

Ecosystem Extinction and Potential Recovery of Caribbean Coral Reefs

Jeremy Jackson

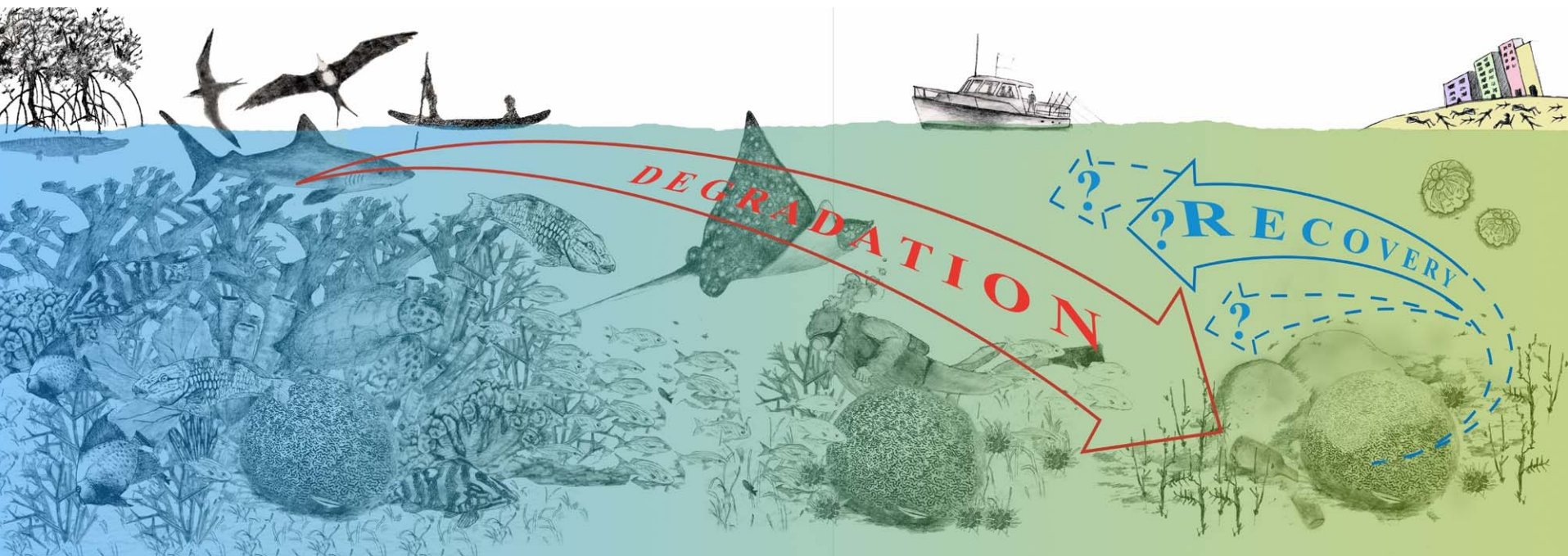
Scripps Institution of Oceanography

La Jolla, California, USA

and

Smithsonian Tropical Research Institute

Republic of Panama



DEGRADATION

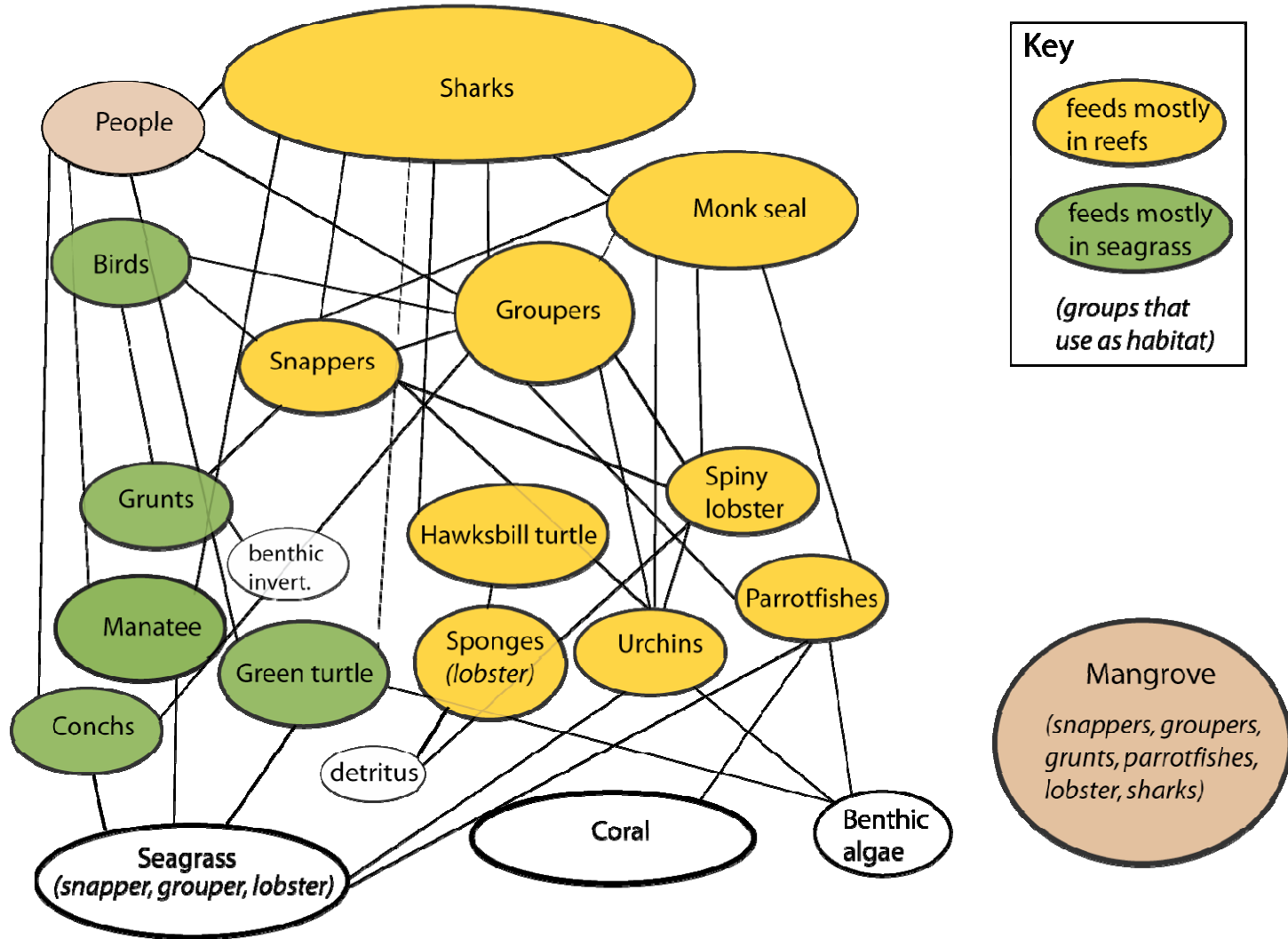
RECOVERY

Three basic questions

1. How much have Caribbean coral reefs been degraded and what have we lost?
2. What were and are now the major causes of reef degradation?
3. Can we restore coral reefs to some semblance of their past?

Cast of characters

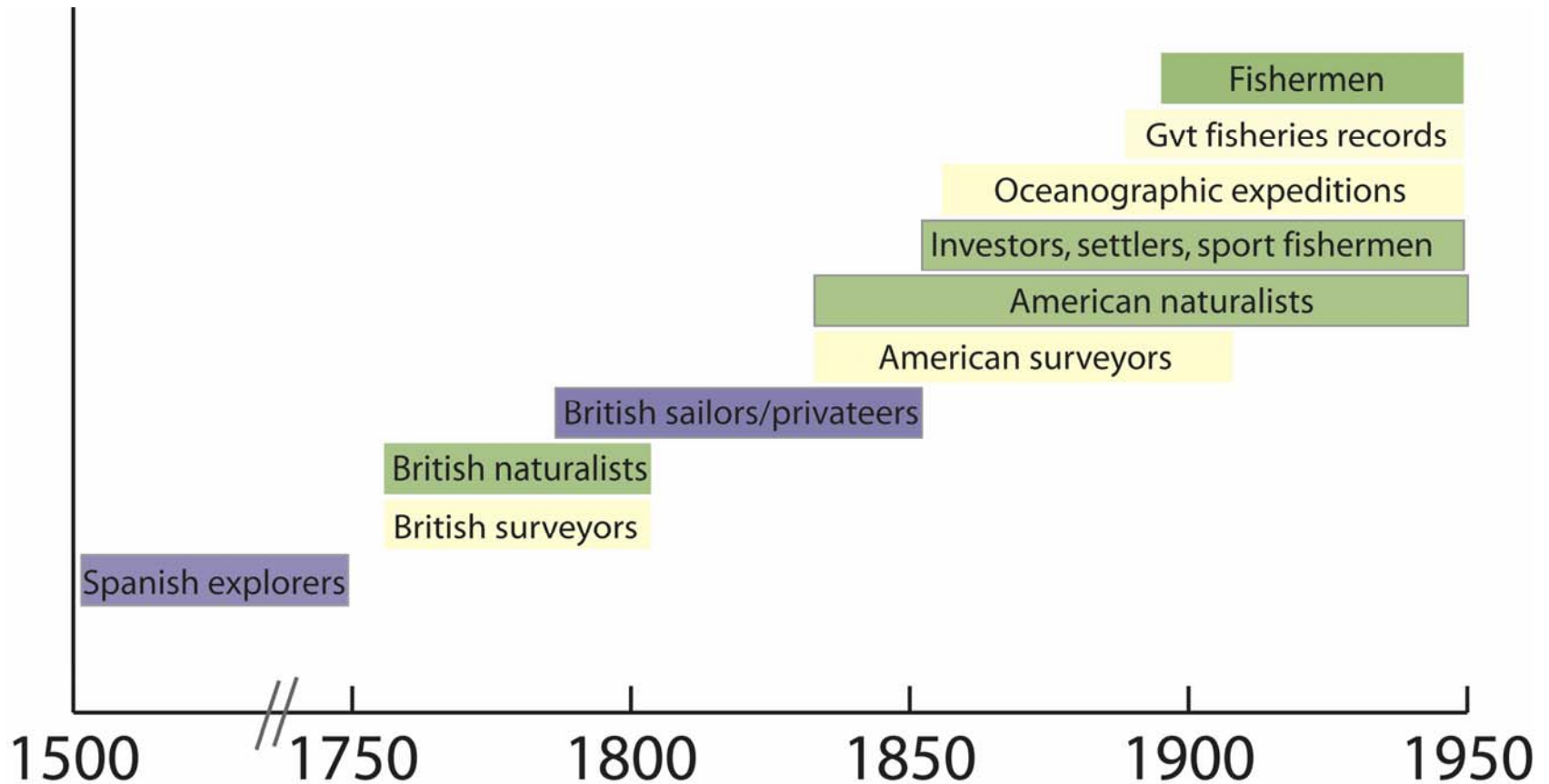
Historic Northern Caribbean Food Web



Who were the victims?

