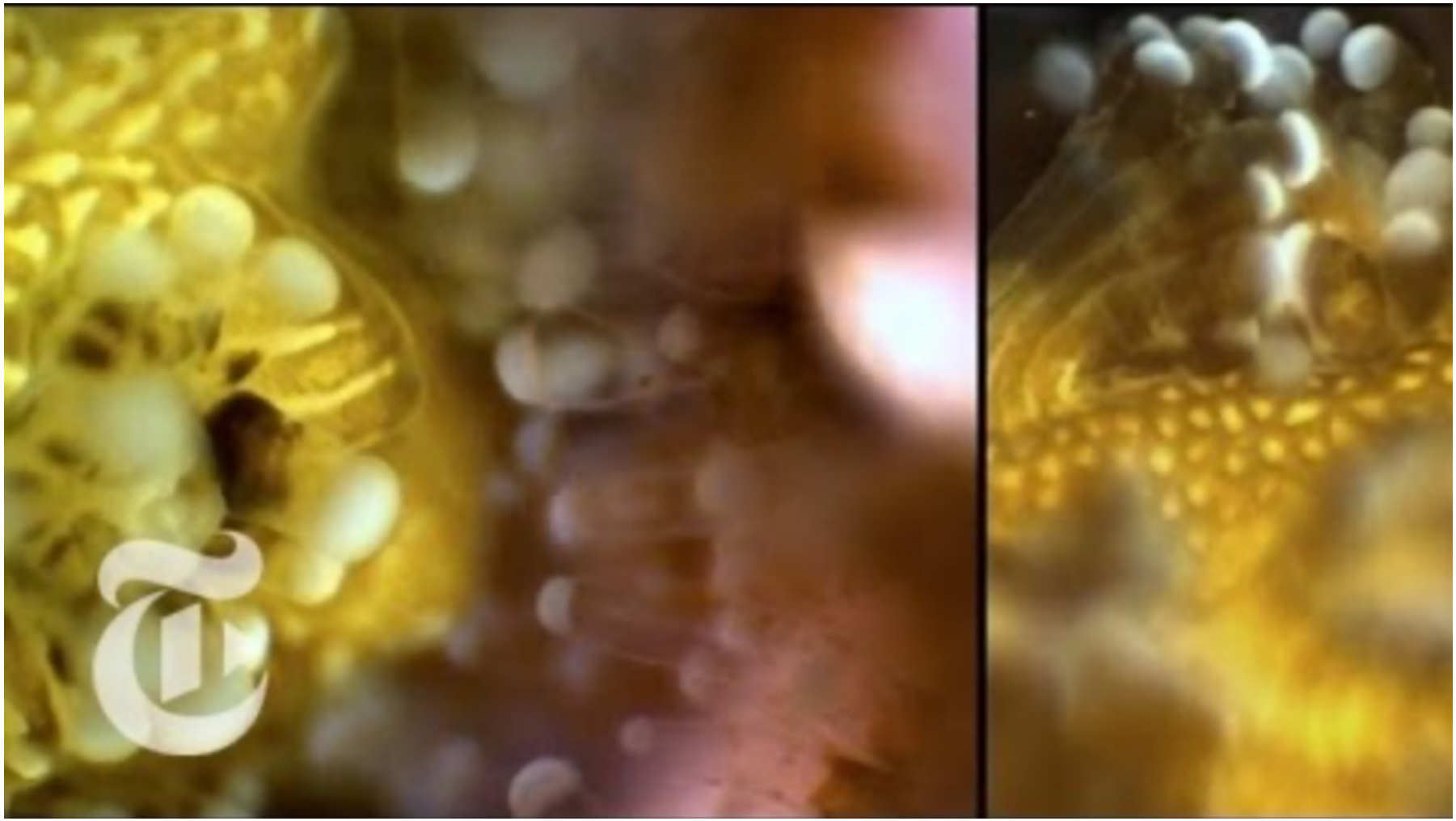


https://jaffeweb.ucsd.edu/2016/07/benthic-underwater-microscope-work-published-in-nature-communications/

Mullen et al. 2016 Nature Communications

Corals are both autotrophs and heterotrophs: a symbiosis

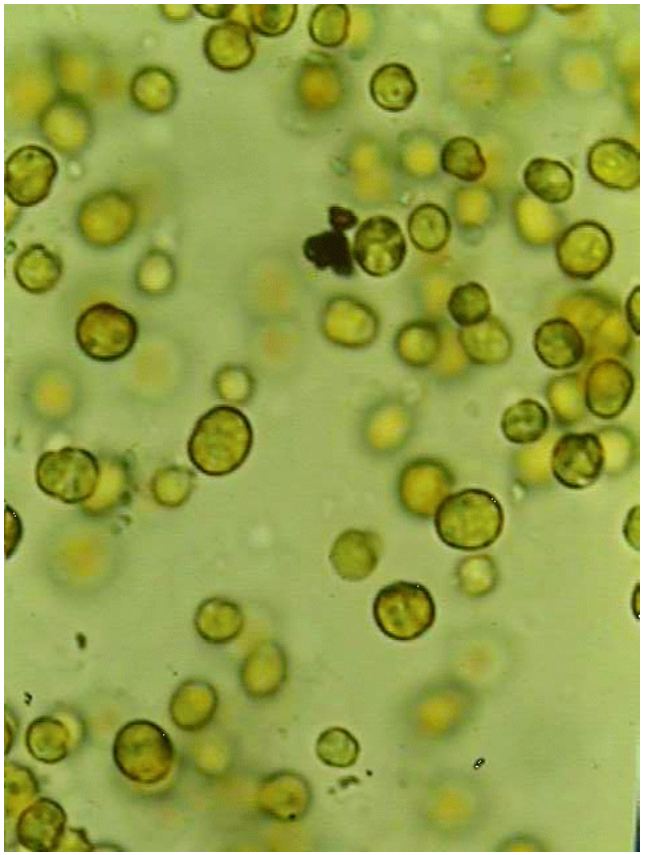
Benefits to coral:

1) food
2) calcification
3) nutrient recycling
4) provision of O_2

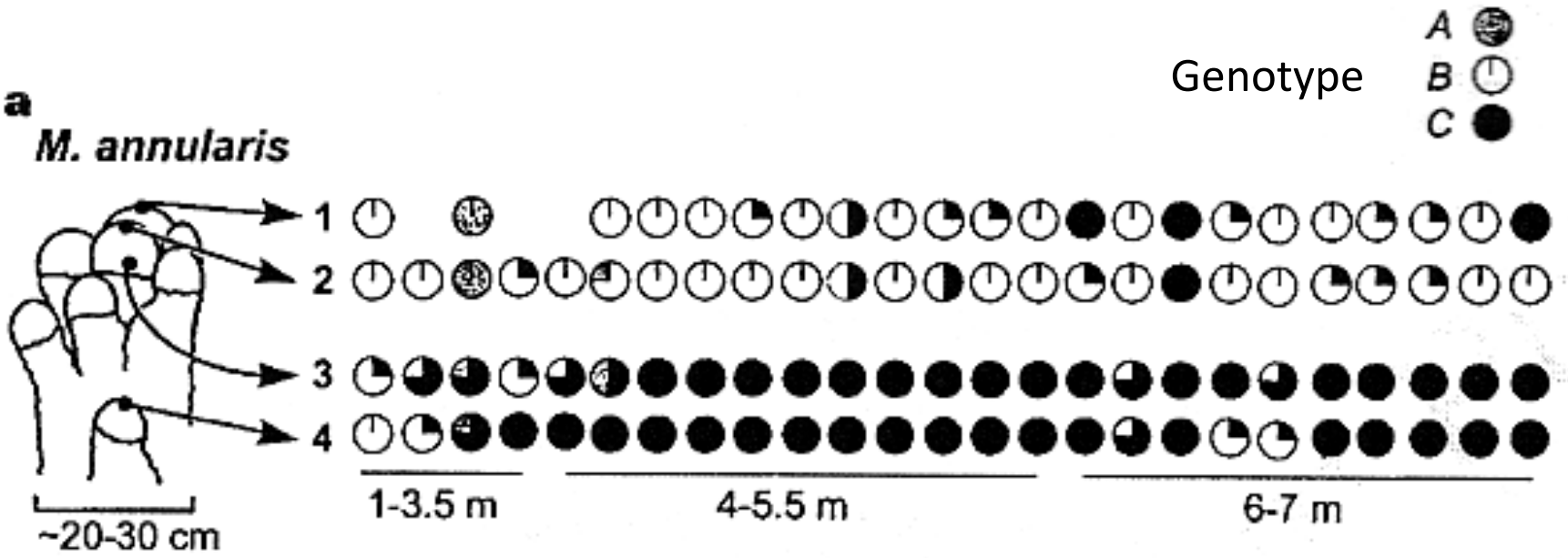
Benefits to zooxanthellae:

1) protection from predators
2) regulation of environment
3) nutrient recycling
4) provision of CO_2

Zooxanthellae
(dinoflagellates)



Many corals have multiple ‘species’ of zooxanthellae



Different zooxanthellae found in different zones of the coral: Genotype B dominant in high light areas, C in shaded areas.

The Sydney Morning Herald

Environment Climate change Paris Agreement

Barrier Reef doomed as up to 99% of coral at risk, report finds

By Nick O'Malley and Mike Foley
April 1, 2021 — 5.00am

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The New York Times

Great Barrier Reef Is Bleaching Again. It's Getting More Widespread.

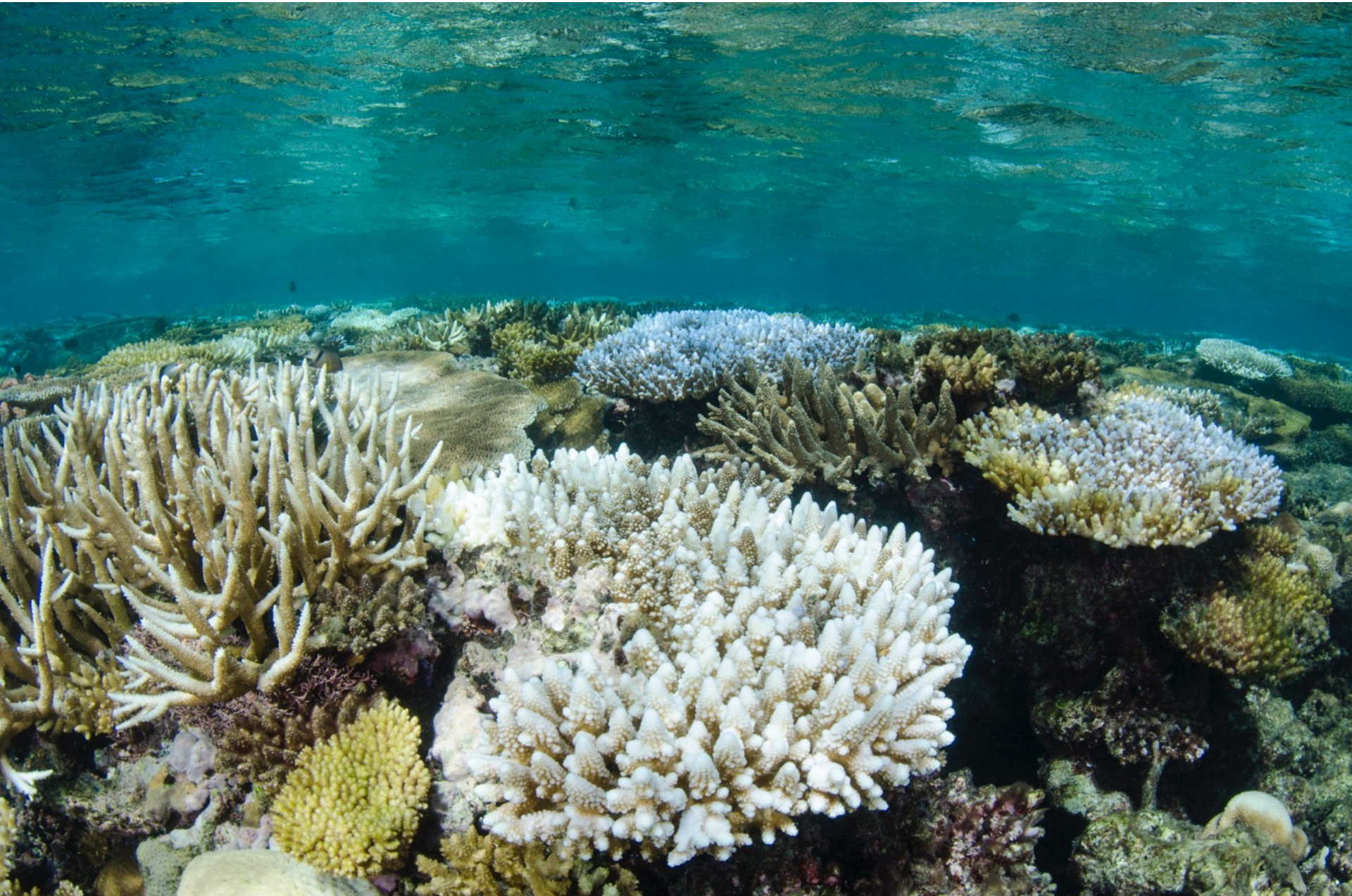
New data shows example after example of overheating and damage along the 1,500-mile natural wonder.

