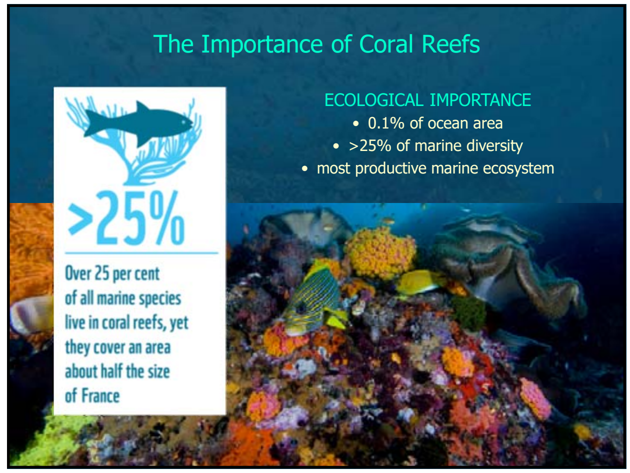
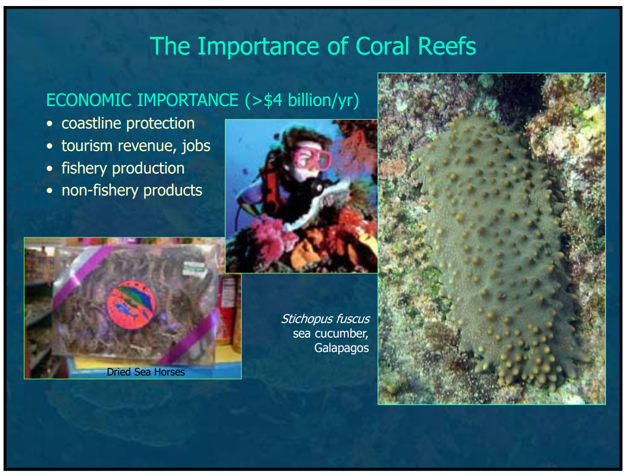
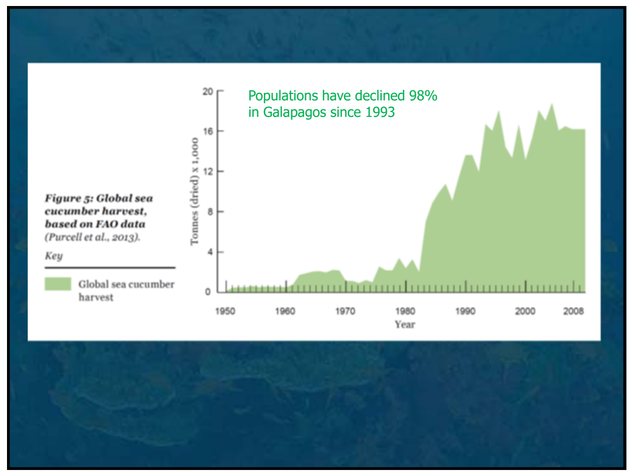
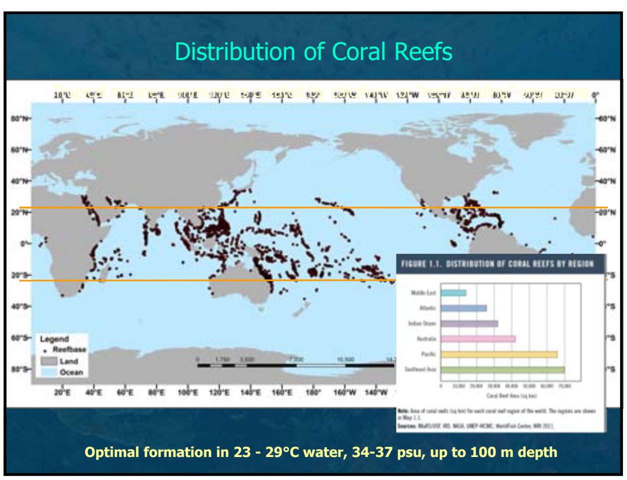
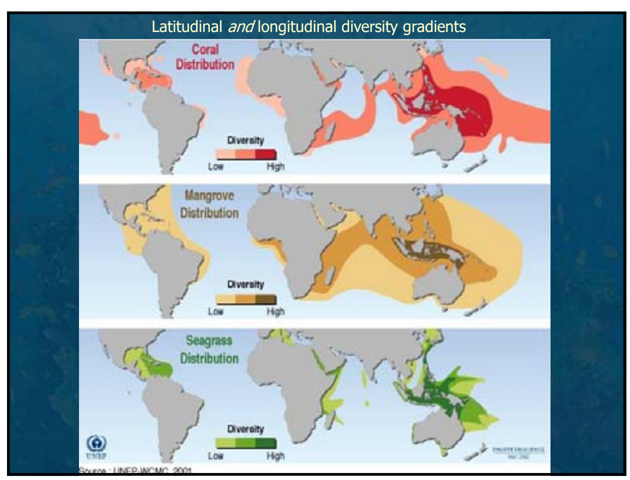