1. Megafauna (turtles, monk seals, manatee, whales, dolphins, and sharks)
2. Fish
3. Corals, sponges, and other benthos

Available Data Sources

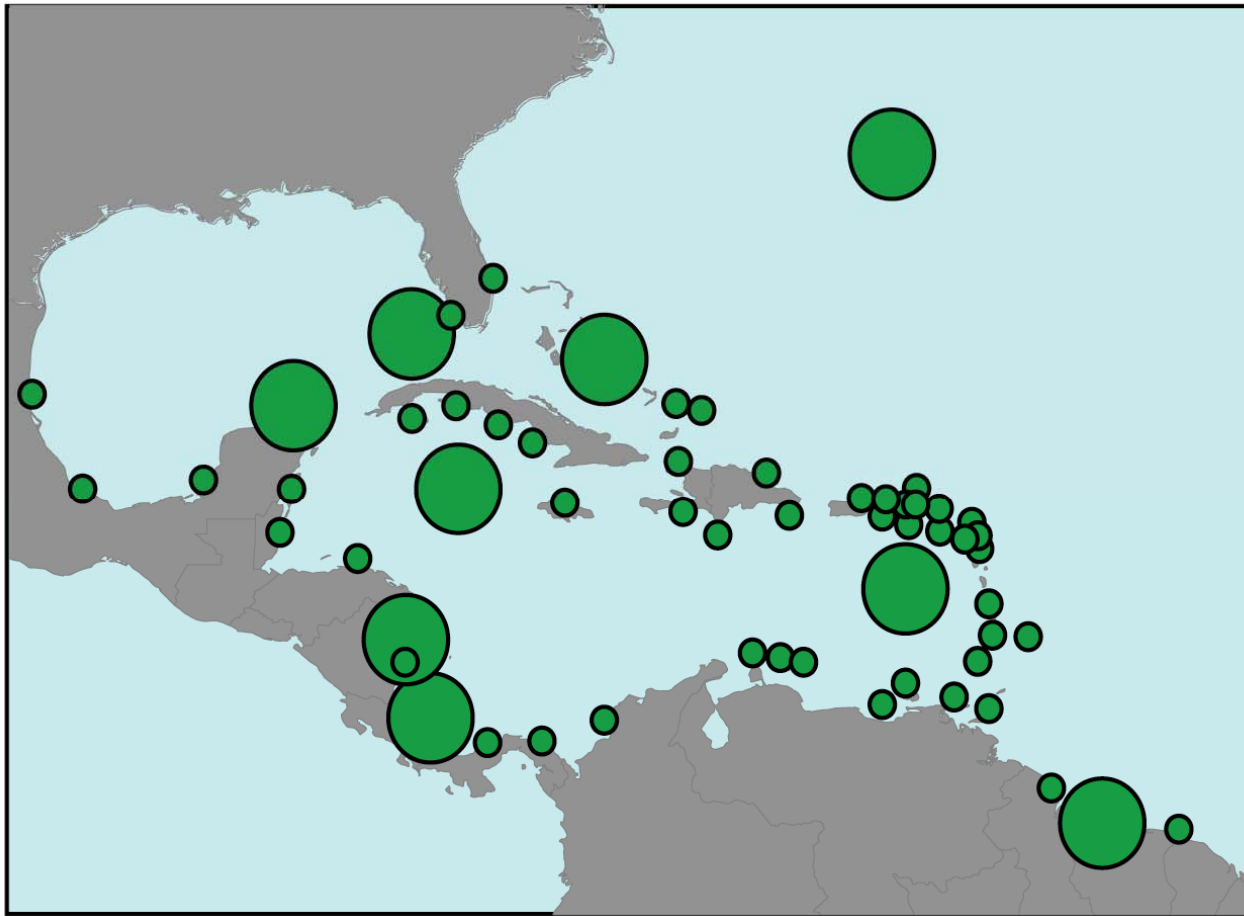
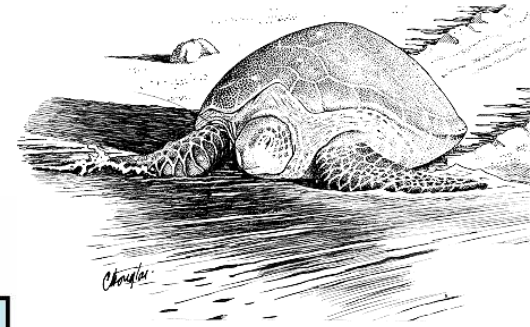


Key West turtle fishery





In Key West, the beef and turtle markets adjoin. They are both supplied with about equal regularity, and very many prefer the turtle to the beef, particularly after the latter has been submitted to the hardships of a voyage from the mainland. Turtle are shipped alive to the northern markets from Key West, and sometimes car-loads of them pass over the Florida Transit and Peninsular Railroad from Cedar Keys on their way north. –Gambier 1883

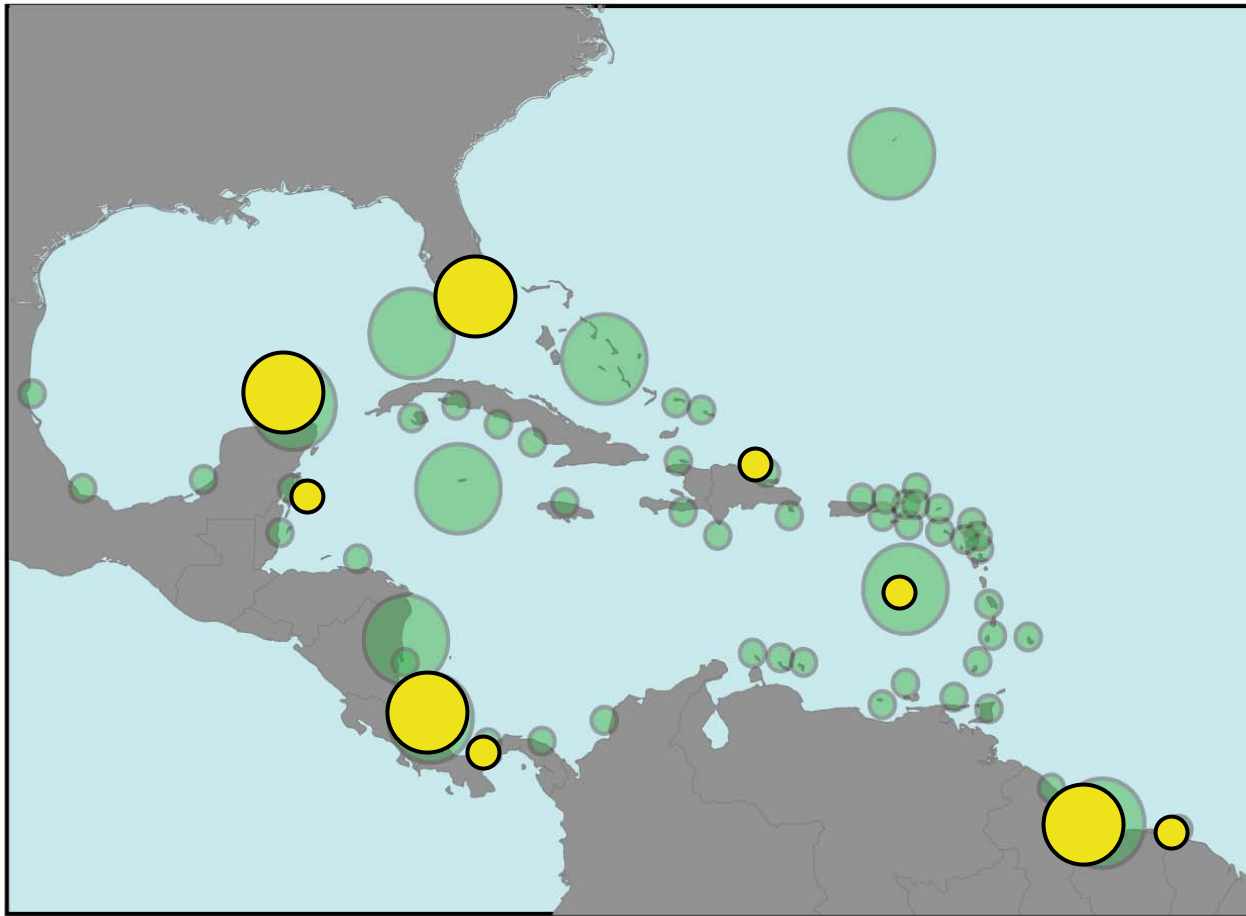
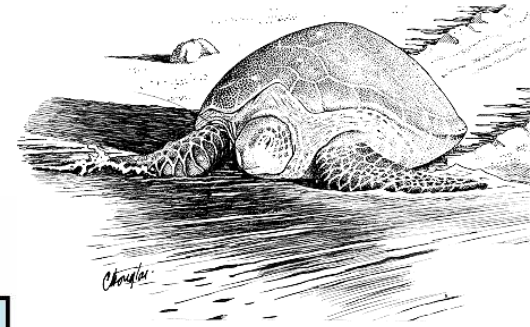
Green Turtle Nesting Beaches