Coral bleaching at the Great Barrier Reef in 2016. Kyodo, via Getty Images

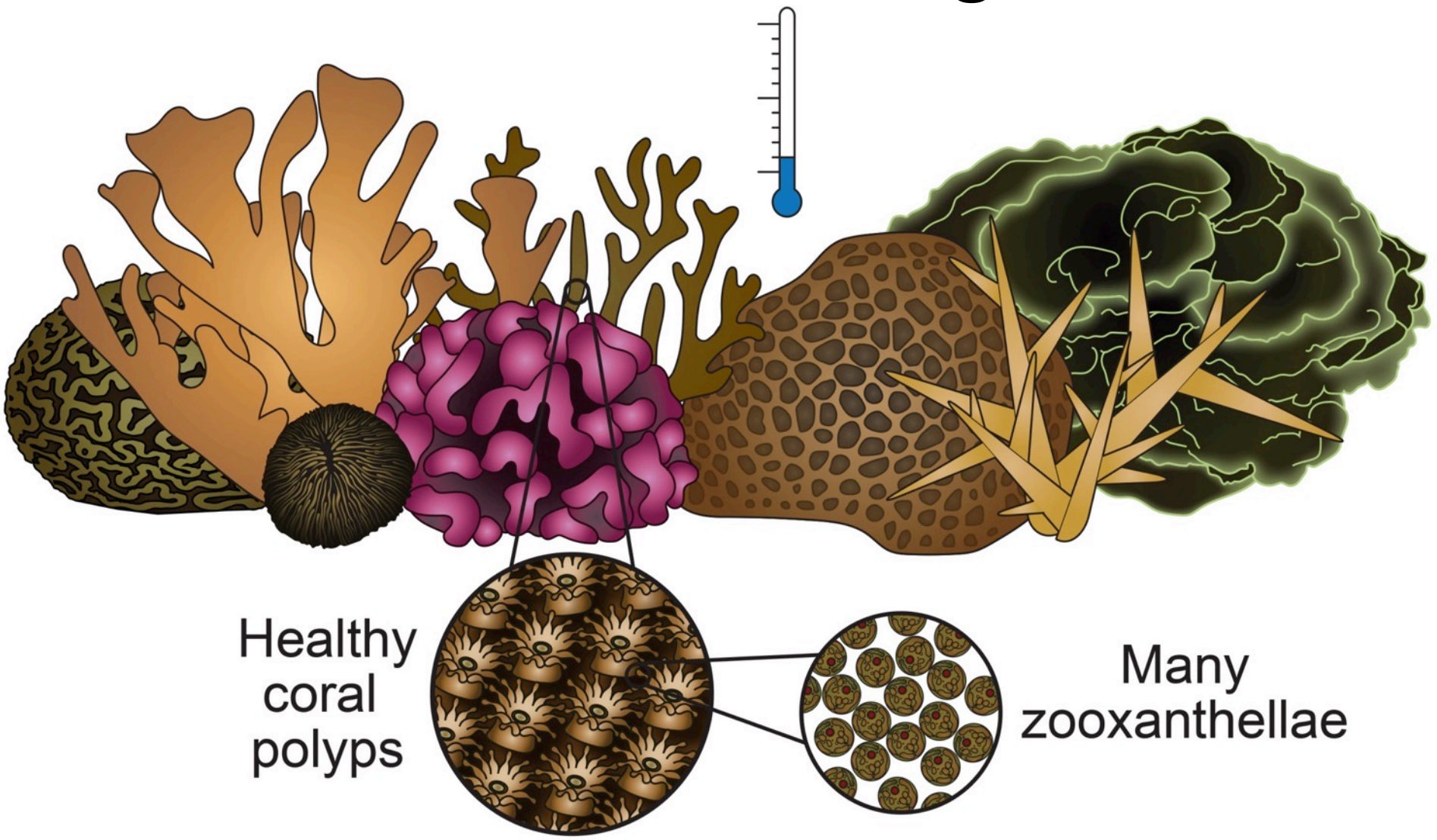
By Damien Cave

April 6, 2020

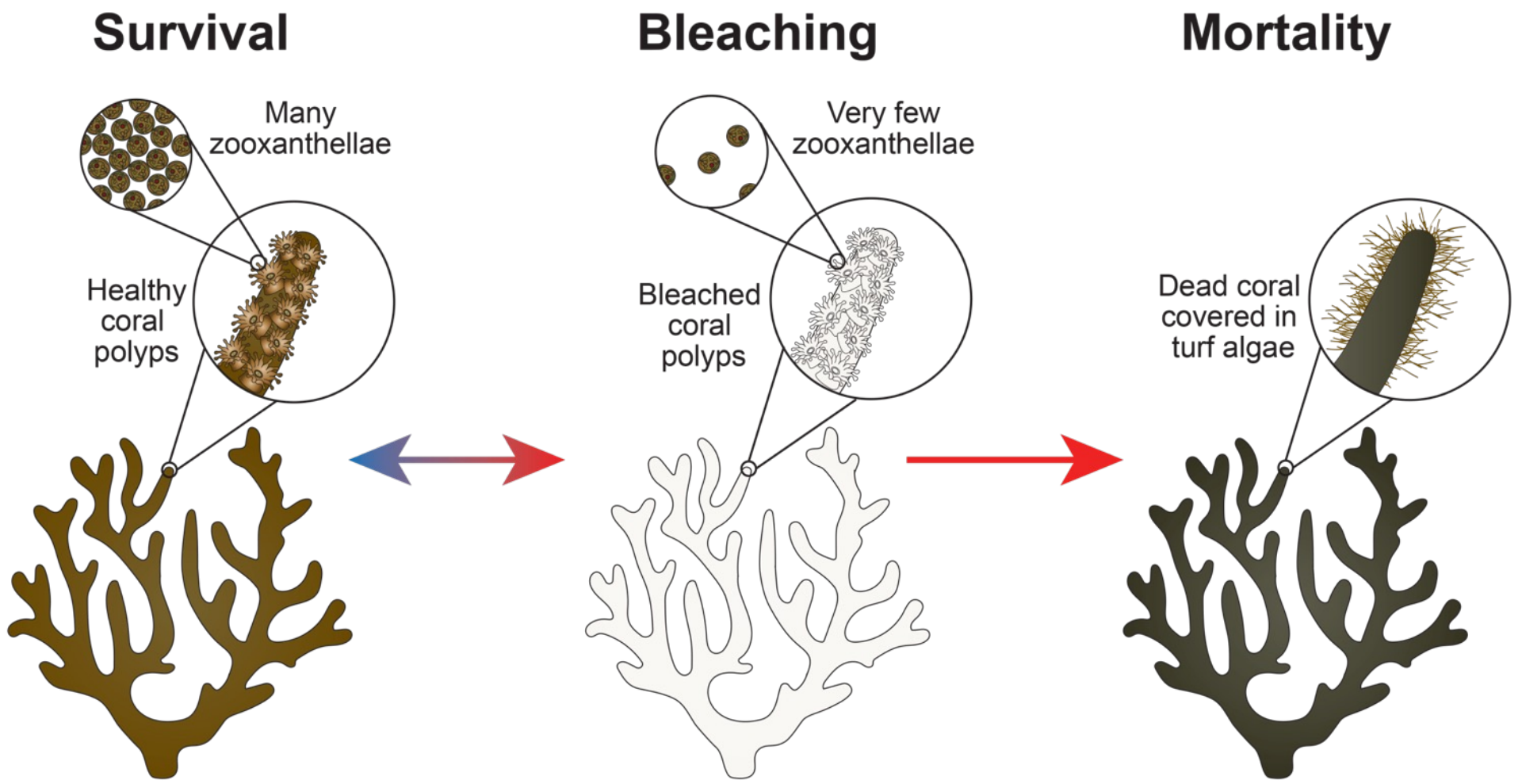
Coral bleaching: expulsion of zooxanthellae due to high temperature or light



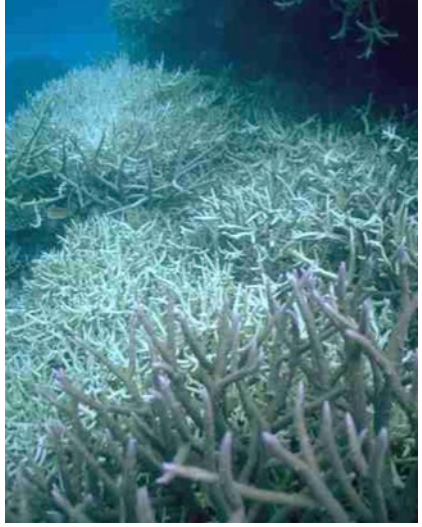
Coral bleaching



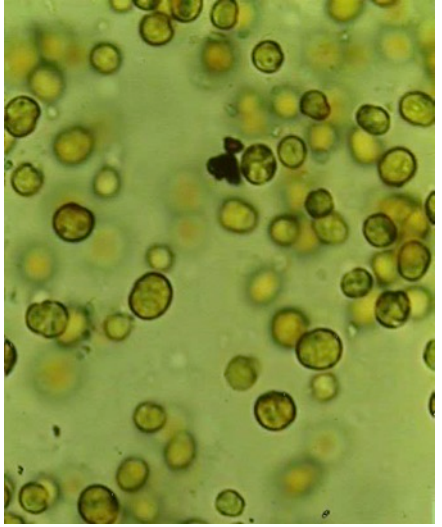
Corals can expulse their zooxanthellae during bleaching, which can occur when corals are exposed to higher than average water temperatures and/or light.



If water temperatures return to normal, the corals can regain their zooxanthellae and recover. If water temperatures remain warm, however, corals can die.



Coral Bleaching



- what is it? a stress response to unfavorable environmental conditions that disrupts the symbiosis
  loss of algal pigments or zooxanthellae expulsion or both

- causes: -change in seawater temperature outside of normal range
  -increase in visible or UV light
  -decreased salinity
  -synergism of many stressors

- mechanism: -possibly production of toxic compounds such as reactive oxygen species (but cellular mechanism is still unknown!)