CORAL REEFS

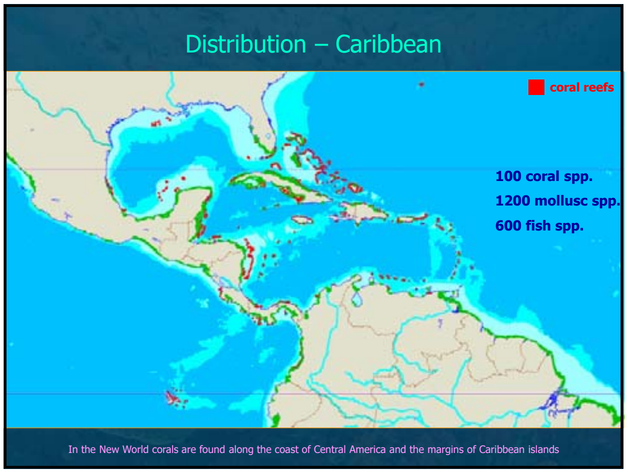

The Importance of Coral Reefs
ECOLOGICAL IMPORTANCE
• 0.1% of ocean area
• >25% of marine diversity
• most productive marine ecosystem
>25%
Over 25 per cent of all marine species live in coral reefs, yet they cover an area about half the size of France

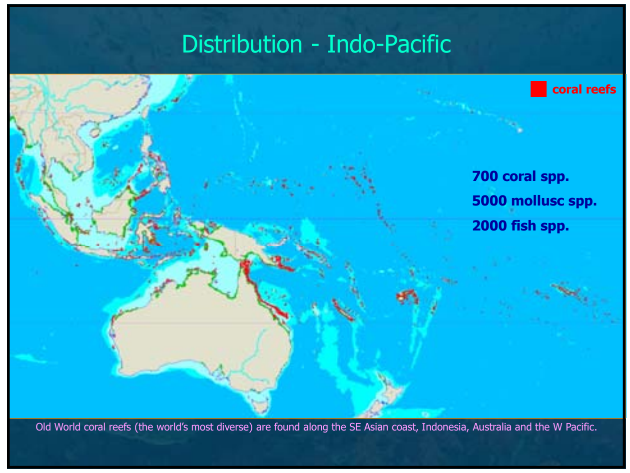

The Importance of Coral Reefs
ECONOMIC IMPORTANCE (>$4 billion/yr)
• coastline protection
• tourism revenue, jobs
• fishery production
• non-fishery products
Dried Sea Horses
Stichopus fuscus sea cucumber, Galapagos

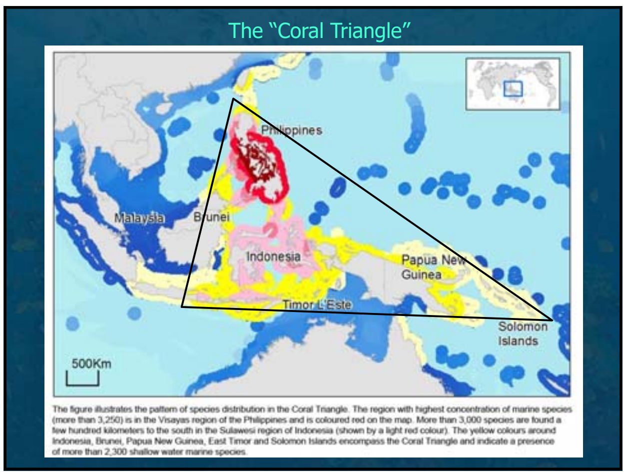

Populations have declined 98% in Galapagos since 1993
Figure 5: Global sea cucumber harvest, based on FAO data (Purcell et al., 2013).
Key
Global sea cucumber harvest
Tonnes (dried) x 1,000
0
4
8
12
16
20
1950
1960
1970
1980
1990
2000
2008
Year