**Historic
population
91 million**



-  = Historic nesting beach (major)
-  = Historic nesting beach

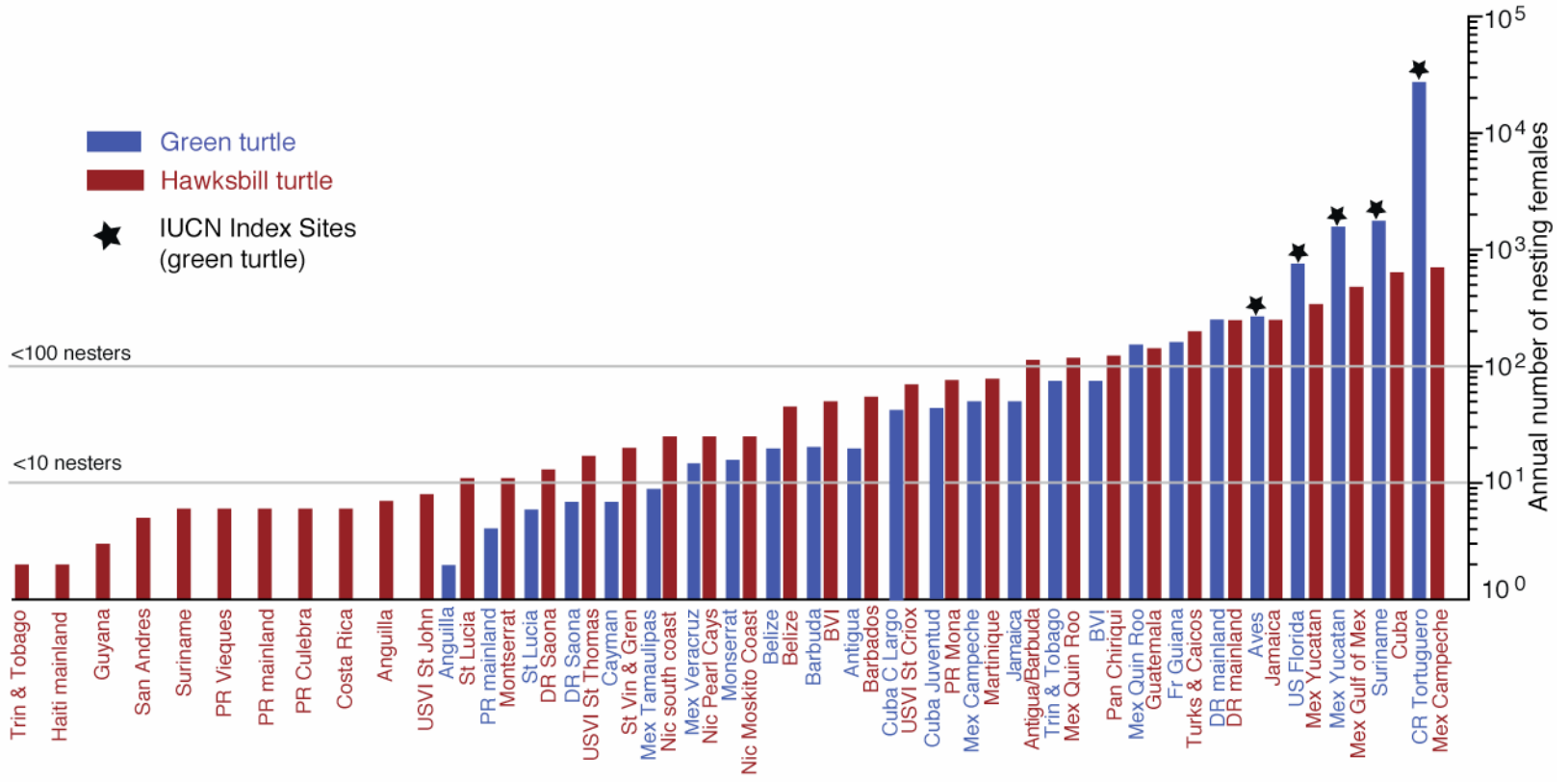
Green Turtle Nesting Beaches

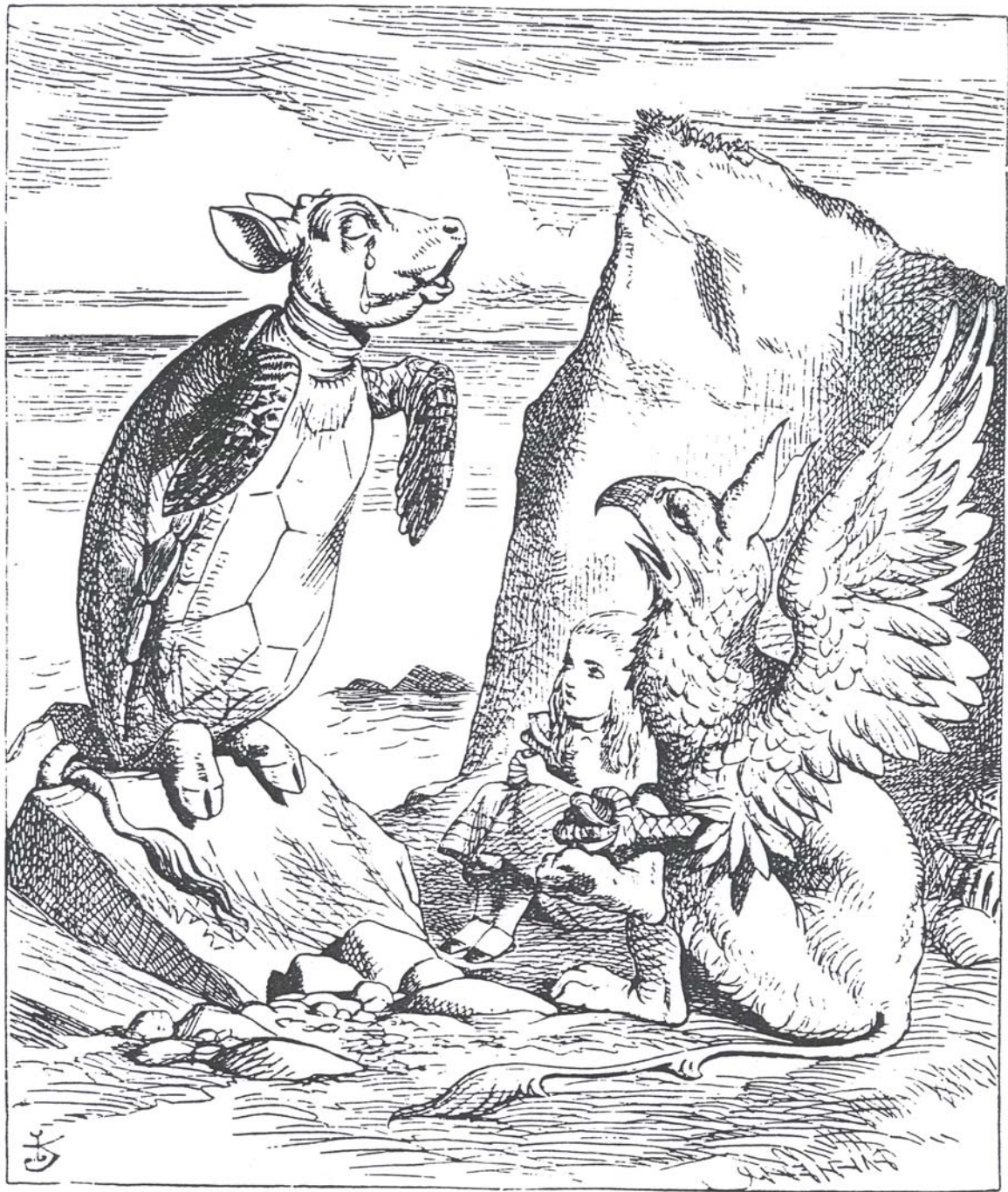


**Historic
population**
91 million

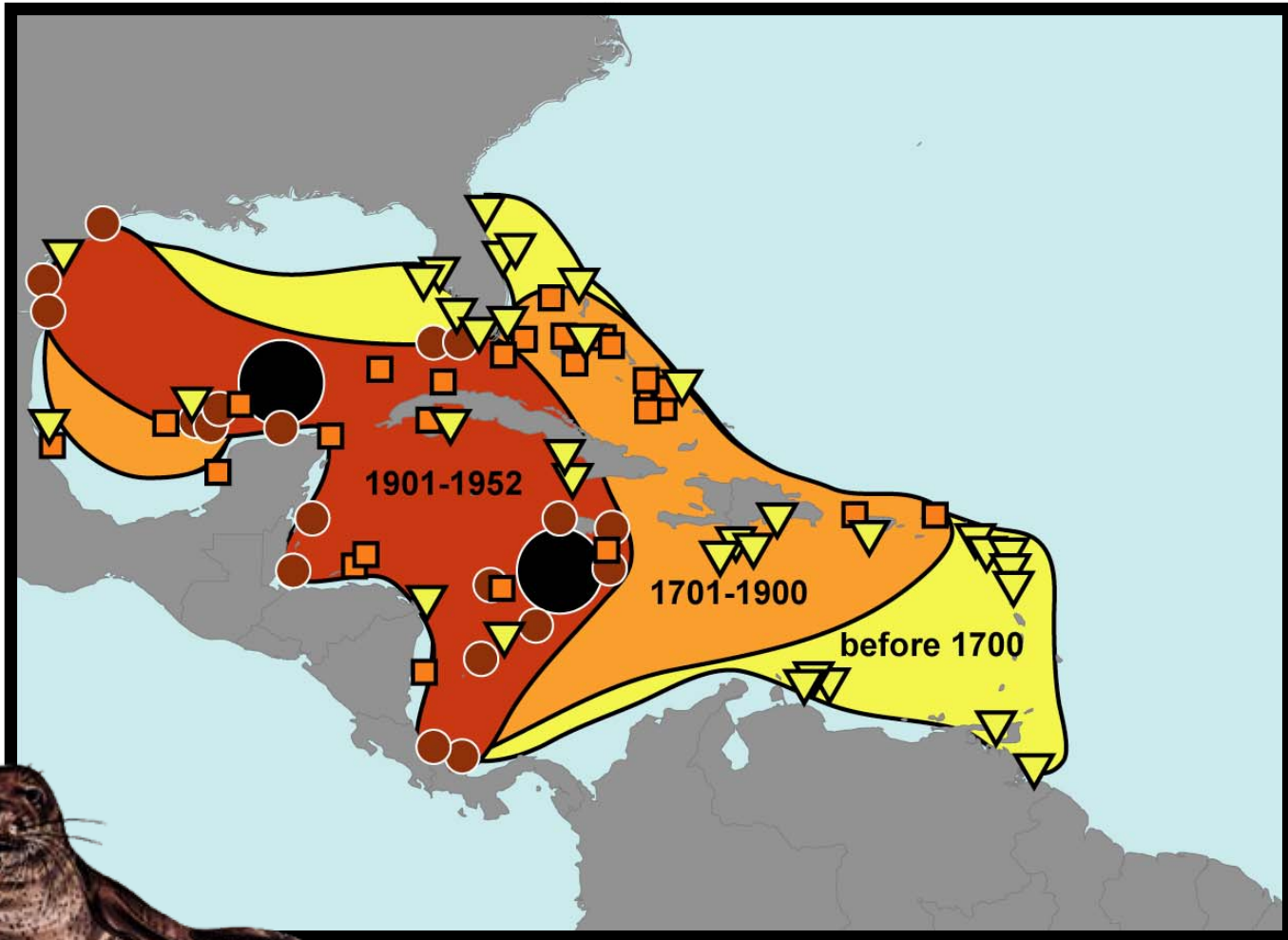
**Modern
population**
< 300,000

-  = modern nesting beach (major)
-  = modern nesting beach





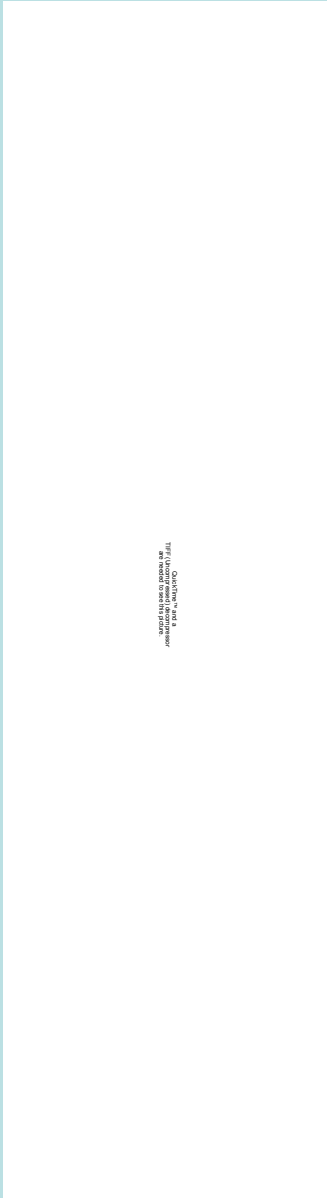
Monk Seals: Changes in Distribution



Key West shark fishery



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needed to see this picture.



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needed to see this picture.





Baseline: Who was fished in 1880?

Seriola punctatus. Amber-fish.

Hemulon punctatus. White Grunt, Yellow Grunt, Black Grunt.

Lutjanus caxis. Gray Snapper.

Lutjanus Blackfordii. Red Snapper.

Lutjanus Stearnsii. Mangrove Snapper.

Mesoprion uninotatus (?). Schoolmaster Snapper.

Ocyurus chrysurus. Yellow-tail Snapper.

Trisotropis brunneus. Black Grouper.

Trisotropis fulcatus. Grouper.

Trisotropis undulosus. Rockfish.

Epinephelus morio. Red Grouper.

Epinephelus striatus. Nassau Grouper.

Epinephelus nigritus. Jew-fish.

Epinephelus Drummond-Hayi. Deer Grouper, Deer Grouper, Hind.

Holacanthus tricolor. Black Angel-fish.

Sparus pagrus. Porgee, Margate fish, Goat's-head Porgee, Sheep's-head Porgee.

Scomberomorus regalis. Kingfish or Cero.

Scomberomorus maculatus. Spanish Mackerel.

Scomberomorus caballa. Kingfish or Cero.

Sphyræna picuda (?). Barracuda.

Lagodon rhomboides. Sailor's-Choice.

Lachnolæmus falcatus. Hogfish.

Sciaenops ocellatus. Channel Bass.

Centropristis atrarius. Sea Bass.

Balistes capriscus. Turbot.

Pomatomus saltatrix. Bluefish.

Menticirrhus alburnus. Whiting.

Cyphosus Boscii. Brim.

How much fish was caught?

Average of 4,000 fish daily by 75 fishermen

-Goode 1887



Image from Monroe County Library

Fishes commonly caught in the 1880s: *Groupers and snappers*

- C. bimaculatus*
- H. ciliaris*
- H. flavolineatum*
- L. apodus*
- L. griseus*
- H. tricolor*
- O. chrysurus*
- C. fulva*
- S. barracuda*
- C. hippos*
- L. campechanus*
- L. synagris*
- M. bonaci*
- M. interstitialis*
- E. morio*
- E. striatus*
- E. itajara*
- P. pagrus*
- S. regalis*
- S. maculatus*
- L. maximus*
- K. sectator*
- D. punctuatus*
- C. crysos*



Schoolmaster snapper



Gray snapper



Black grouper



Nassau grouper



Itajara

Fish Common in 1880, Now Listed by IUCN

Nassau grouper (*Epinephelus striatus*) Critically Endangered

Itajara (*Epinephalus itajara*) Critically Endangered



Speckled hind (*Epinephelus drummondhayi*) Critically Endangered

Seabream (*Pagrus pagrus*) Endangered



Hogfish (*Lachnolaimus maximus*) Vulnerable



Historic Data Show Ecosystem Change

Spiny Lobster and Conch Historically Abundant on Reefs

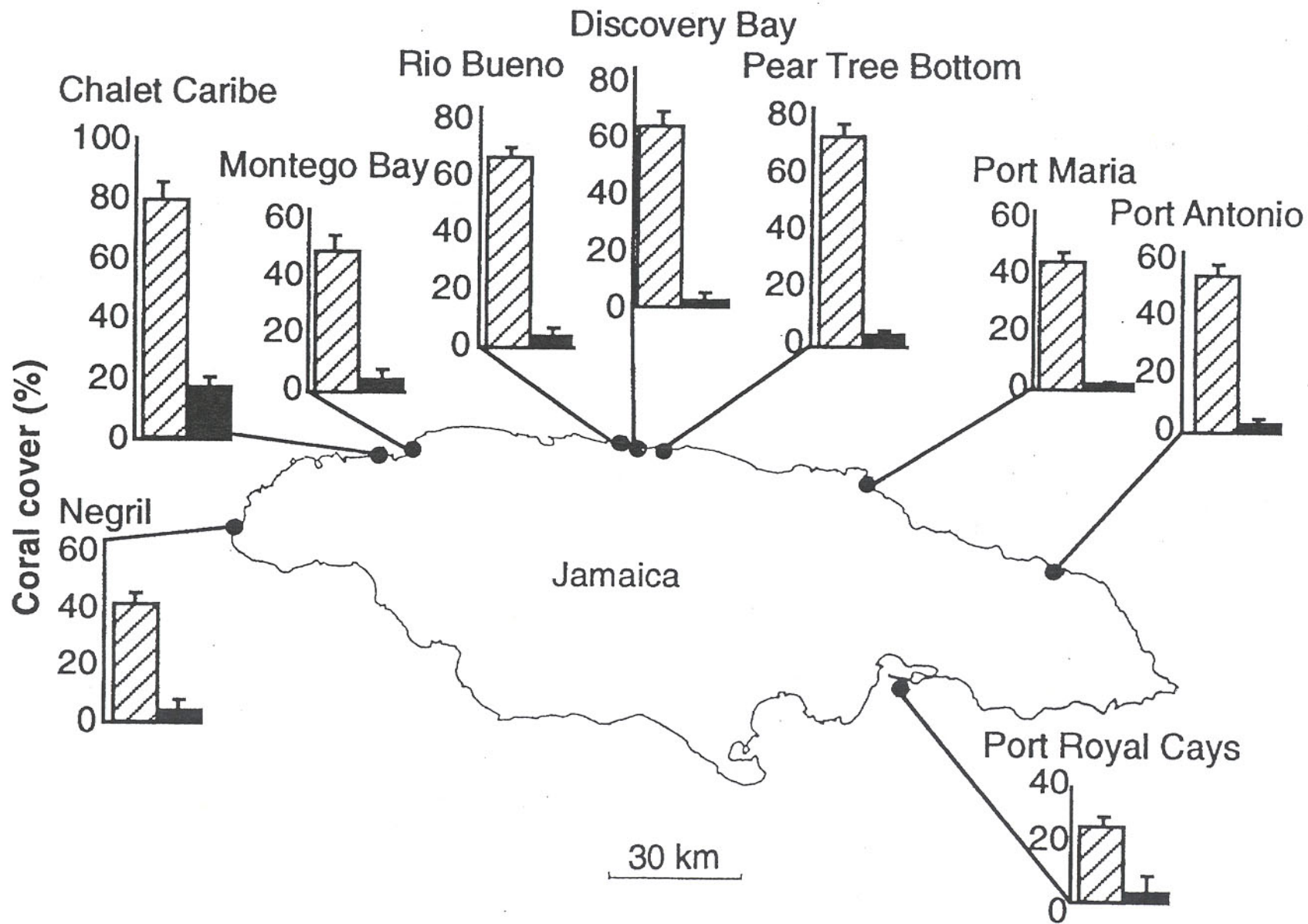
- Invertebrate overfishing in 20th century may have contributed to depletion in fish populations