- effects: variable - recovery from short term bleaching possible; longer-term bleaching can be fatal.

Corals can and often do recover from bleaching

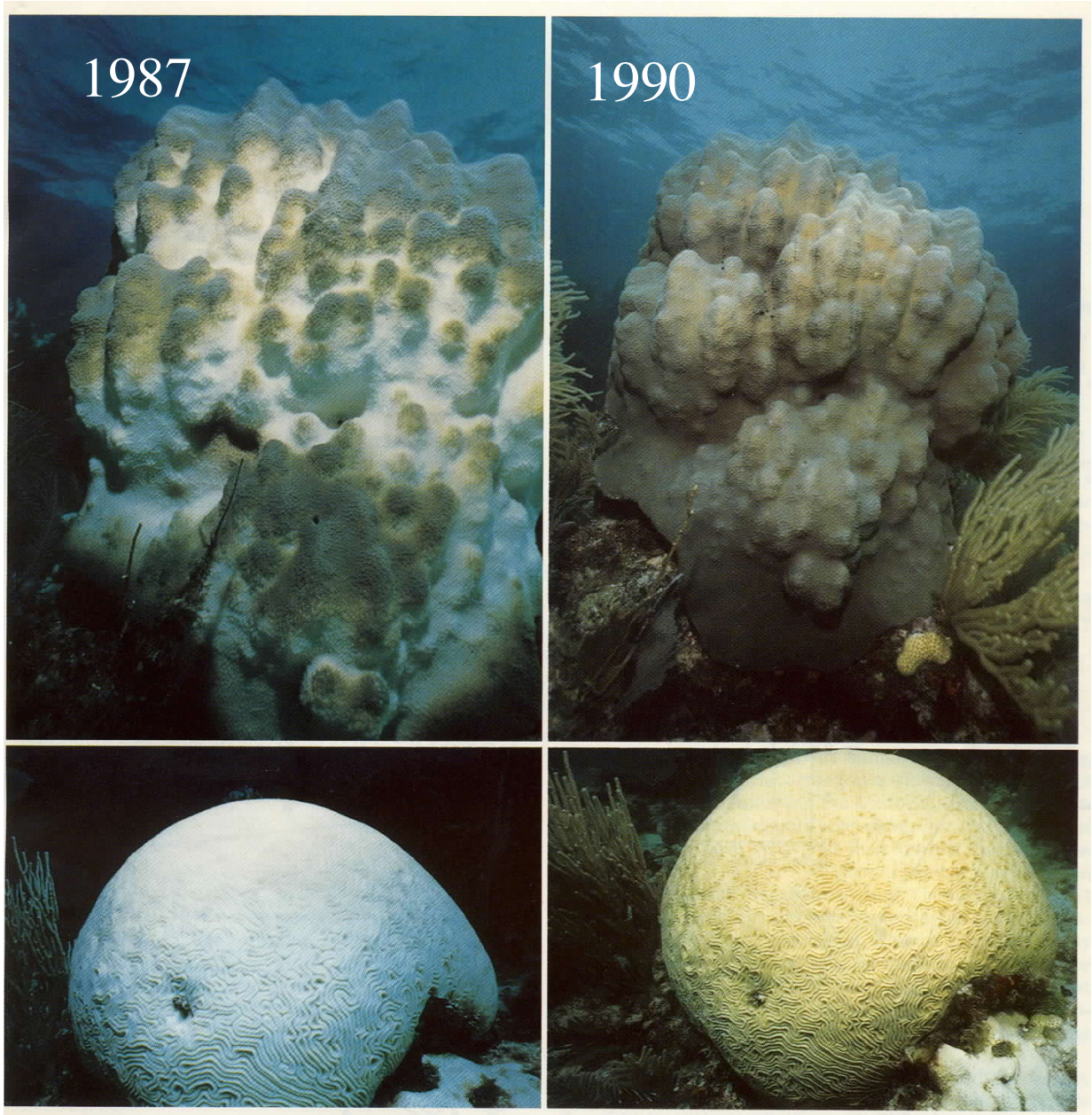
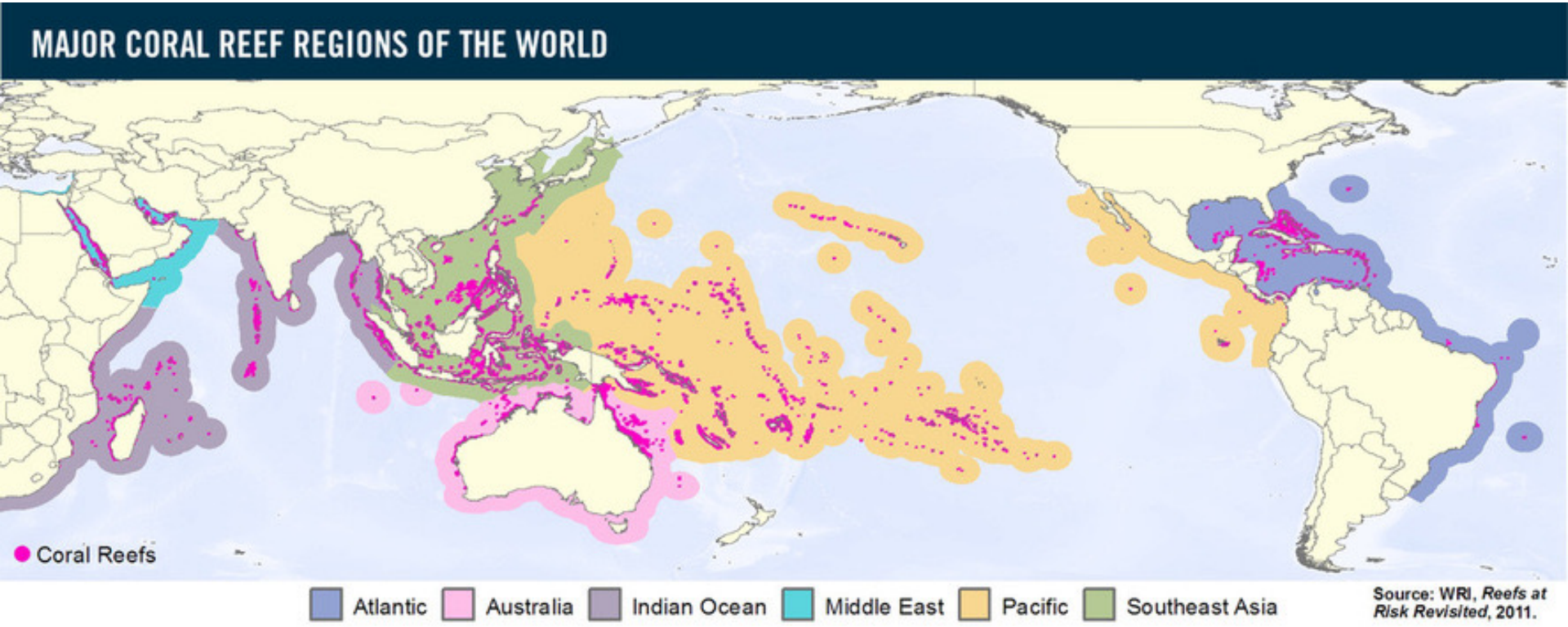


Fig. 1. *Montastrea annularis* (above) and *Diploria labyrinthiformis* (below) on Grecian Rocks Reef in the Key Largo National Marine Sanctuary during the "bleaching event", October of 1987 (left), and after recovery of normal coloration in August of 1990 (right)

Coral Paradox ("Darwin's Paradox")

Corals thrive in warm, shallow, clear water that is nutrient poor. How?



Possible because of:

- symbionts
- key herbivores that reduce algal biomass
- positive feedback loop from reef building corals keeps phytoplankton and nutrients within system

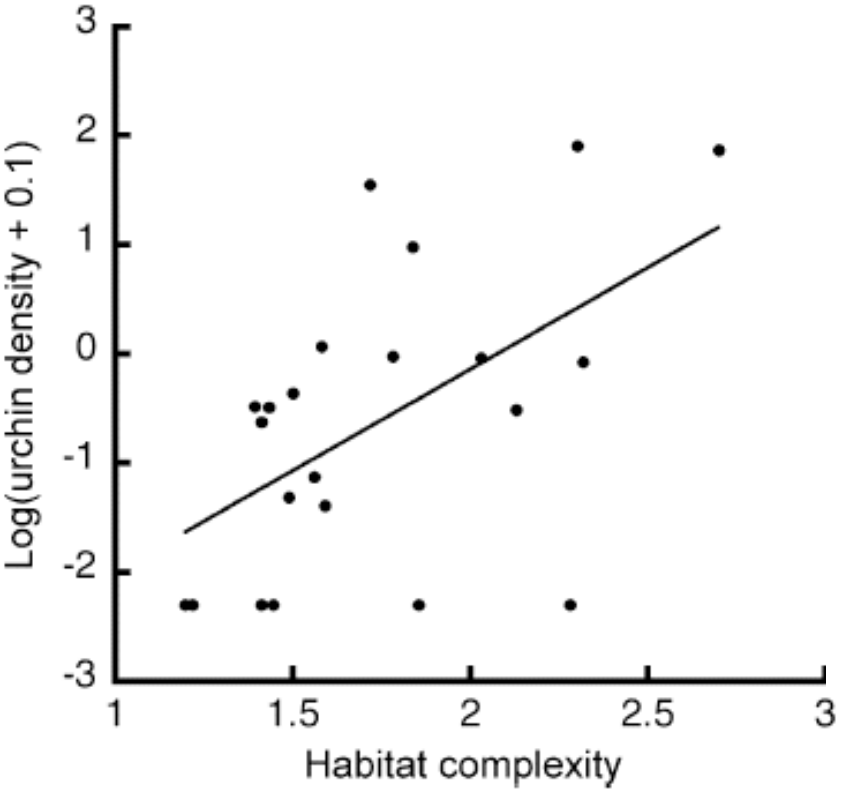
Tropical reefs:

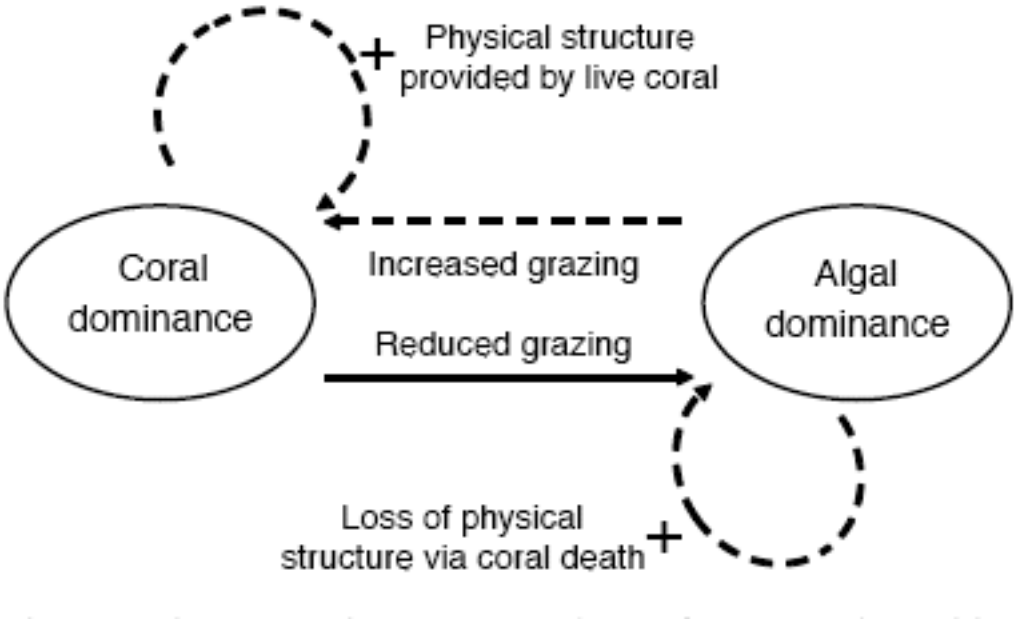
- low nutrients
- lots of herbivorous fishes and invertebrates (~156,000 fish bites m^{-2} day^{-1})
- High coral cover, low algal cover