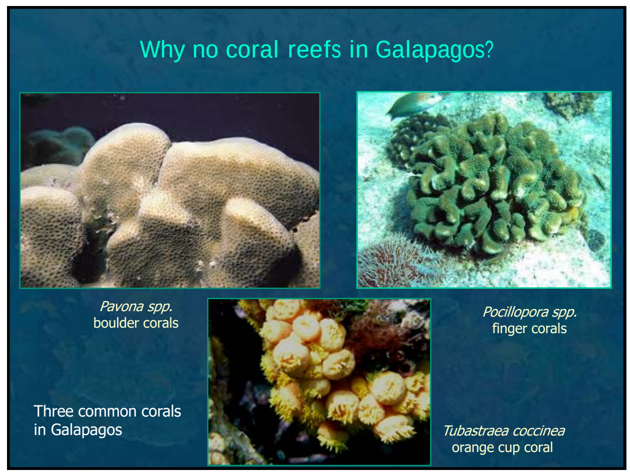

Distribution of Coral Reefs
FIGURE 1.1. DISTRIBUTION OF CORAL REEFS BY REGION
Legend
Reefbase
Land
Ocean
Optimal formation in 23 - 29°C water, 34-37 psu, up to 100 m depth

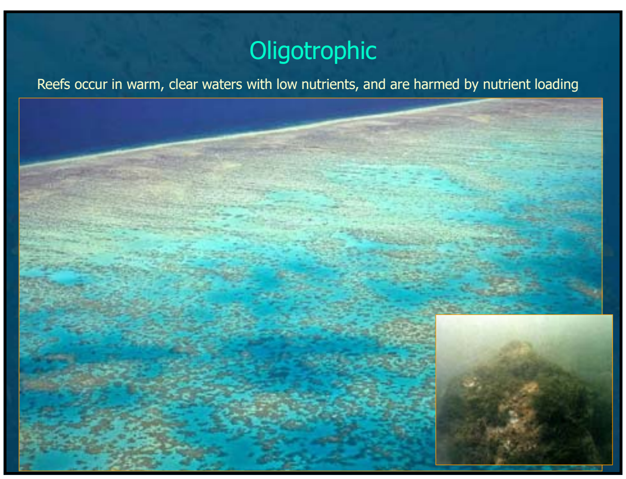

Latitudinal and longitudinal diversity gradients
Coral Distribution
Diversity
Low
High
Mangrove Distribution
Diversity
Low
High
Seagrass Distribution
Diversity
Low
High
Source : UNEP-WCMC, 2001

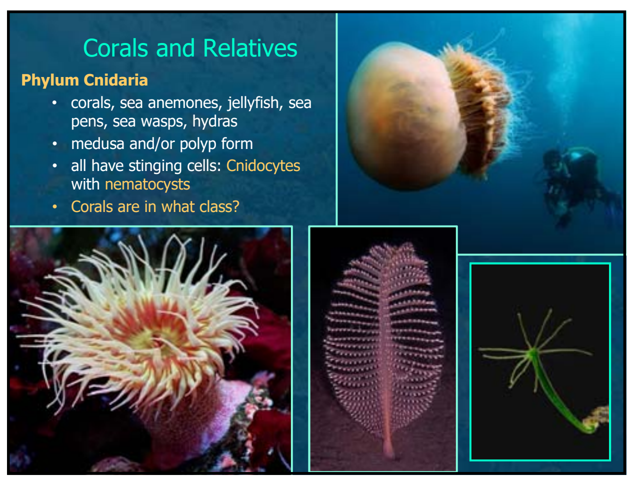

Distribution – Caribbean
coral reefs
100 coral spp.
1200 mollusc spp.
600 fish spp.
In the New World corals are found along the coast of Central America and the margins of Caribbean islands


Distribution - Indo-Pacific
coral reefs
700 coral spp.
5000 mollusc spp.
2000 fish spp.
Old World coral reefs (the world's most diverse) are found along the SE Asian coast, Indonesia, Australia and the W Pacific.