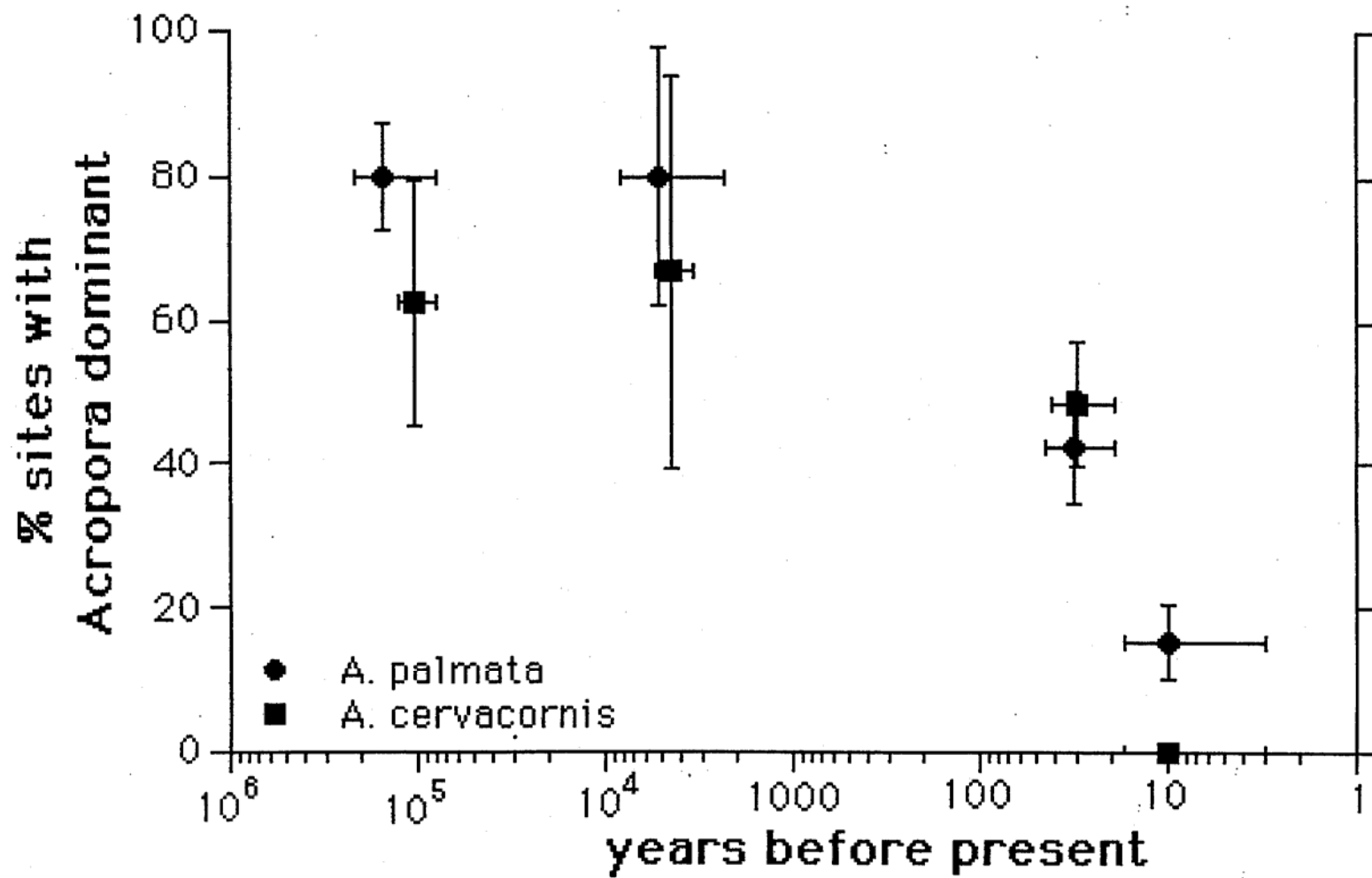
*“There are **such quantities of the largest [lobster]**, that a boat may be loaded with them in a few hours” -Gauld 1760s*

- Conch and spiny lobster used as bait in 1880s

*“These reefs...are exceedingly well populated with all the forms of living **invertebrates** ... and therefore, we find about them **an abundance of fishes**, attracted by the vast stores of food.” -Goode 1880*



QuickTime™ and a
None decompressor
are needed to see this picture.



Key West sponge fishery



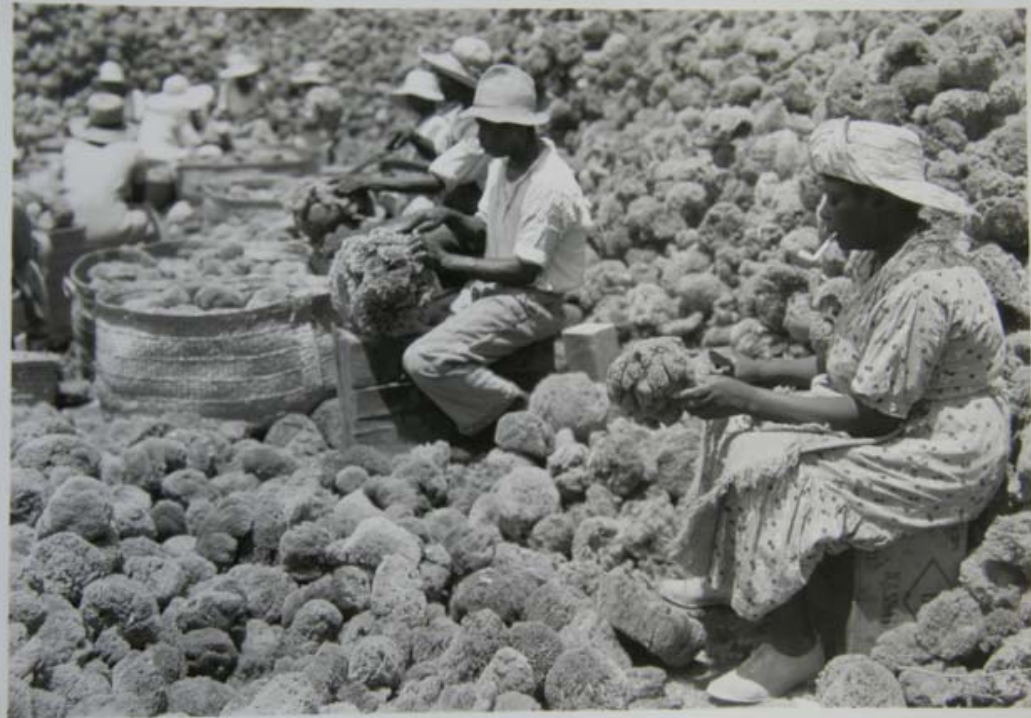
BRINGING SPONGES FROM THE VESSELS TO SPONGE WHARF AT KEY WEST.