Temperate habitats (e.g., kelp forests):

- high nutrients, few herbivorous fishes
- High algal cover, low coral cover

The persistence of reefs depends on the maintenance of mutualistic biotic interactions:

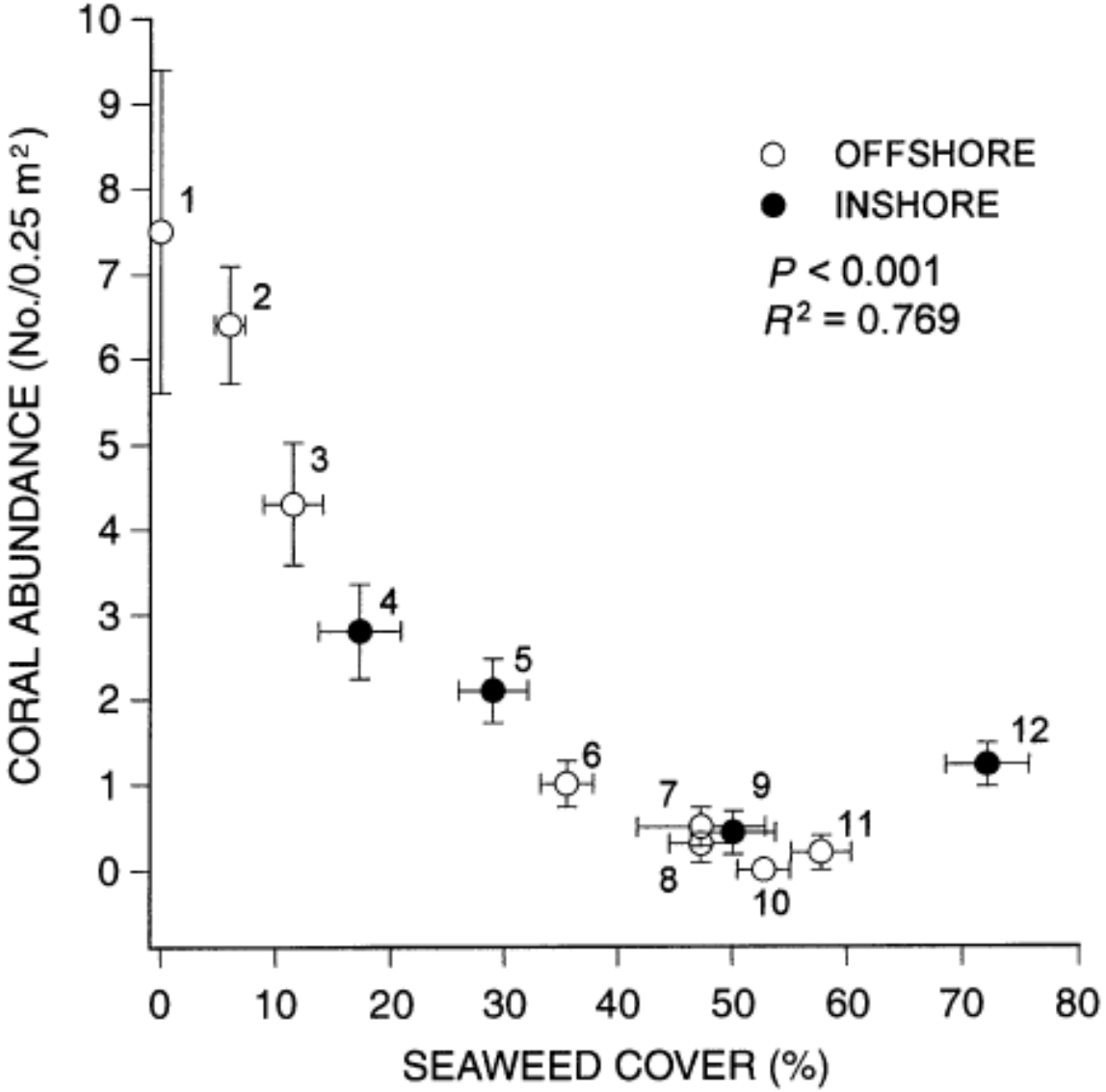




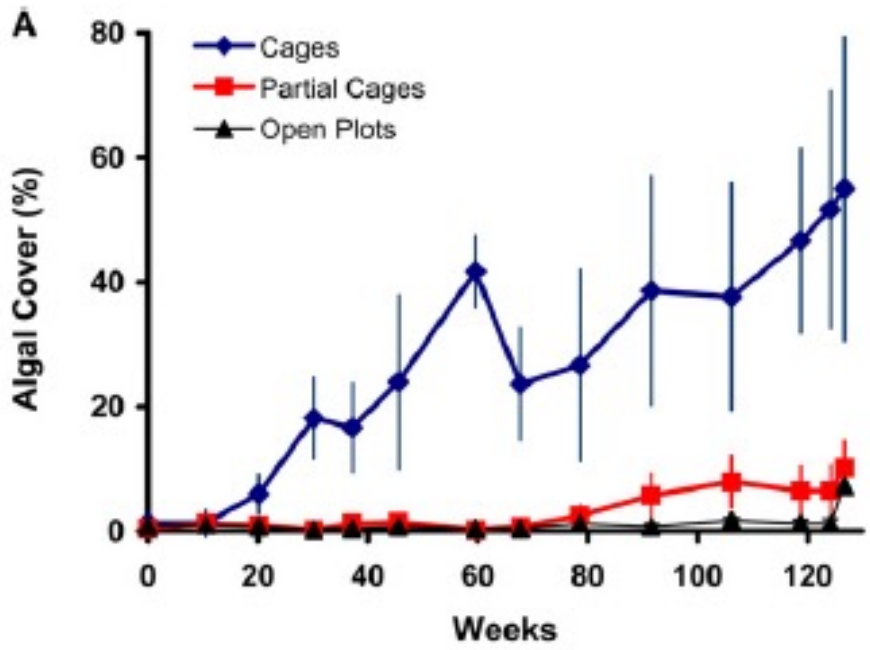
Herbivore grazers are a large contributor to coral reef stability

Lee 2006 Oikos

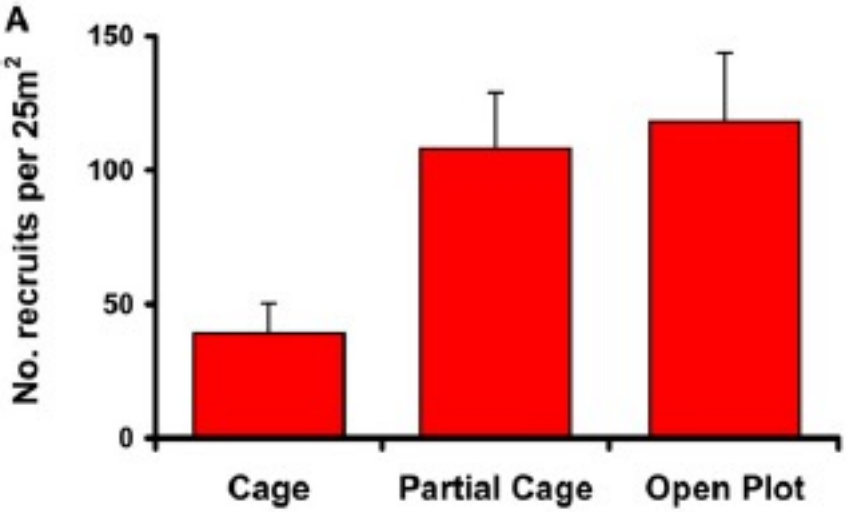
Coral and seaweed cover are negatively correlated

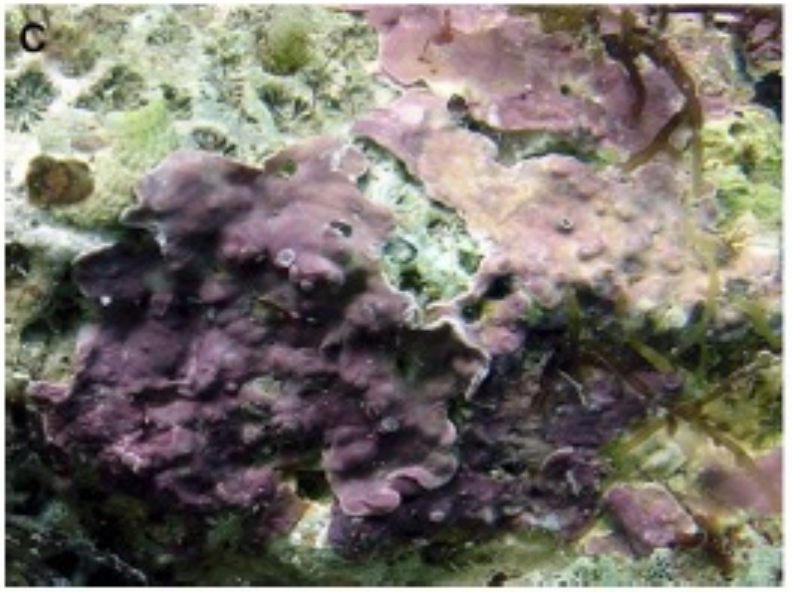


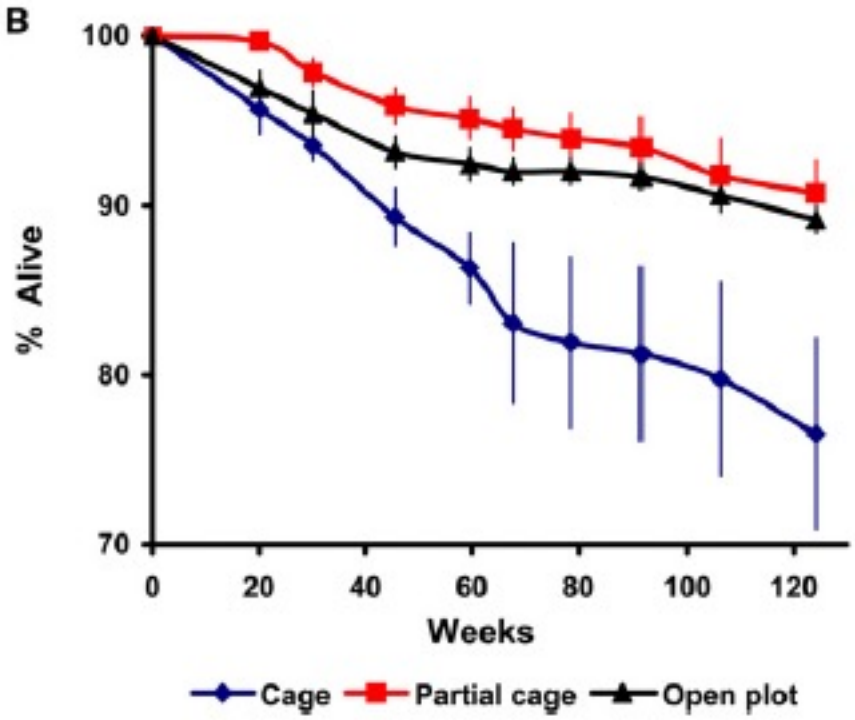
What causes variation in seaweed cover?