The "Coral Triangle"
Philippines
Malaysia
Brunei
Indonesia
Papua New Guinea
Timor L'Este
Solomon Islands
500Km
The figure illustrates the pattern of species distribution in the Coral Triangle. The region with highest concentration of marine species (more than 3,250) is in the Visayas region of the Philippines and is coloured red on the map. More than 3,000 species are found a few hundred kilometers to the south in the Sulawesi region of Indonesia (shown by a light red colour). The yellow colours around Indonesia, Brunei, Papua New Guinea, East Timor and Solomon Islands encompass the Coral Triangle and indicate a presence of more than 2,300 shallow water marine species.

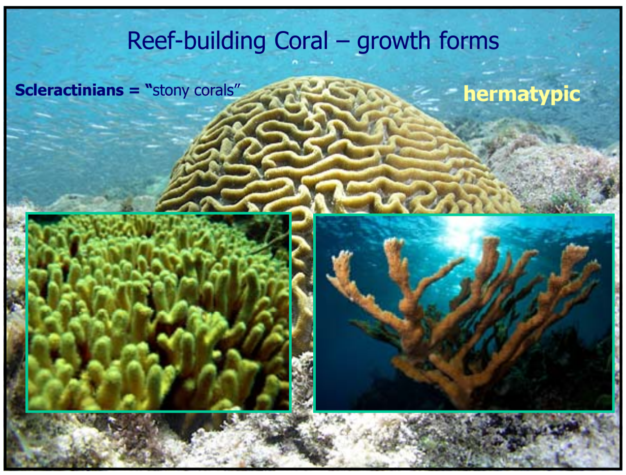

Why no coral reefs in Galapagos?
Pavona spp.
boulder corals
Pocillopora spp.
finger corals
Three common corals
in Galapagos
Tubastraea coccinea
orange cup coral


Oligotrophic
Reefs occur in warm, clear waters with low nutrients, and are harmed by nutrient loading

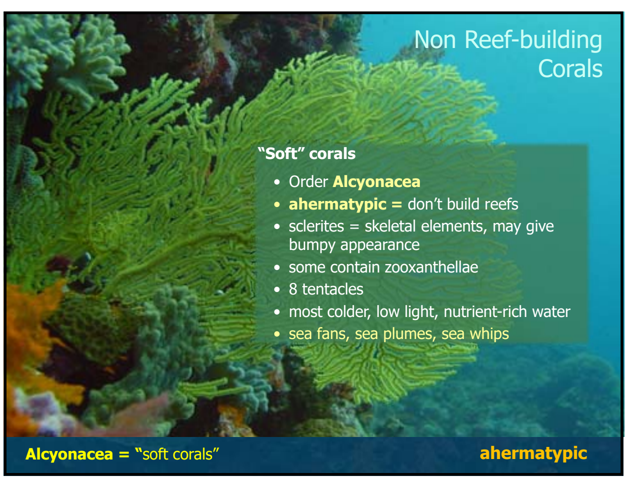

Corals and Relatives
Phylum Cnidaria
• corals, sea anemones, jellyfish, sea pens, sea wasps, hydras
• medusa and/or polyp form
• all have stinging cells: Cnidocytes with nematocysts
• Corals are in what class?

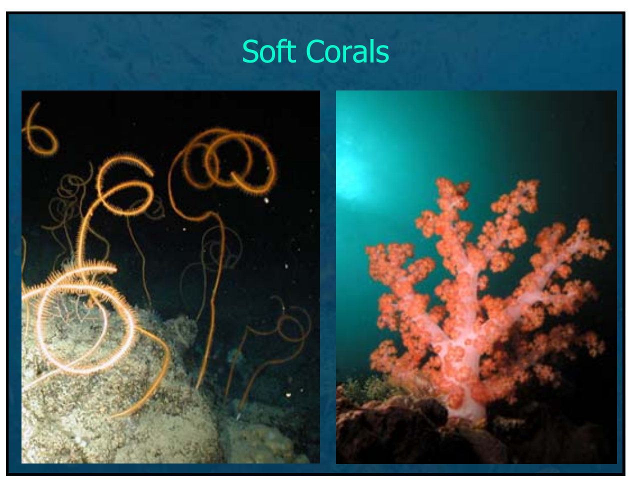

Reef-Building Corals
"Stony" corals – the reef builders!
Order Scleractinia
hermatypic: reef-building
calcification deposit $CaCO_3$ skeleton
most contain zooxanthellae
6 tentacles / septae
mostly warm, well-lit, oligotrophic water