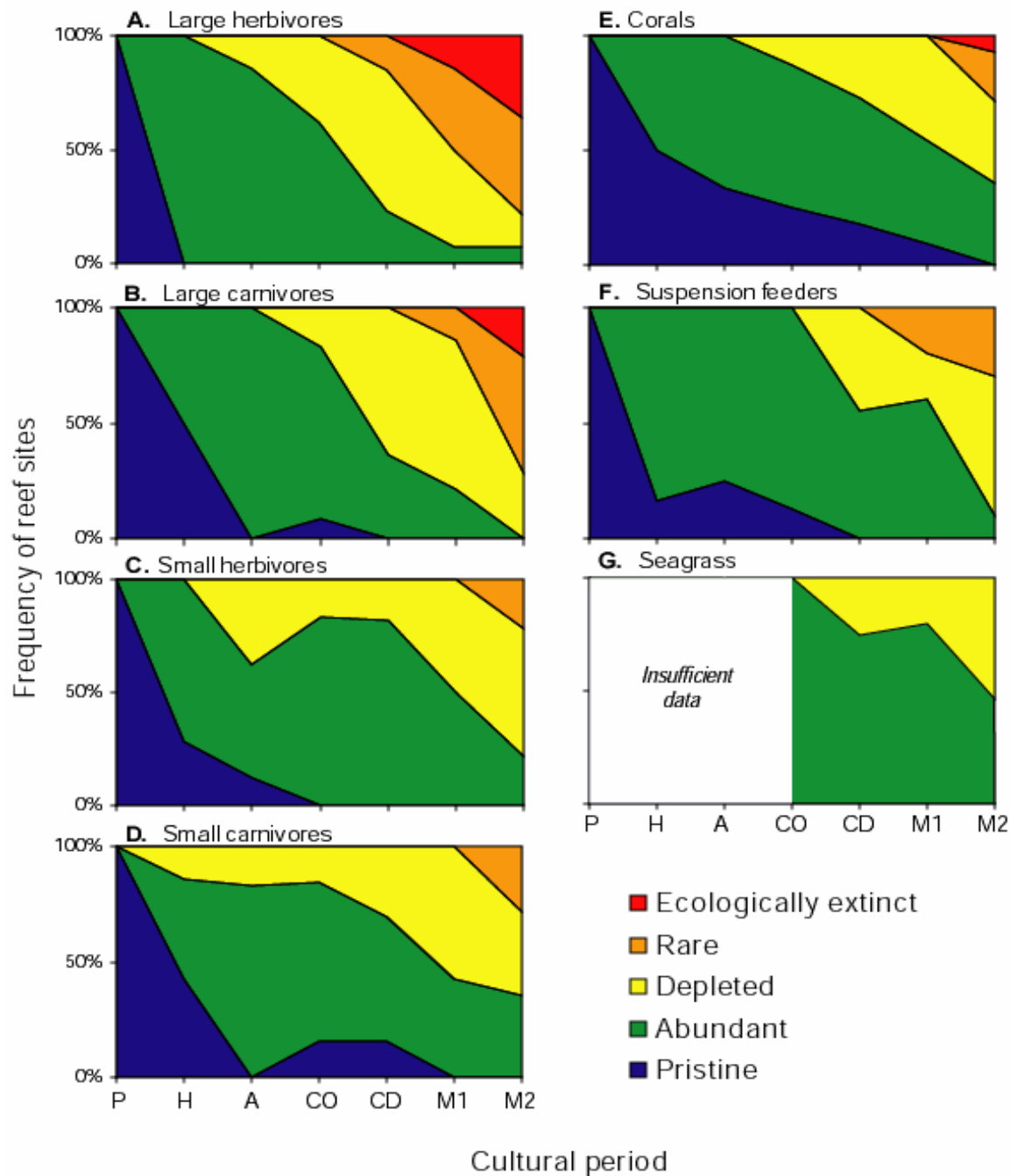


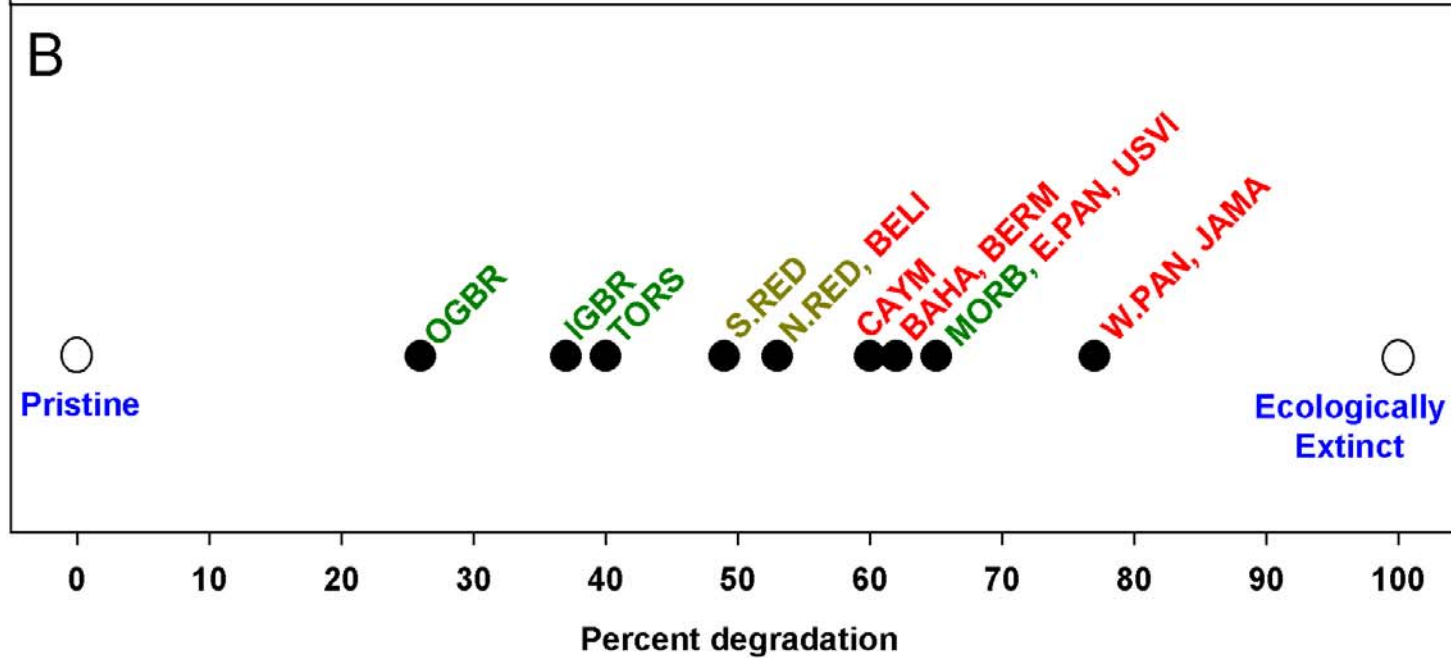
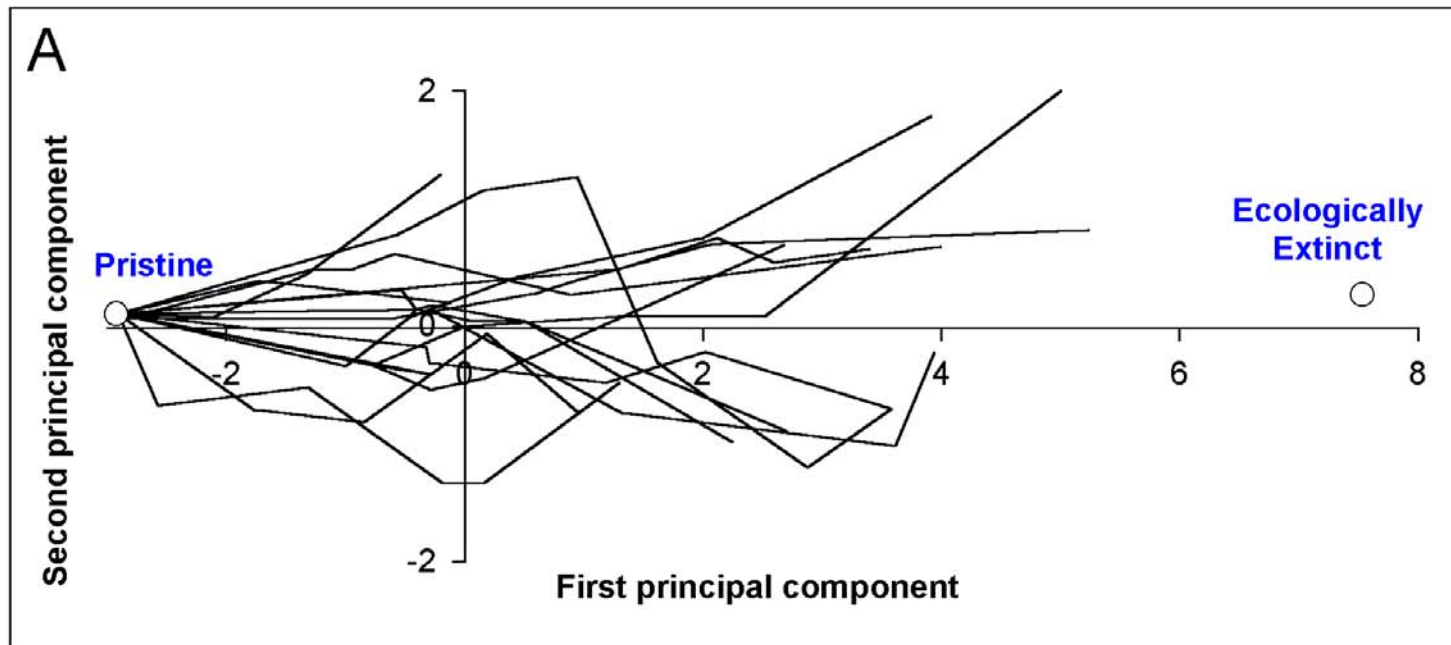
SPONGE YARD AT KEY WEST, SHOWING THE SPONGES DRYING.



Sponge Fishing Boats — Nassau, Bahamas







What were and are now the major causes of degradation?

- Fishing: loss of top-down control, trophic cascades--> increased macroalgae, microbes, and disease
- Nutrient and organic pollution: bottom-up processes more important, increased nutrients and organic carbon--> increased macroalgae, microbes, and disease
- Increase in CO₂:
warming --> coral bleaching, increased macroalgae, microbes, and disease
ocean acidification??? --> decreased coral calcification





Sea urchin die-off 1982



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TIFF (Uncompressed) decompressor
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Coral Disease

Yellow blotch disease
Kills 1 cm/month



~ 30 other diseases
only 5 pathogens
identified

Disease of Branching corals



↑
1971

1988 →

Disease of massive corals



↑
1988

1998 →



Very Challenging Problem

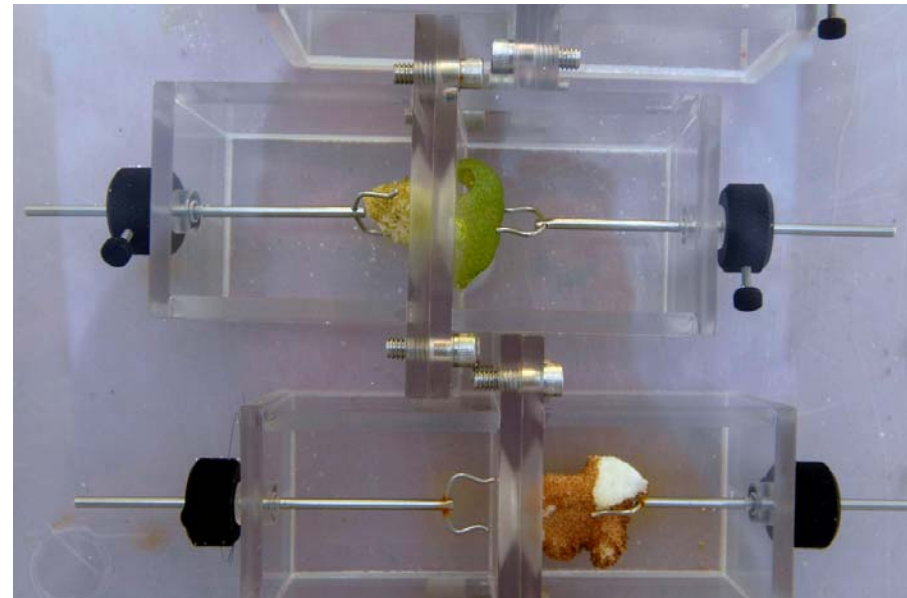
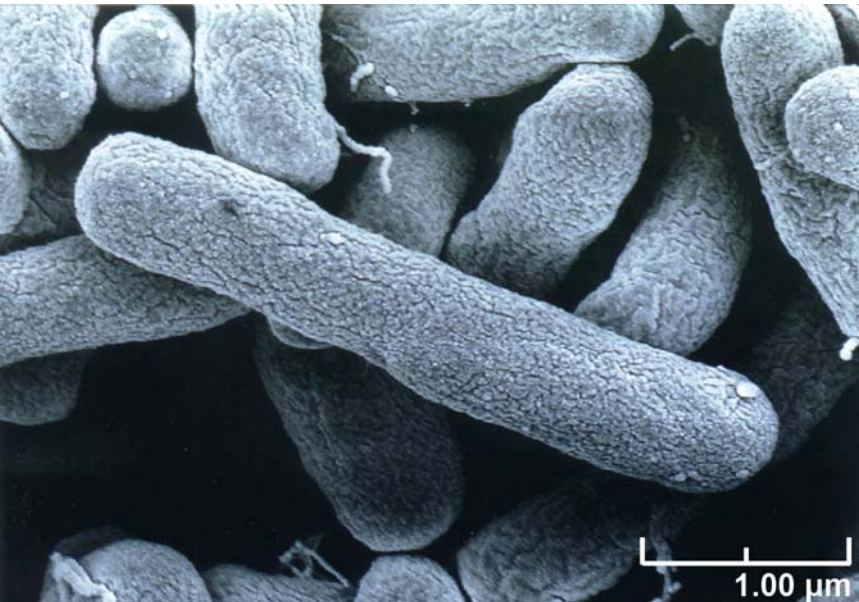
What is the normal bacterial flora?

3 species of corals - 2 locations

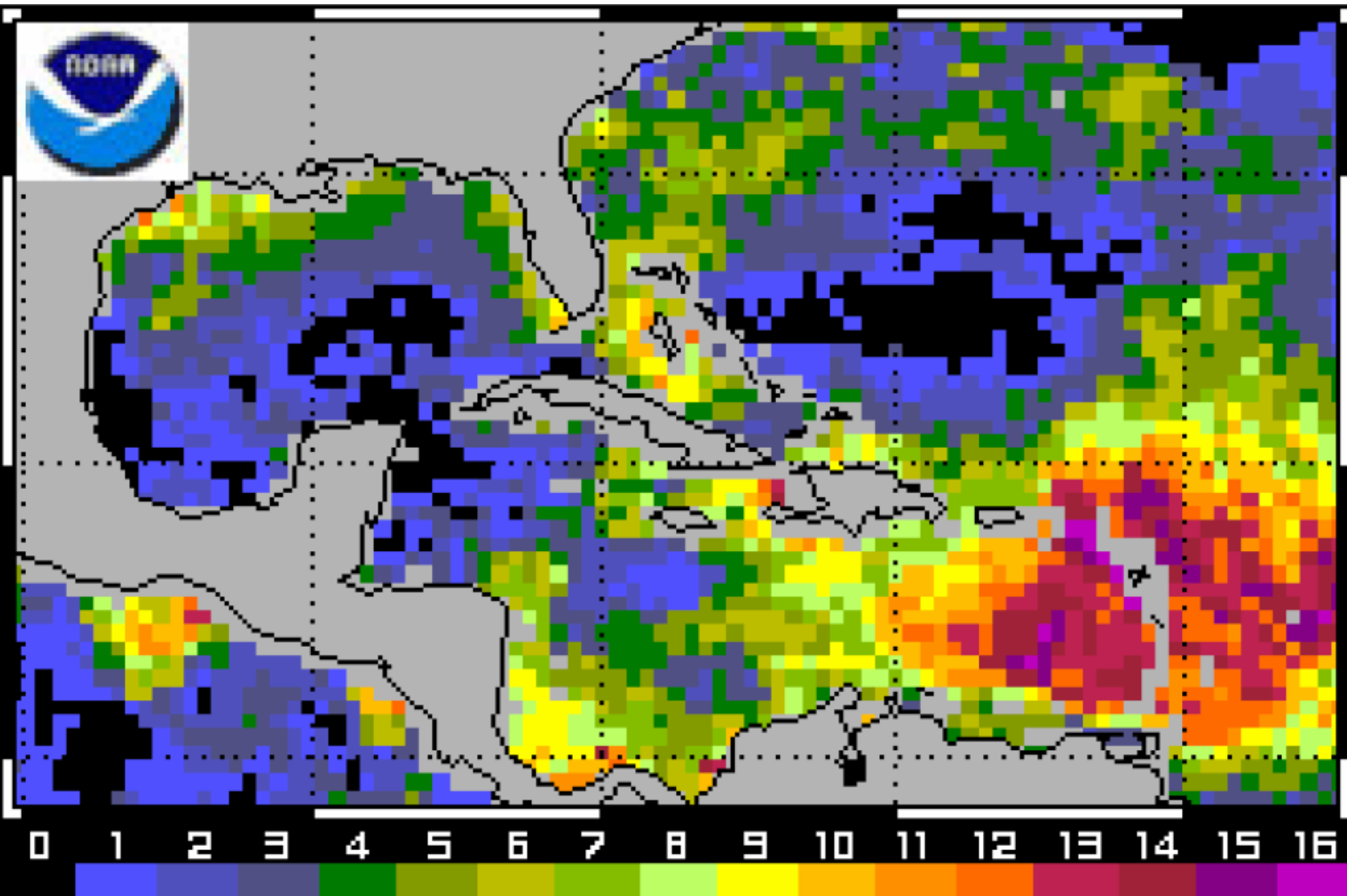
14 samples - ~100 DNA sequences per sample

240 unique sequences observed

~6000 species of bacteria - function??