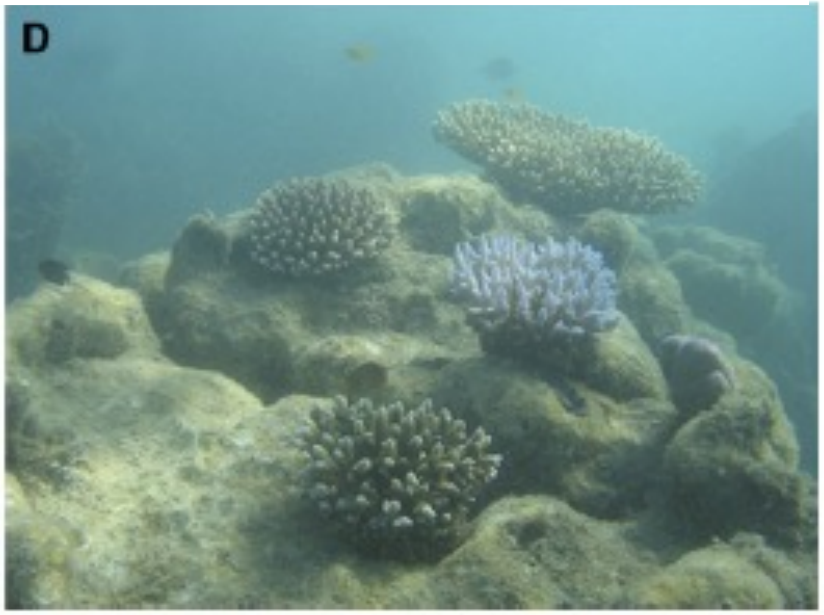


Hughes et al. 2007
Current Biology


A
No. recruits per 25m^2
150
100
50
0
Cage
Partial Cage
Open Plot

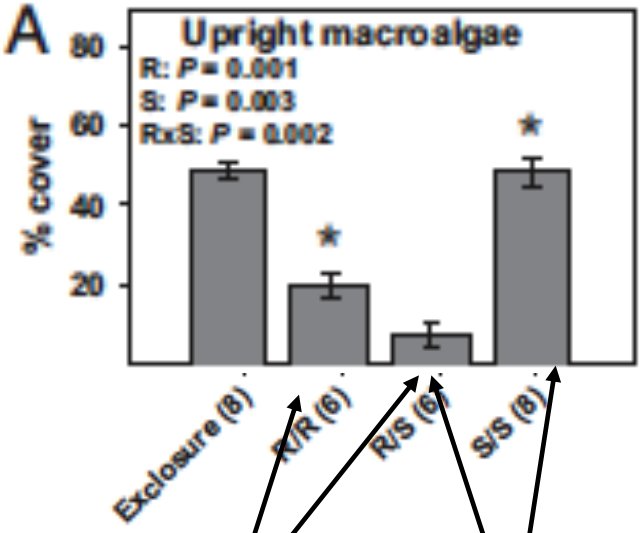

C


B
% Alive
100
90
80
70
0
20
40
60
80
100
120
Weeks
Cage
Partial cage
Open plot


D

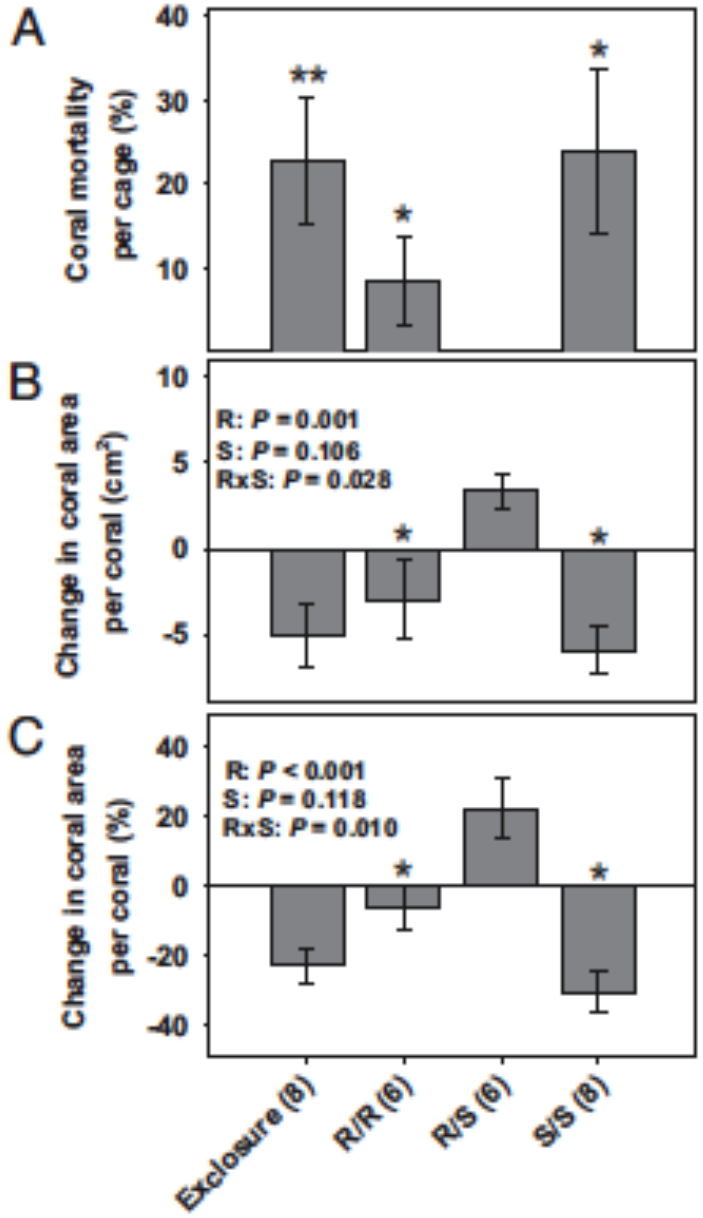
Burkepile and Hay 2008

Herbivore species diversity matters



Redband parrotfish

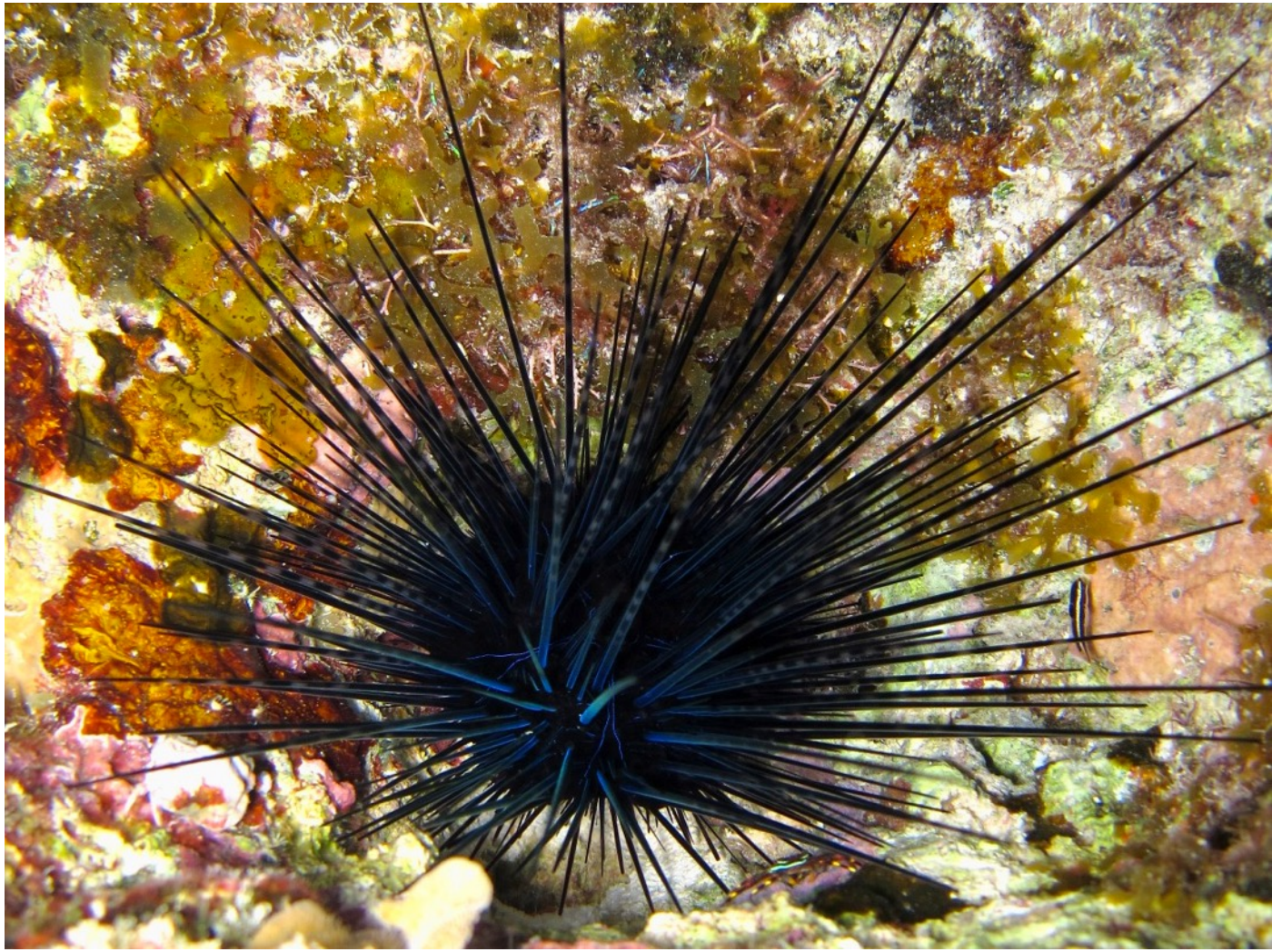
Ocean surgeonfish

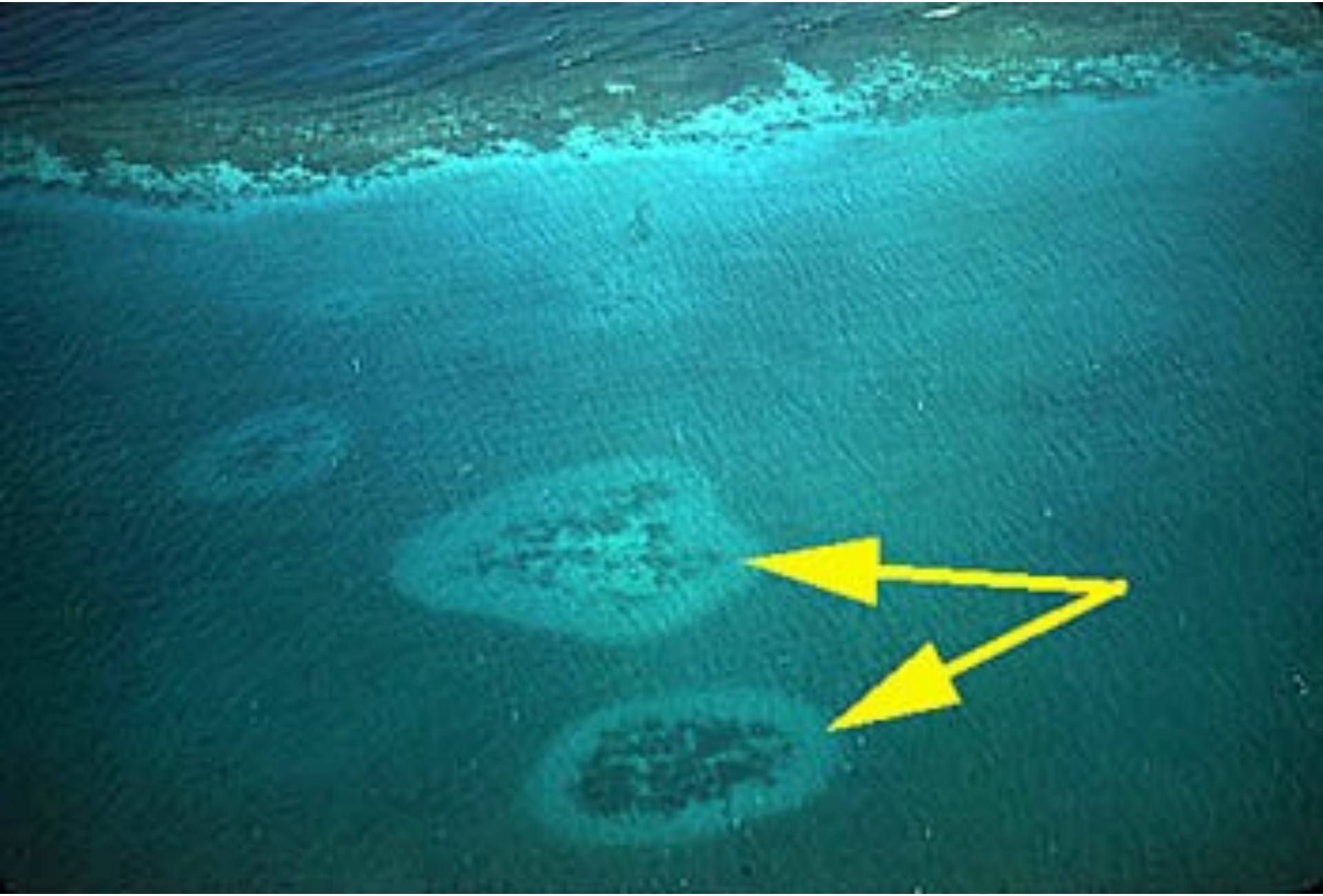