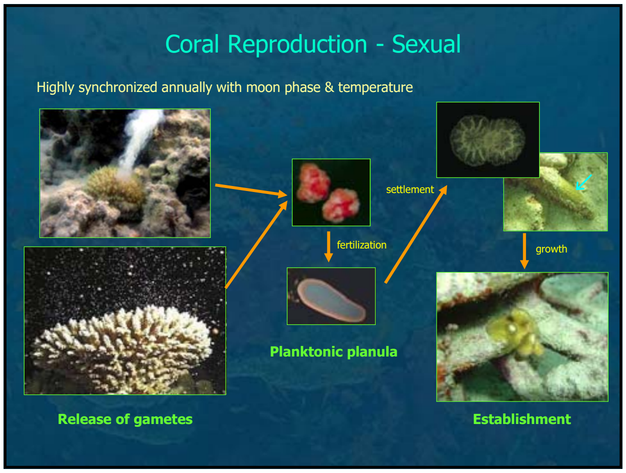

Zooxanthellae = dinoflagellate endosymbionts
supply hermatypic corals with 50-90% of their energy needs

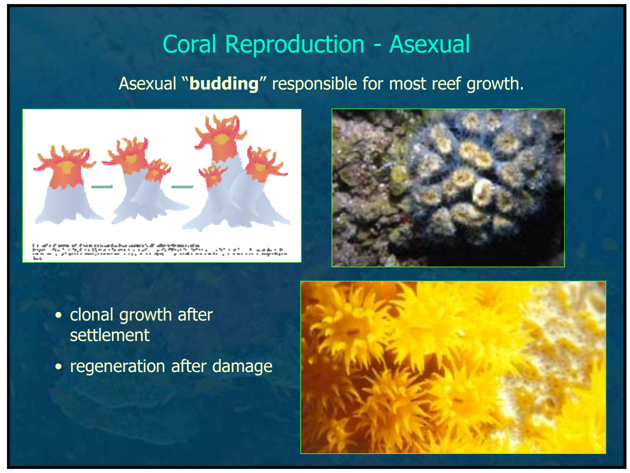

Reef-building Coral – growth forms
Scleractinians = "stony corals"
hermatypic

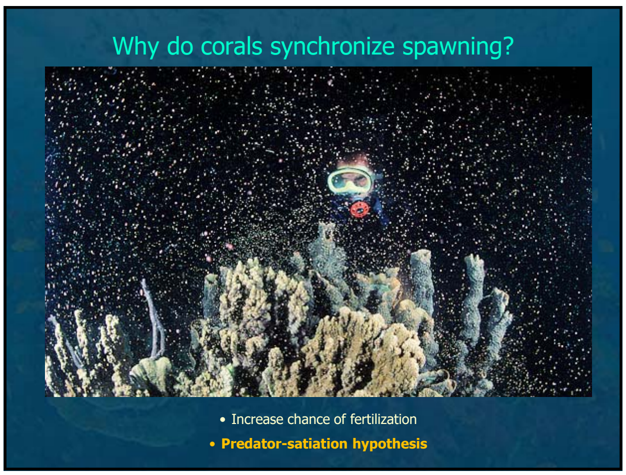

Keystone Species
build the reef!
complex 3D habitat
huge substrate
diverse homes for fish
food

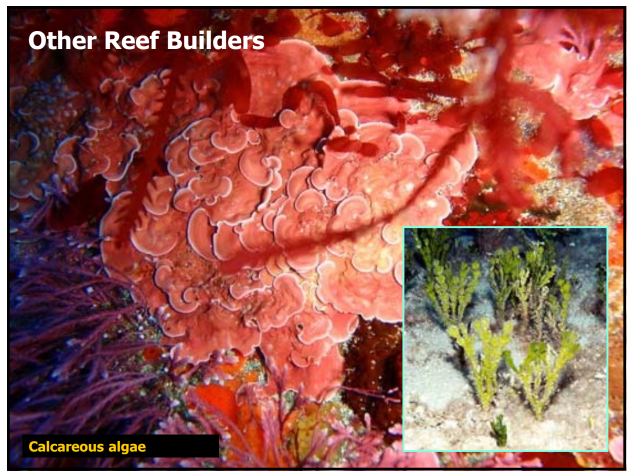

Non Reef-building Corals
"Soft" corals
Order Alcyonacea
ahermatypic = don't build reefs
sclerites = skeletal elements, may give bumpy appearance
some contain zooxanthellae
8 tentacles
most colder, low light, nutrient-rich water
sea fans, sea plumes, sea whips
Alcyonacea = "soft corals"
ahermatypic