Caribbean Degree Heating Weeks - 2005



Coral Bleaching



Image courtesy of David Kline.

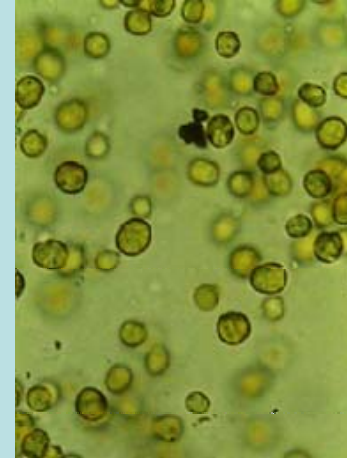


Image courtesy of Scott R. Santos,
Auburn University

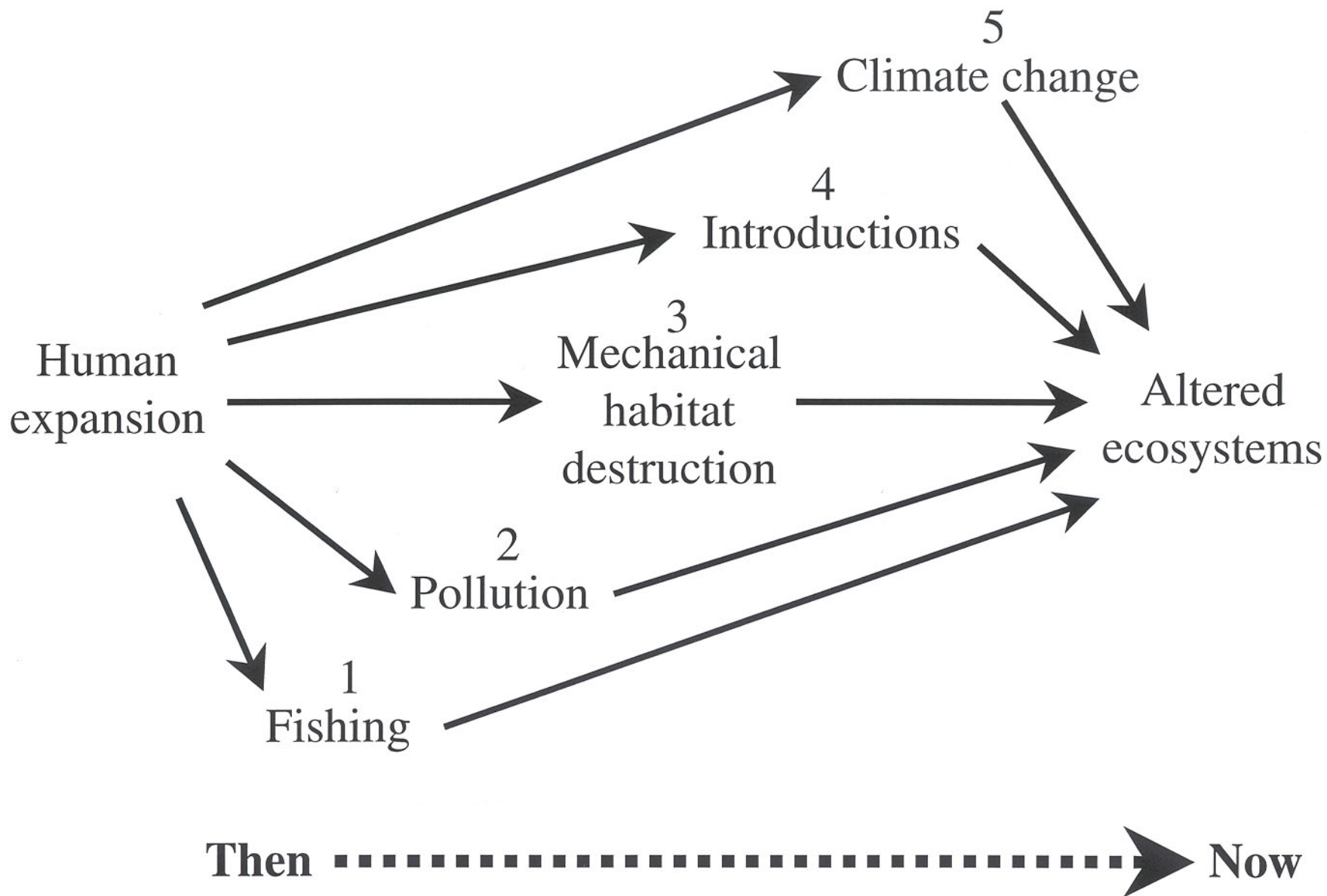
- Breakdown in mutualism between coral and symbionts caused by high temperature
- Highly variable response depending on species, environment, and history

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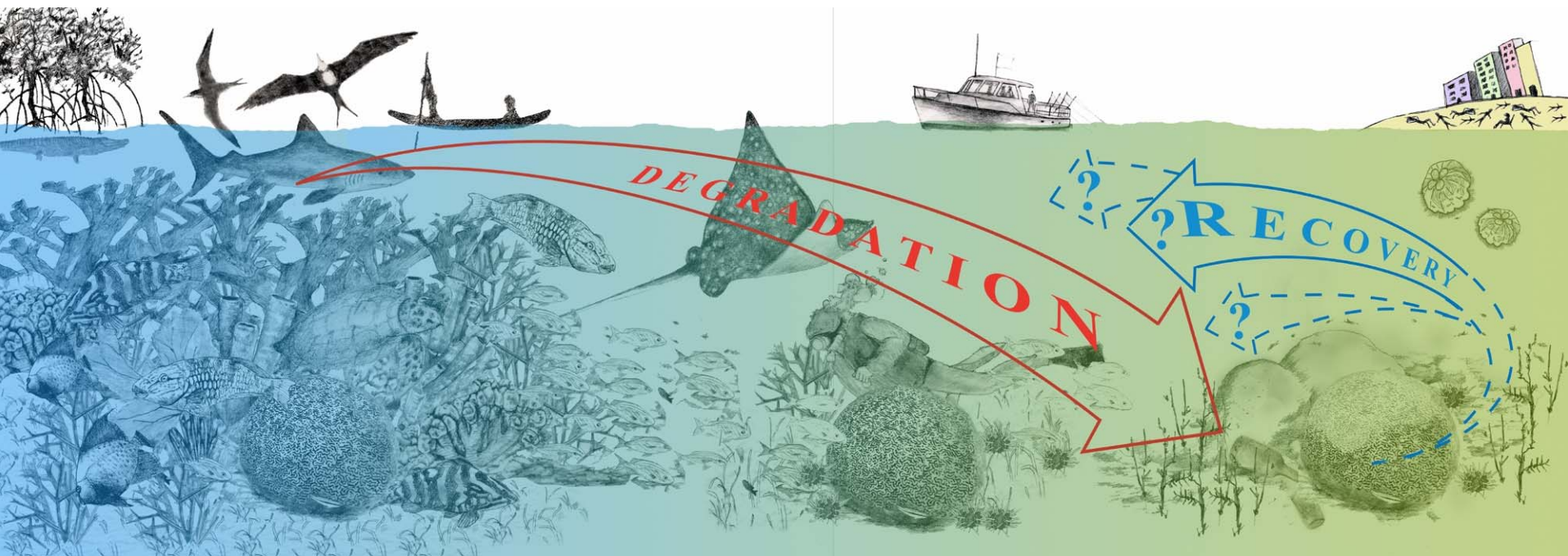
Trials and tribulations of reef corals

1. Overfishing → trophic cascades, algal overgrowth and coral death
2. Trawling and dynamiting → loss of corals and 3-dimensional structure
3. Introduced species → “killer algae” overgrowing corals
4. Warming → coral bleaching and death
5. Pollution → reduced coral growth and reproduction, coral death
6. Rise of slime → coral disease, explosions of seaweeds, coral death

ALL of these are demonstrably significant threats to the future of corals and coral reefs. They cannot be successfully dealt with one by one.



Can we restore coral reef
ecosystems to some
semblance of their past?



DEGRADATION

? RECOVERY ?

Early 1900s

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Hove decoder are
required to see this picture.

Today

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H264 decompressor
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The Northern Line Islands as an ecological time machine

- Four isolated central Pacific atolls on a 700 km long NW-SE transect at 2-6°N
- Similar oceanographic conditions within a single biogeographic province although islands different in shape and size
- Human population from zero to nearly 10,000

KINGMAN REEF

0 people



Photo by Rob Shallenberger/USFWS

PALMYRA ATOLL

10 people



TABUAERAN

1500 people



10,000 people



KIRITIMATI

KIRITIMATI





Photo: Jen Smith

*On every side of us swam sharks
innumerable, & so voracious that they bit
our oars and rudder, & I actually struck
my hanger 2 inches into the back of one
whilst he has the rudder between his
teeth.*

Trevenen describing the lagoon at
Christmas Island, 1777



TABUAREAN



PALMYRA

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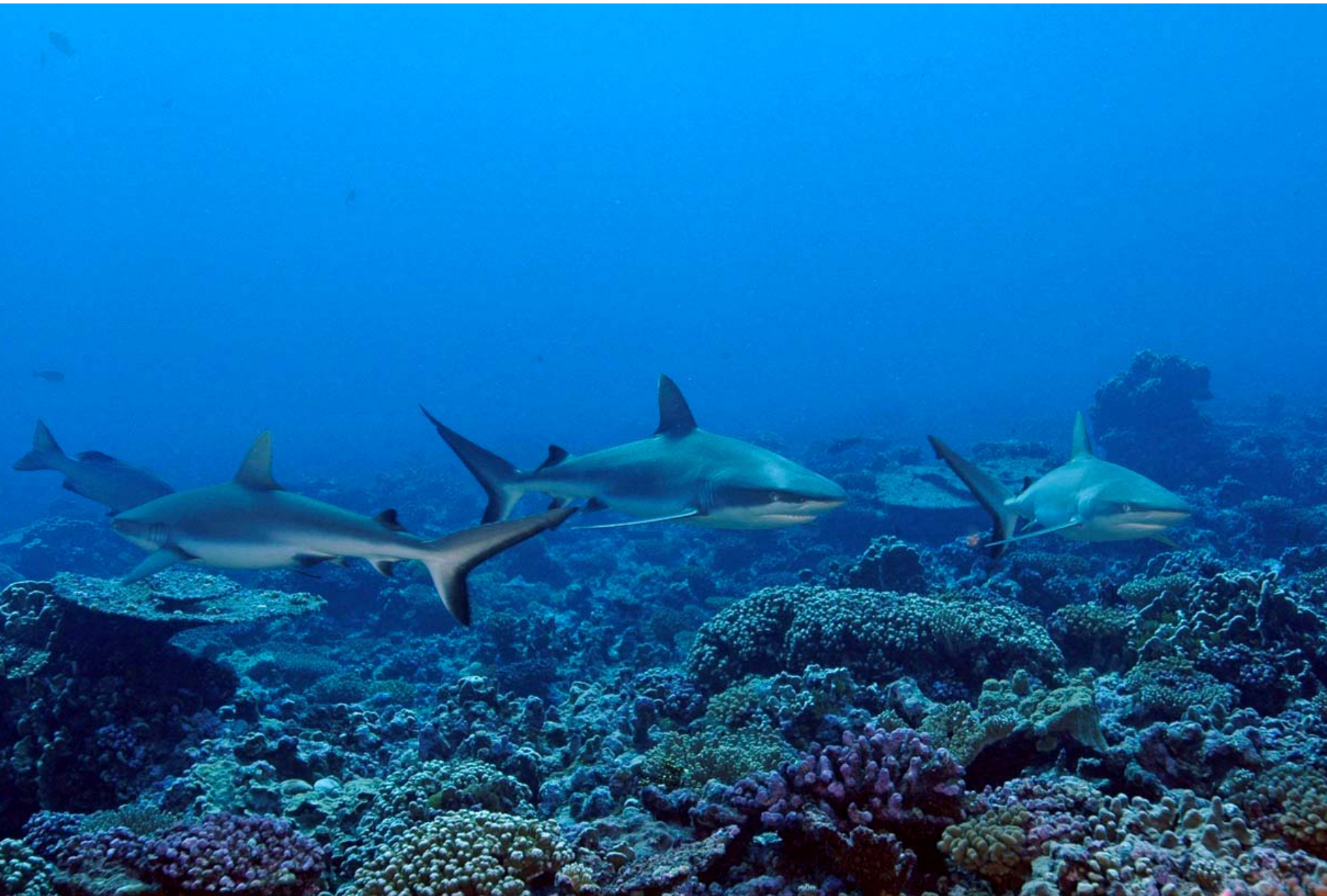