Long-spined sea urchin, *Diadema antillarum*

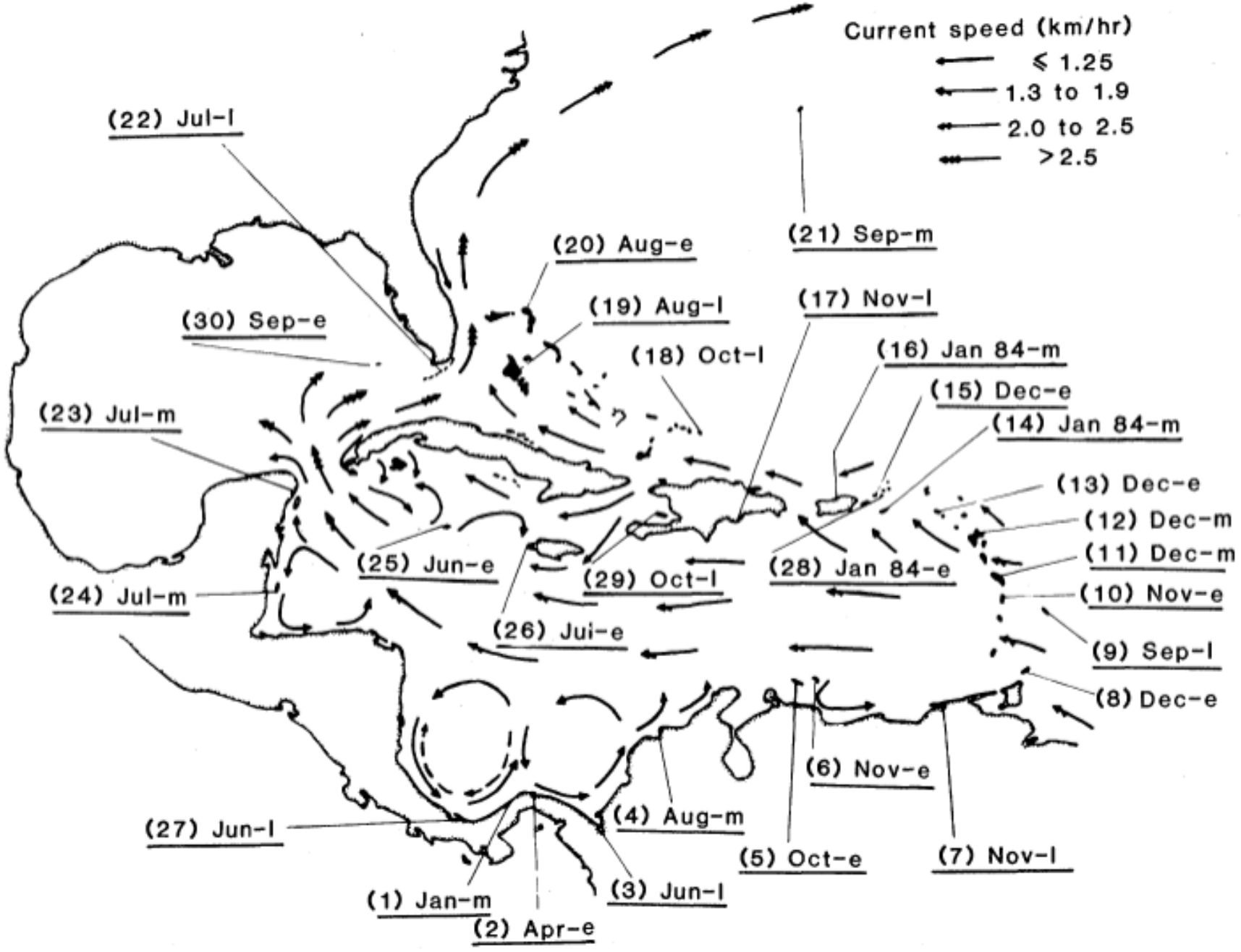
a story of overfishing, disease, and demise of Caribbean reefs

Pre-1983 densities:
70 m^{-2}

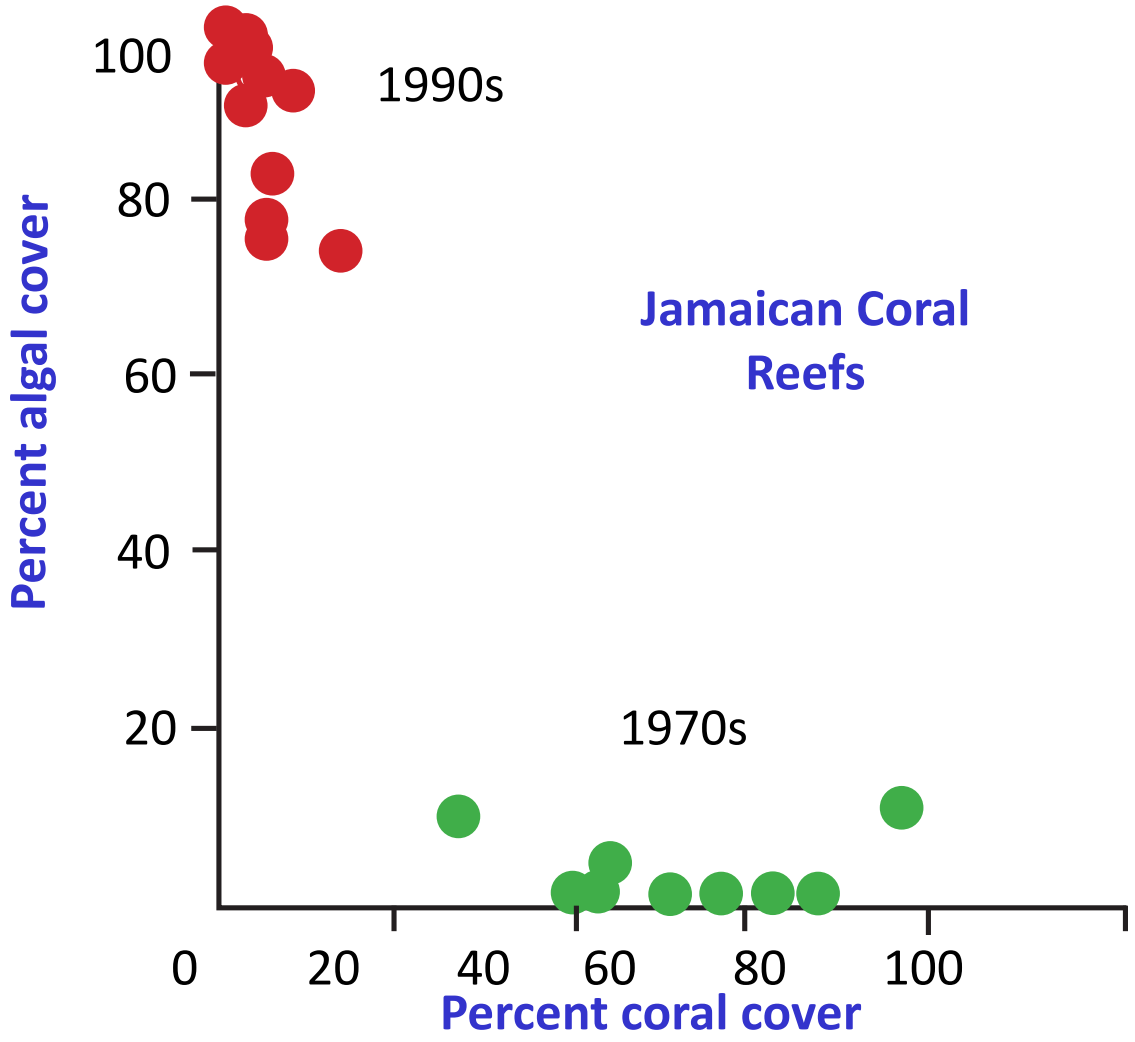




Mass mortality in 1983: population reduced to 1% of initial size

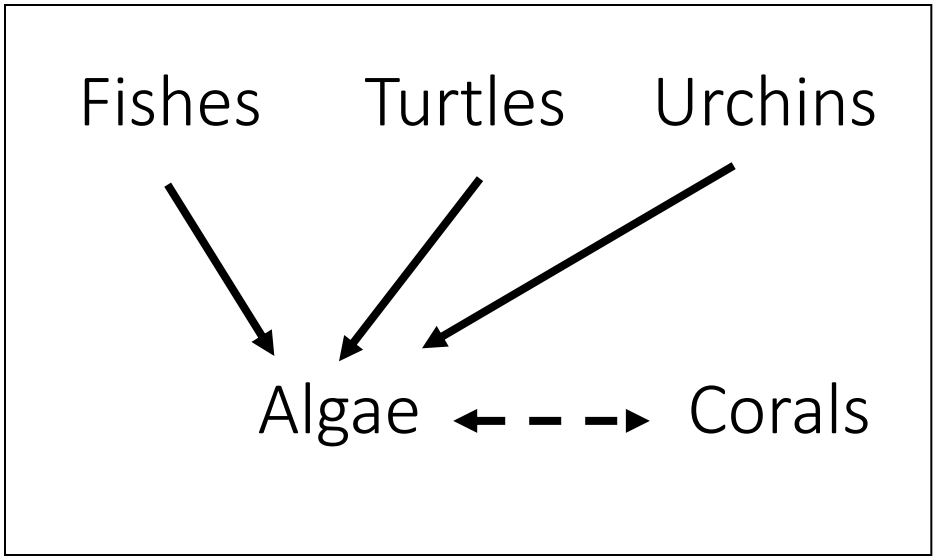


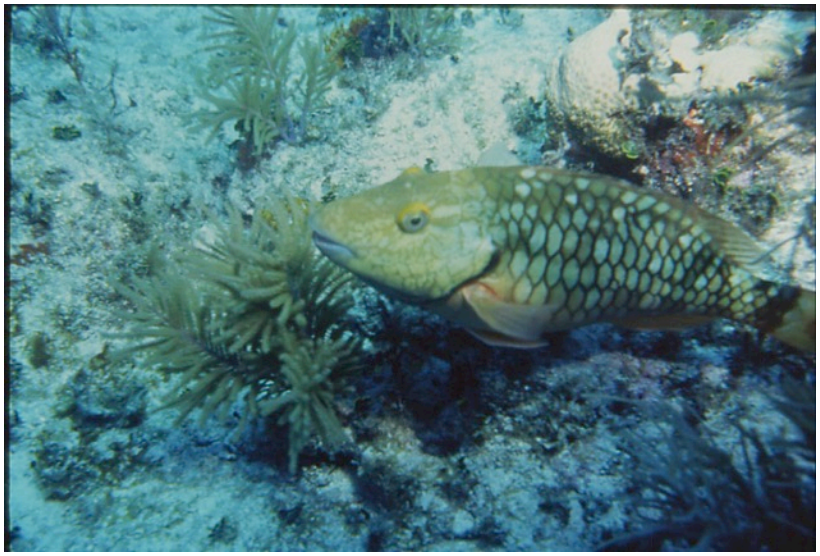
Phase shifts on Jamaican reefs



Die-off of *Diadema*: Seems to have flipped Jamaican reefs into alternative state (also a result of storm damage).