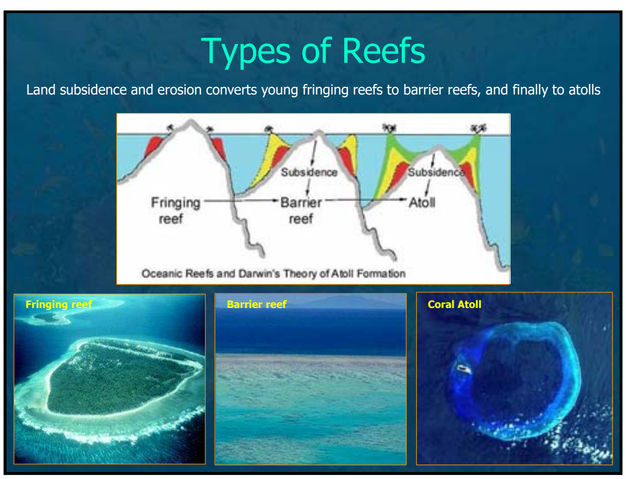

Soft Corals

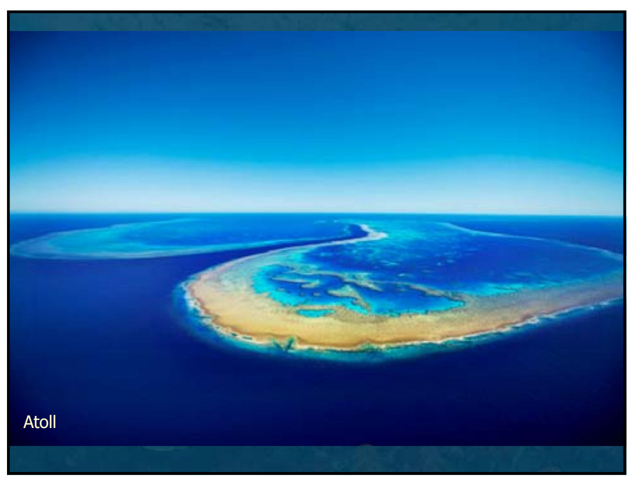

Coral Reproduction - Sexual
Highly synchronized annually with moon phase & temperature
settlement
fertilization
growth
Planktonic planula
Release of gametes
Establishment

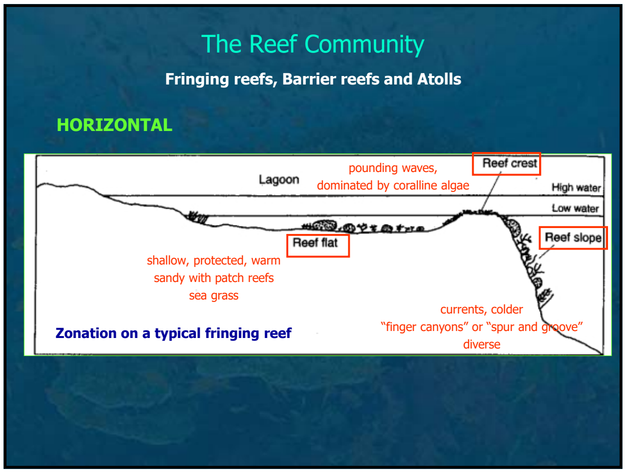

Coral Reproduction - Asexual
Asexual "budding" responsible for most reef growth.
• clonal growth after settlement
• regeneration after damage

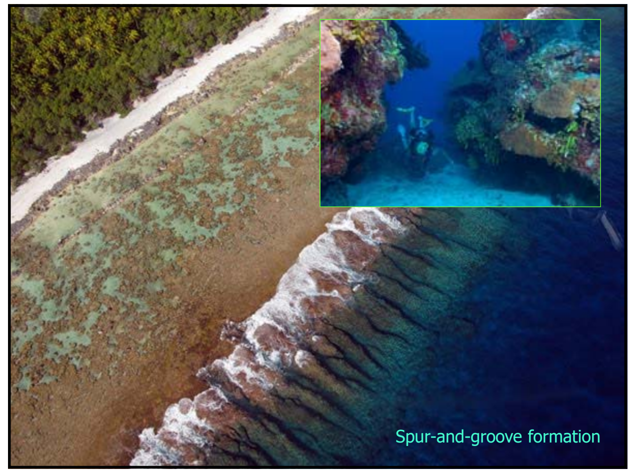

Why do corals synchronize spawning?
• Increase chance of fertilization
• Predator-satiation hypothesis