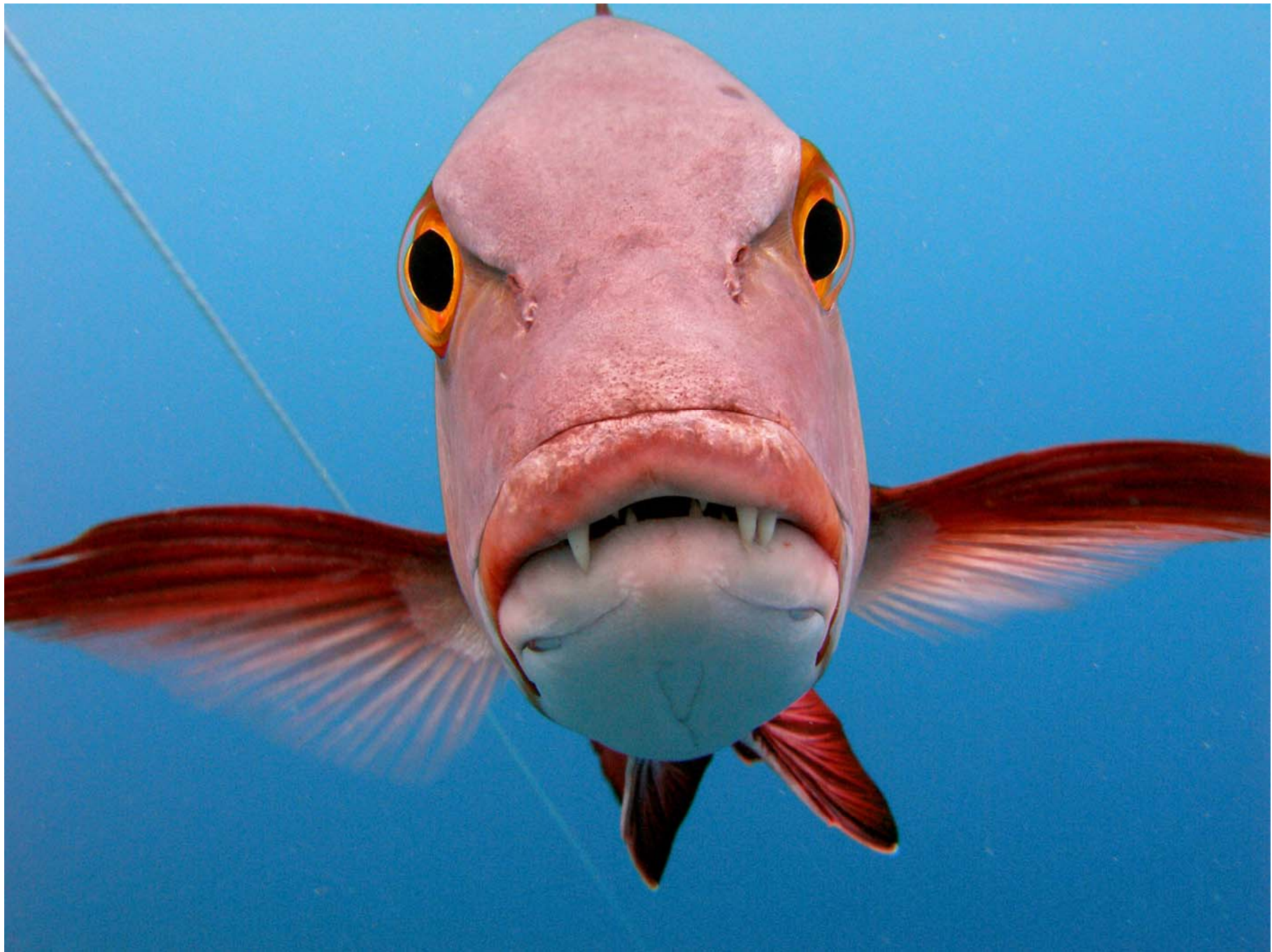
KINGMAN REEF

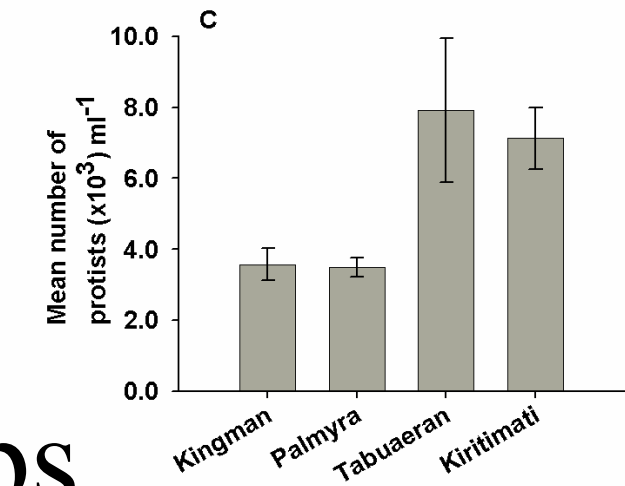
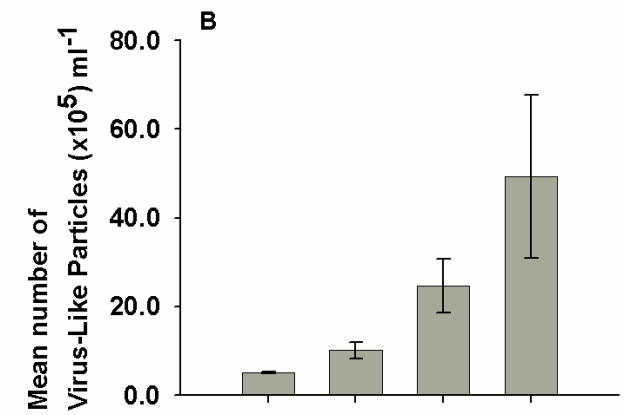
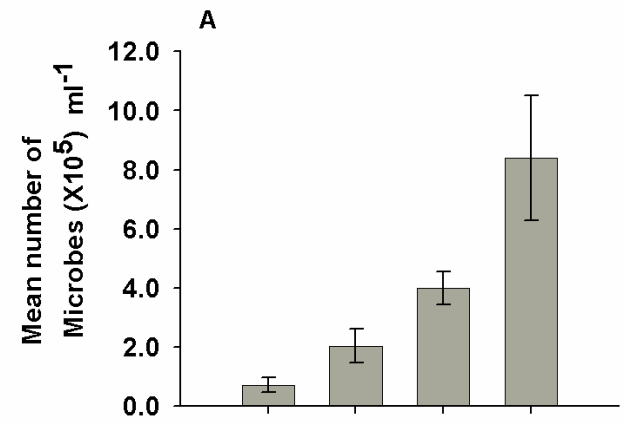
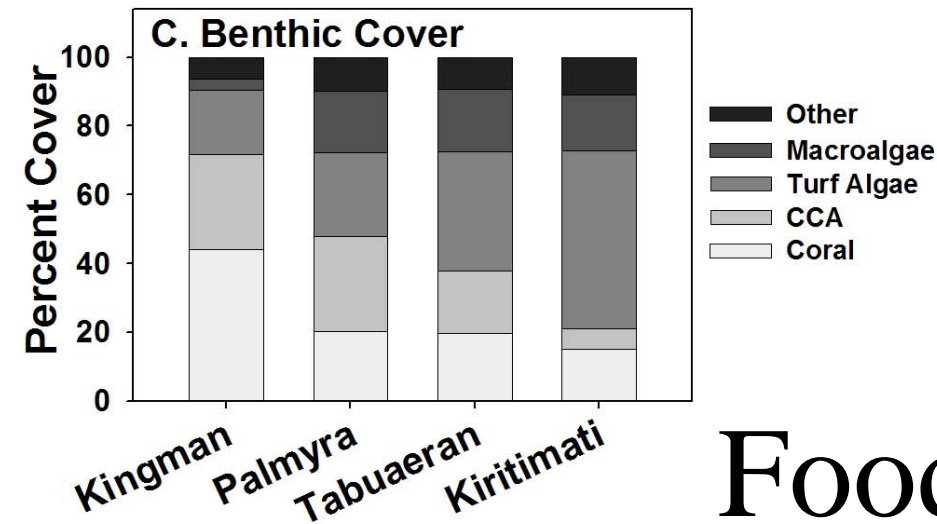
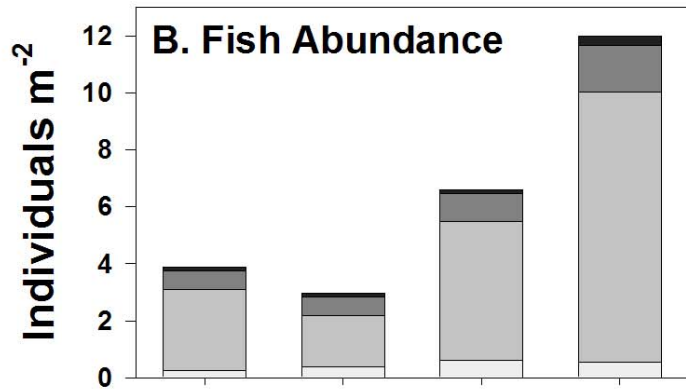
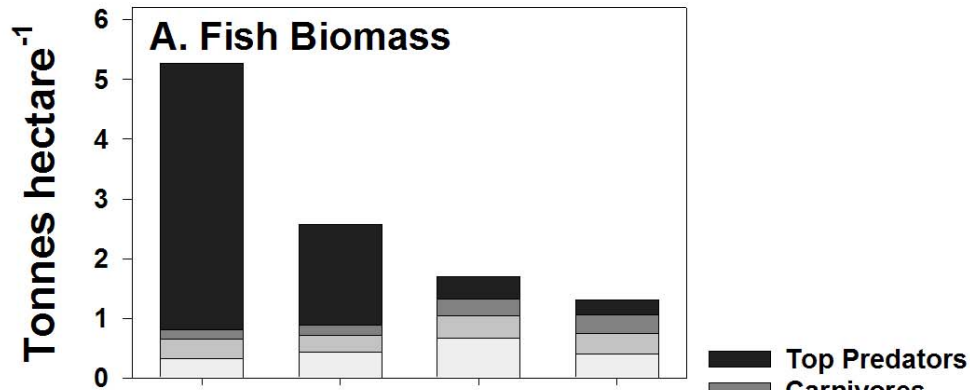


Photo by Rob Shallenberger/USFWS

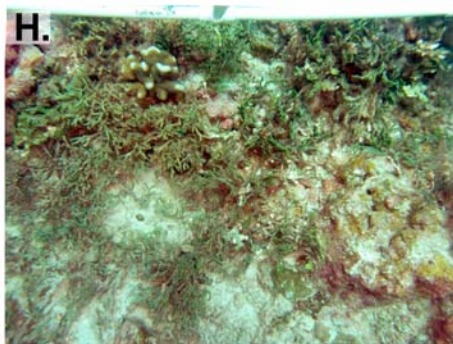
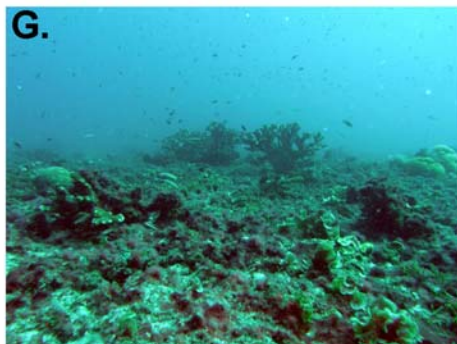
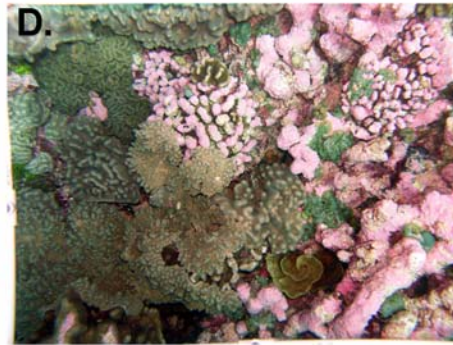
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Foodwebs