Pre- European contact reefs:





Pre-dieoff, overfishing appeared to have little impact because urchins compensated for decreased fish grazing.

After the *Diadema* died off, reefs that had been overfished became overgrown by seaweed because few grazers remained

Reefs with less fishing pressure and large, herbivorous fishes remained coral dominated. (until coral diseases and bleaching)

Prospects for recovery of Diadema?

- still at low abundance throughout most of the region

-allee effects (fertilization limitation)

-residual pathogens keeping populations low?

-BUT where they are recovering locally (up to 5 per sq. m), algal cover is decreasing and coral recruitment, growth and survival is higher.

Carpenter and Edmunds 2006

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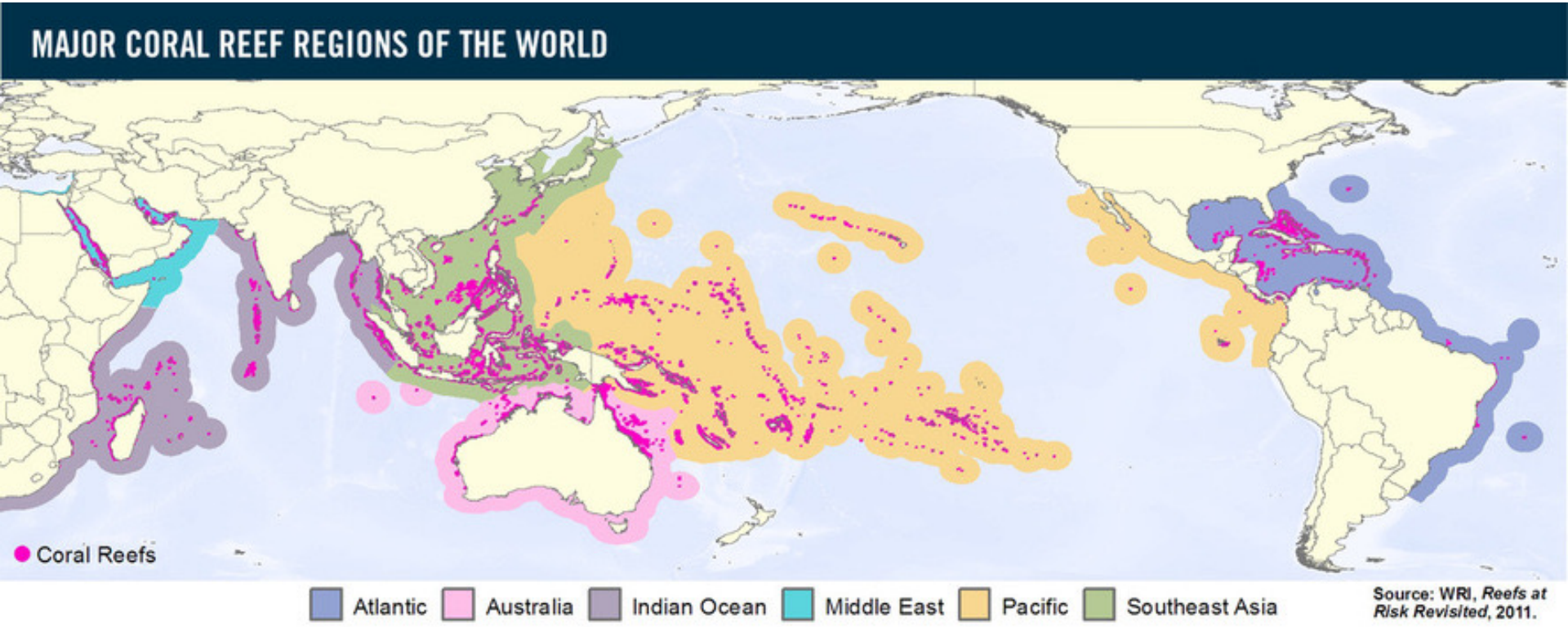

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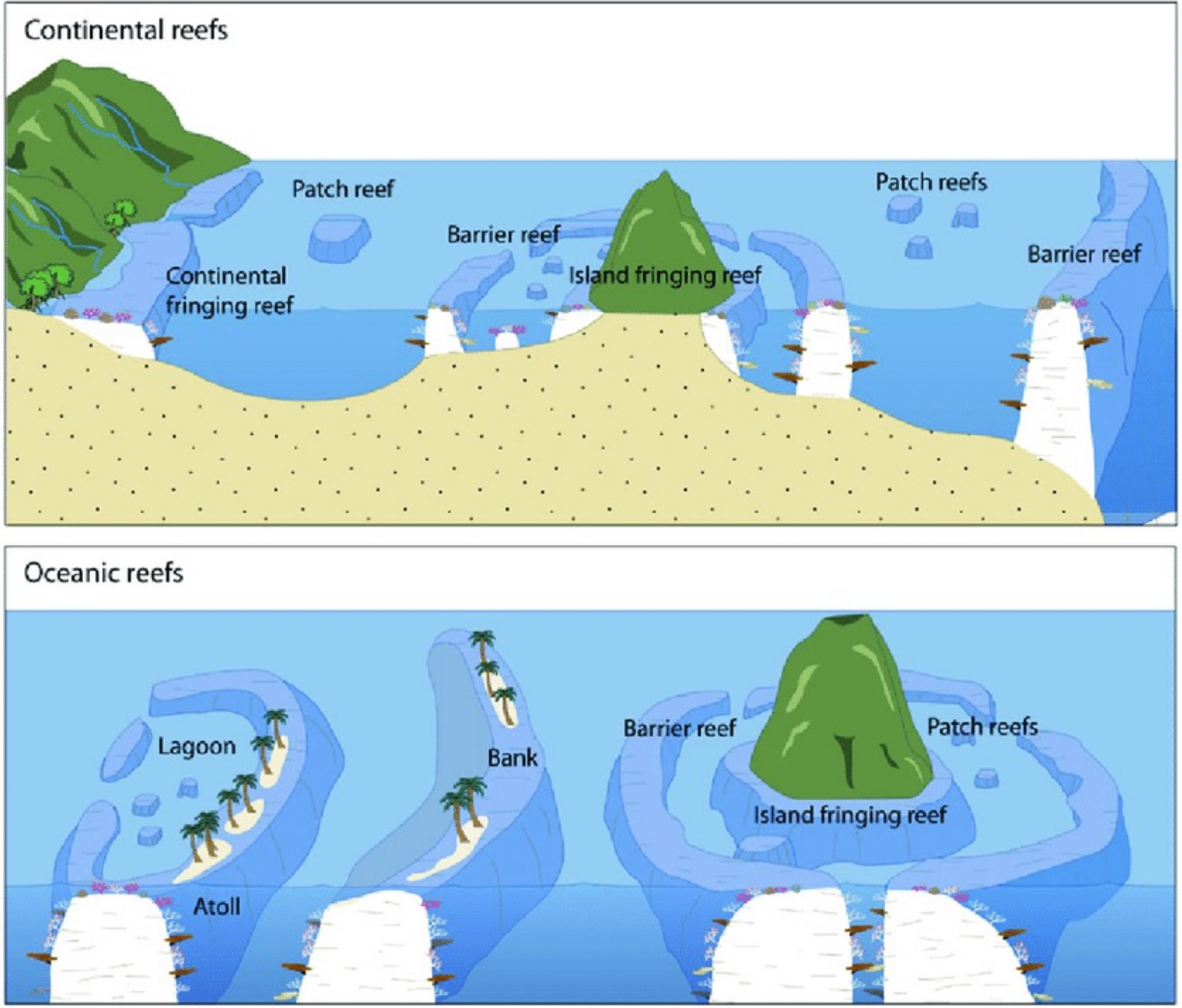
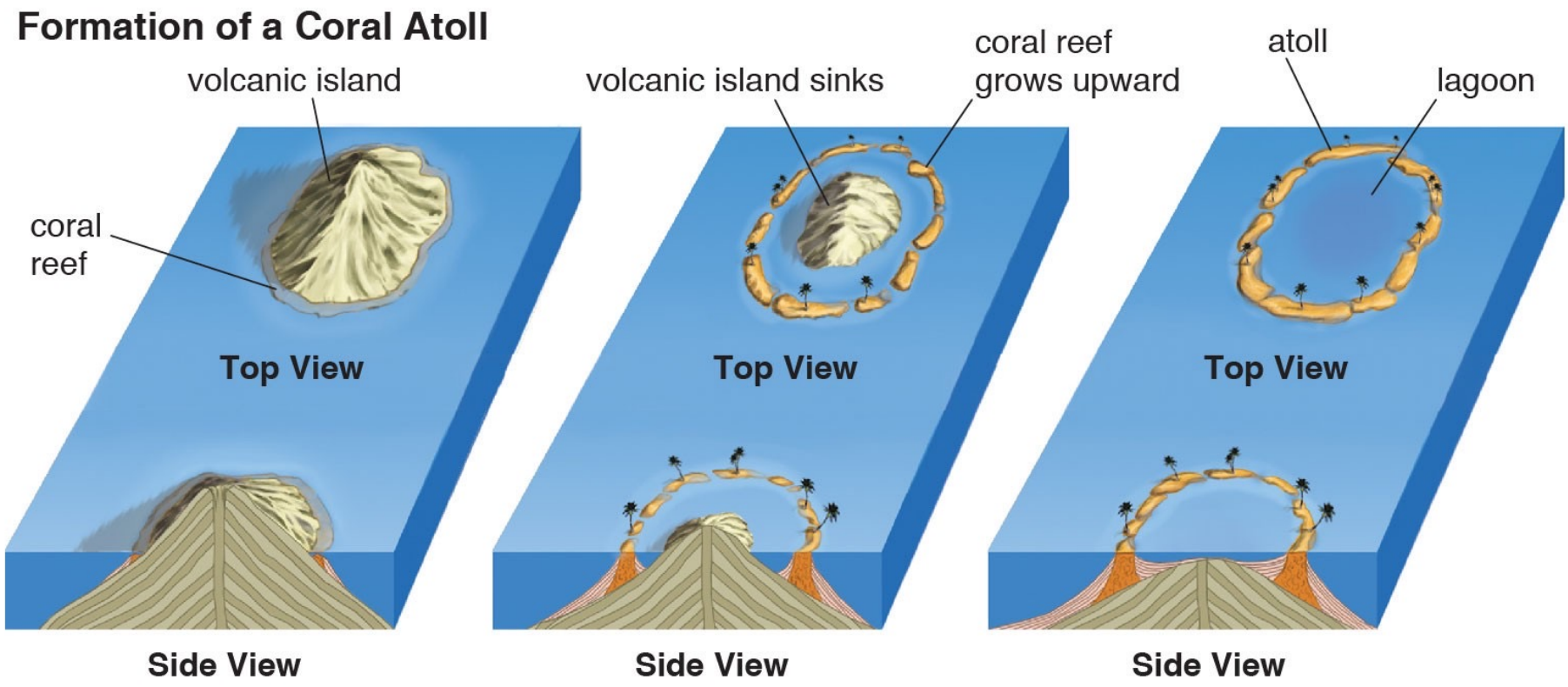