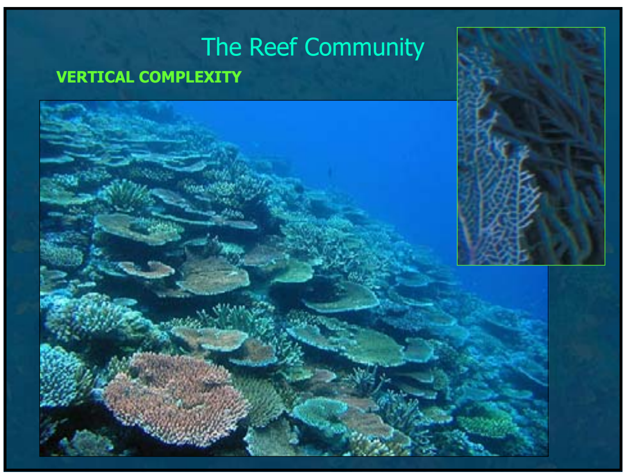

Other Reef Builders
Calcareous algae


Types of Reefs
Land subsidence and erosion converts young fringing reefs to barrier reefs, and finally to atolls
Subsidence
Subsidence
Fringing reef
Barrier reef
Atoll
Oceanic Reefs and Darwin's Theory of Atoll Formation
Fringing reef
Barrier reef
Coral Atoll


Atoll

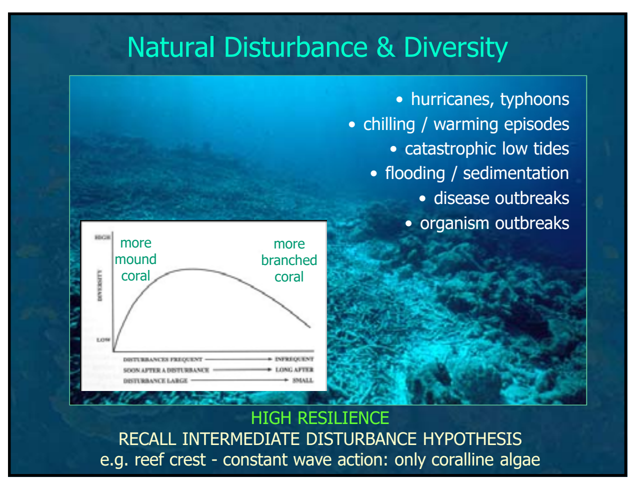

The Reef Community
Fringing reefs, Barrier reefs and Atolls
HORIZONTAL
Lagoon
pounding waves,
dominated by coralline algae
Reef crest
High water
Low water
Reef flat
Reef slope
shallow, protected, warm
sandy with patch reefs
sea grass
currents, colder
"finger canyons" or "spur and groove"
diverse
Zonation on a typical fringing reef


Spur-and-groove formation


The Reef Community
VERTICAL COMPLEXITY

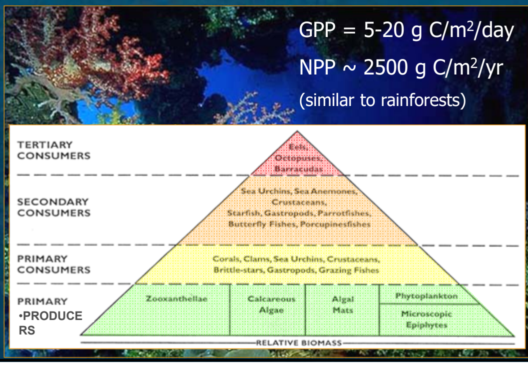

Competition for Light & Space
COMPETITION
• Light
• branched corals = fast growing, light demanding
• mound corals = slower growing, more shade tolerant
Staghorn coral - Acropora palmata
Mound coral Orbicella


Competition for Light & Space
COMPETITION
• Space
• coral vs. algae
• coral vs. coral
• nematocysts & inhibitory chemicals


Natural Disturbance & Diversity
• hurricanes, typhoons
• chilling / warming episodes
• catastrophic low tides
• flooding / sedimentation
• disease outbreaks
• organism outbreaks
more mound coral
more branched coral
HIGH RESILIENCE
RECALL INTERMEDIATE DISTURBANCE HYPOTHESIS
e.g. reef crest - constant wave action: only coralline algae