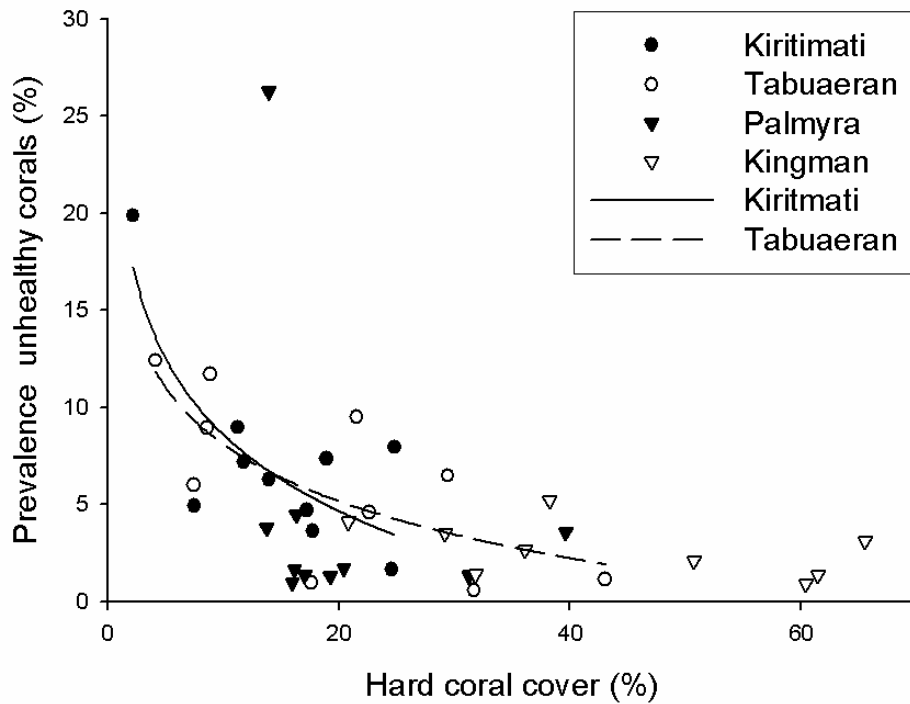
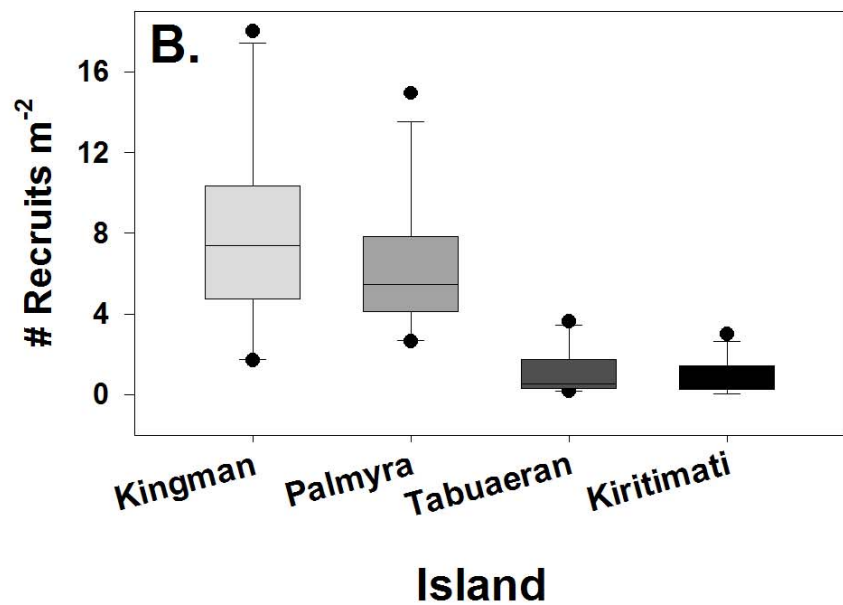
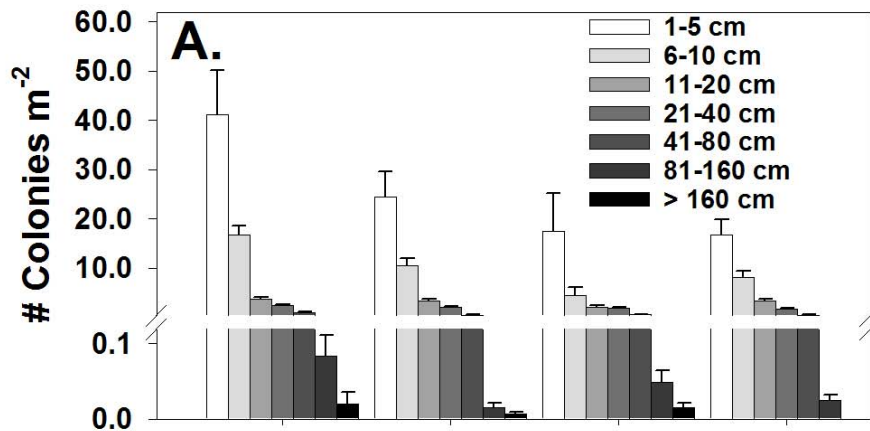


Kingman
(0)

Palmyra
(10)

Tabuaeran
(2,000)

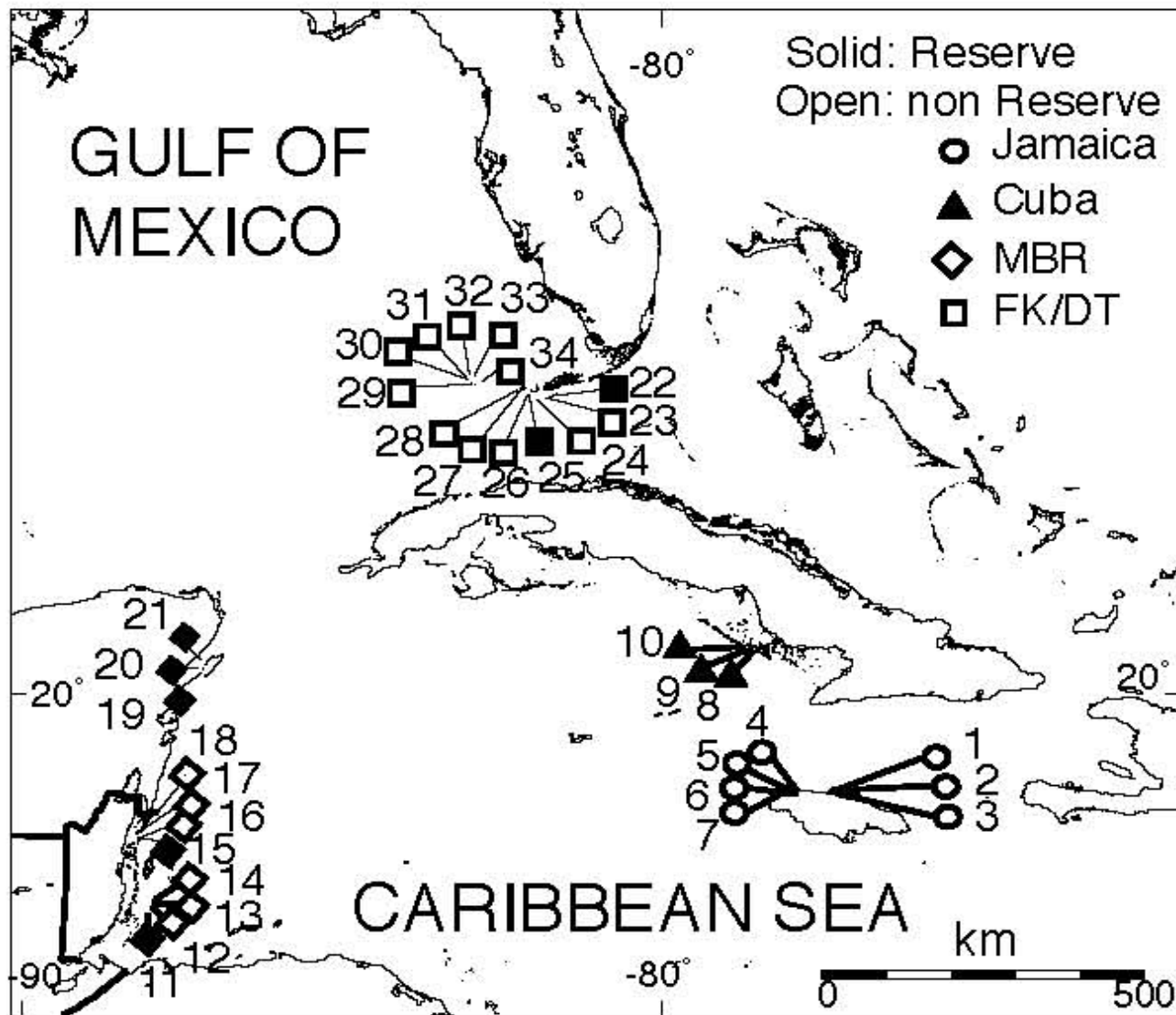
Kirimati
(10,000)



Resilience

Comparable effectiveness of MPAs in the Northern Caribbean?

Newman et al. 2006. Ecology Letters



Gradient in northern Caribbean fish abundance

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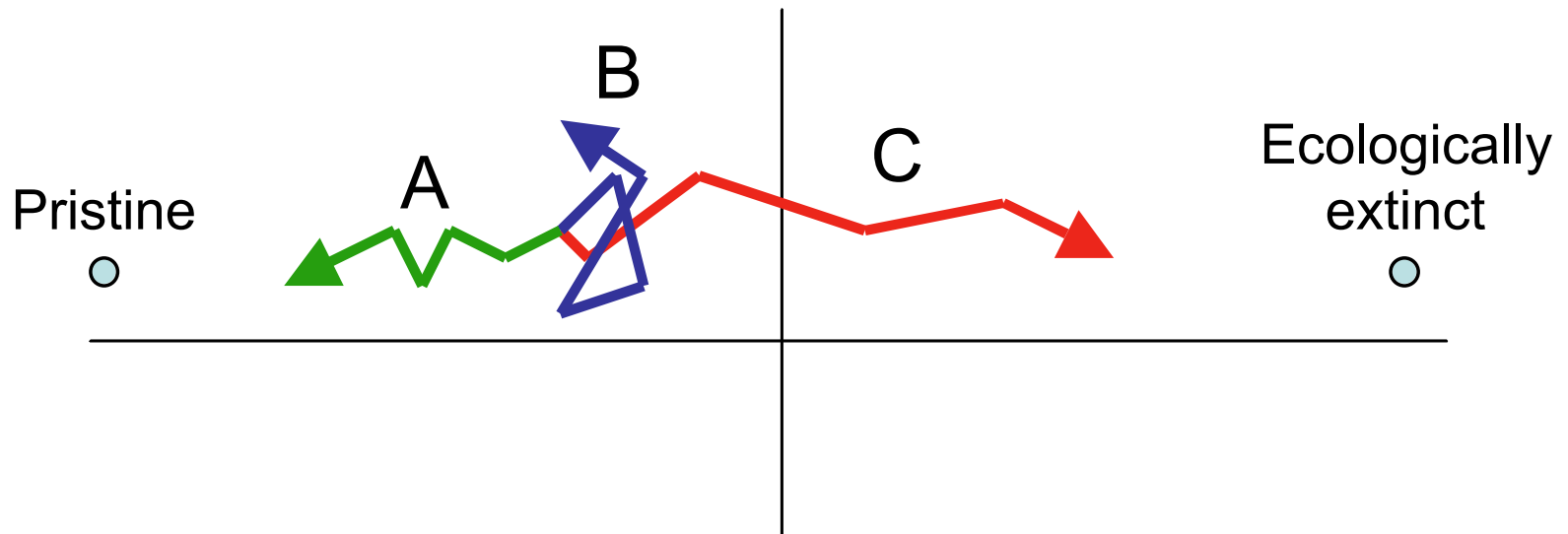
The good news

- Protection works on appropriately large spatial and temporal scales in the Northern Line Islands, NW Hawaiian Islands, and northern Caribbean
- More intact food webs and stronger top-down control provide greater resilience in the face of global change and the rise of slime (greater coral recruitment after bleaching and less coral disease at Kingman than Christmas)
- Strong local protection can make a big difference for the future of coral reefs and is the best insurance we've got against global climate change.

The bad news

- Extreme asymmetry of destruction versus recovery (the Humpty Dumpy Effect)
- Consequent extreme time lags in benthic community response to management actions in a sound bite world
- Uncertainties of the outcome of conservation because of nonlinearities and contingency
- Timidity of scientists and managers to take large scale management risks as experiments and to have the courage to be wrong

Uncertainties of ecosystem restoration



So the challenge for the future of coral reefs is to figure out how to move from the right to the left.

This is not a conventional scientific question.