Continental reefs
Patch reef
Barrier reef
Patch reefs
Barrier reef
Continental
fringing reef
Island fringing reef
Oceanic reefs
Lagoon
Bank
Barrier reef
Patch reefs
Island fringing reef
Atoll



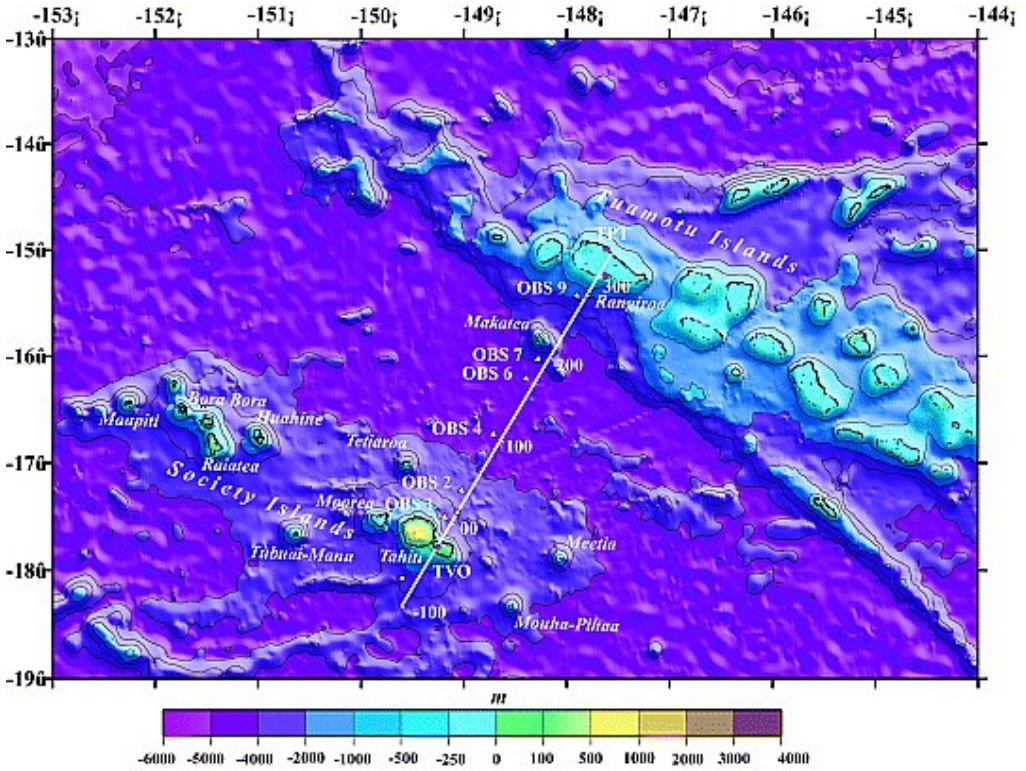
Fringing reef

Barrier reef

Atoll

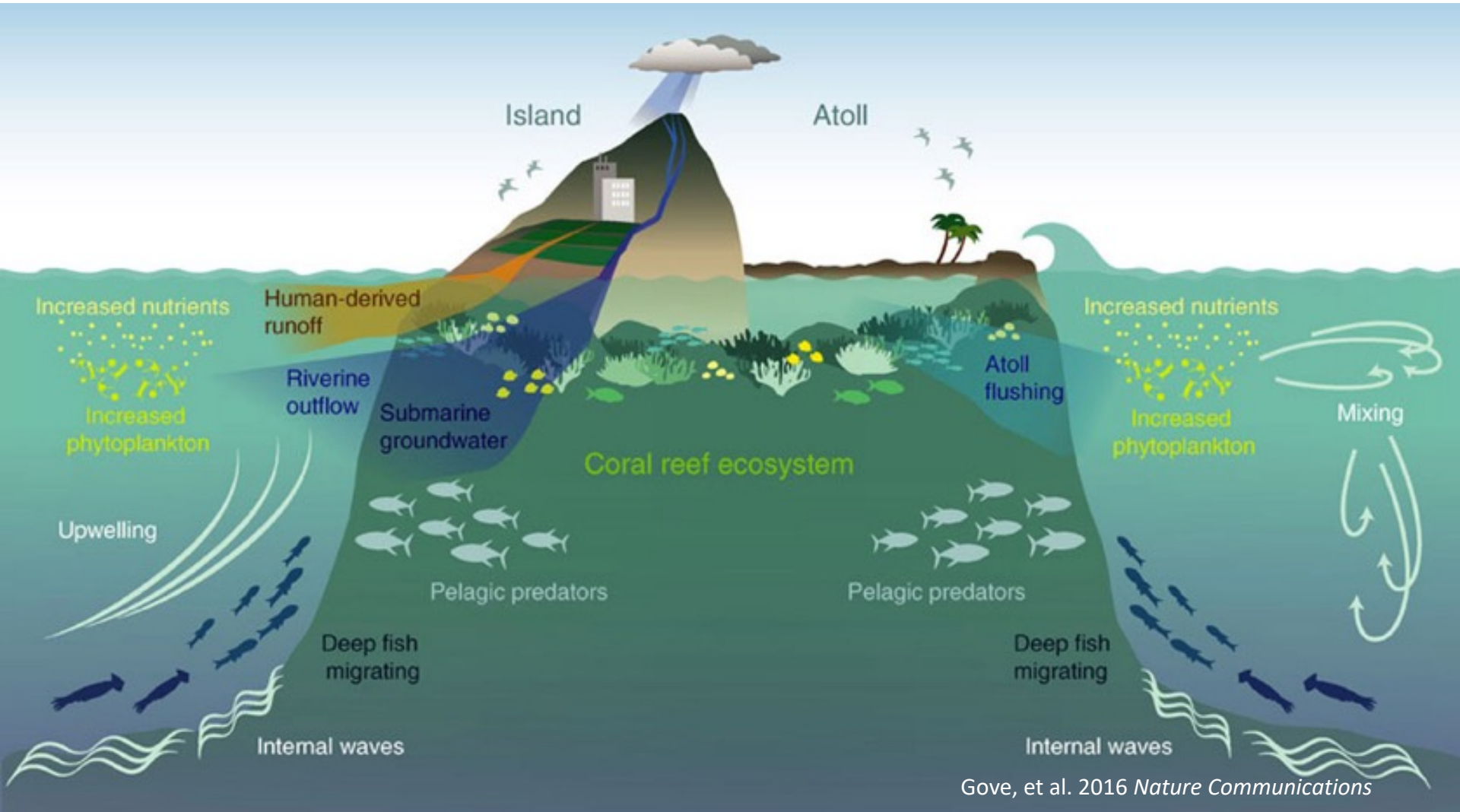
Which island group is older?

Hawaiian Islands



French Polynesia

- Land masses promote mixing and upwelling, which promotes phytoplankton growth
- Supply coral growth and reef development. Coral reefs, especially atolls and large barrier reefs, further increase ”Island Mass Effect”
- Positive feedback: the larger the reef, the more phytoplankton retained



Gove, et al. 2016 *Nature Communications*

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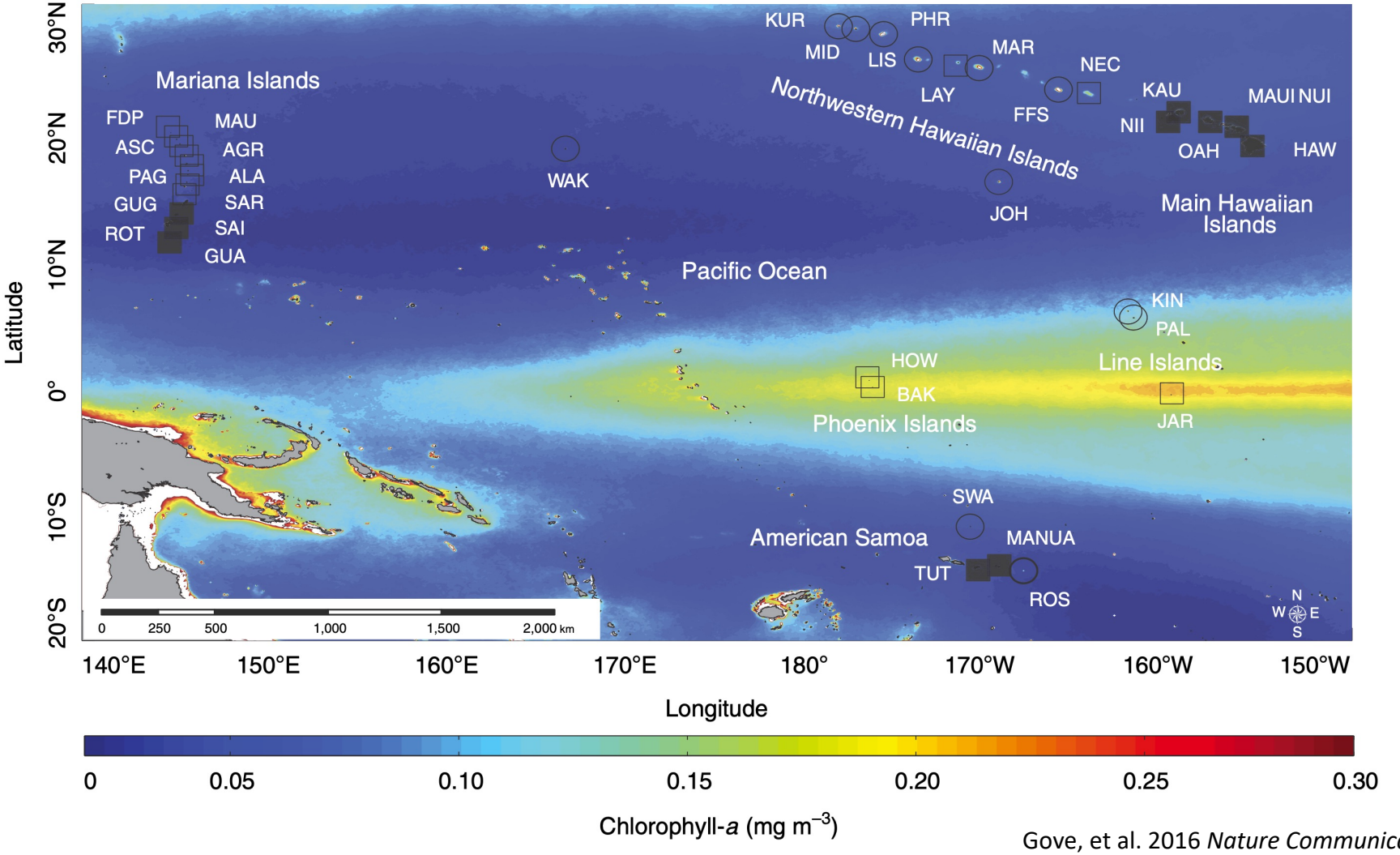

Gove, et al. 2016 *Nature Communications*