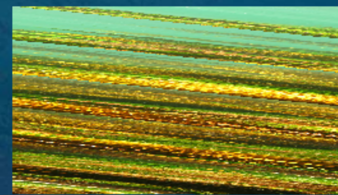
Primary Productivity

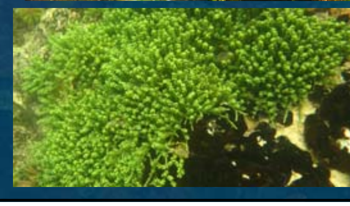
Coral reefs have enormous **gross primary productivity** compared to the surrounding ocean



Trophic Groups - Primary Producers

PRIMARY PRODUCERS
- **Macroalgae**
  - calcareous algae
  - macro-algal mats
- important food source
- fast growing
- competes with coral for space
- some invasive

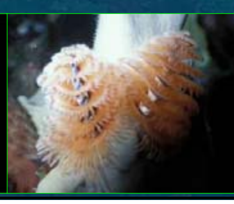




Trophic Groups – Planktivores

Suspension Feeders – feed on suspended plankton and POM
- **Filter feeders** – relies on currents, sifting structure
  - sponges, polychaete worms, bivalves
  - corals = heterotrophism increases with depth
- **Fish, birds, whales**
  - gill rakers in fish
  - e.g., herring, whale shark, pelican, baleen whales





Trophic Groups - Herbivores

HERBIVORES
- **"Grazers"** – feed on algae
  - fish: damsels, surgeons, parrotfish
  - urchins, gastropods

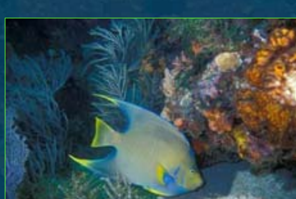

sea urchin


surgeonfish


nudibranch

Ecological Interactions - Herbivory

GRAZING
- prevents competitive exclusion of coral by algae
- 50 - 100% algae cover removed by grazers
- ↑ algal diversity, ↓ algal cover
- opens up space for coral recruitment

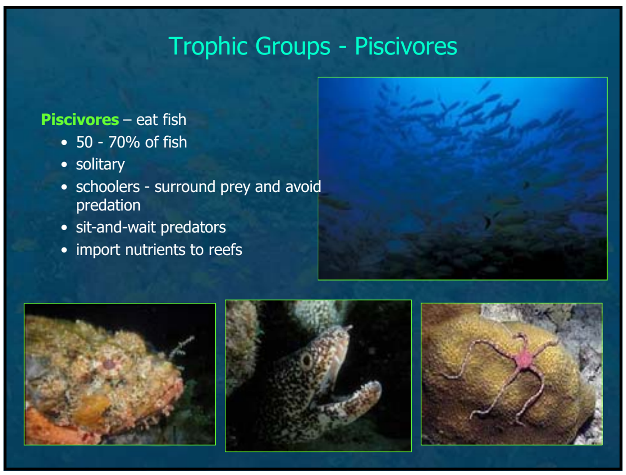

Importance of Grazing on Reefs

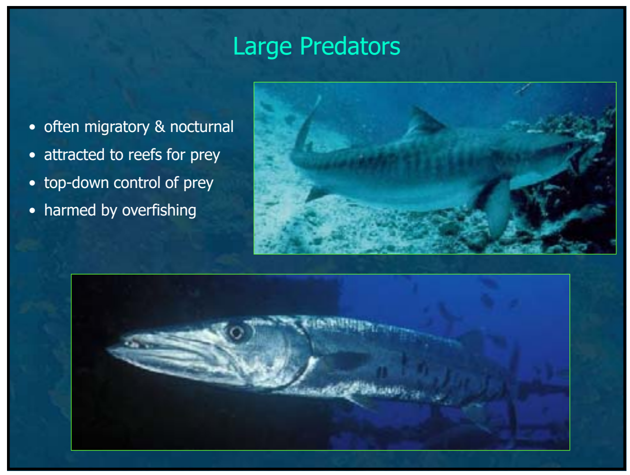
- **CASE STUDY** – *Diadema antillarum* urchin
- 1980 hurricane killed coral
- 1984 – die-off of *Diadema* urchins
- overfishing had reduced other grazers
- algae smothered corals
- >75% coral mortality in Jamaica
- Essentially irreversible

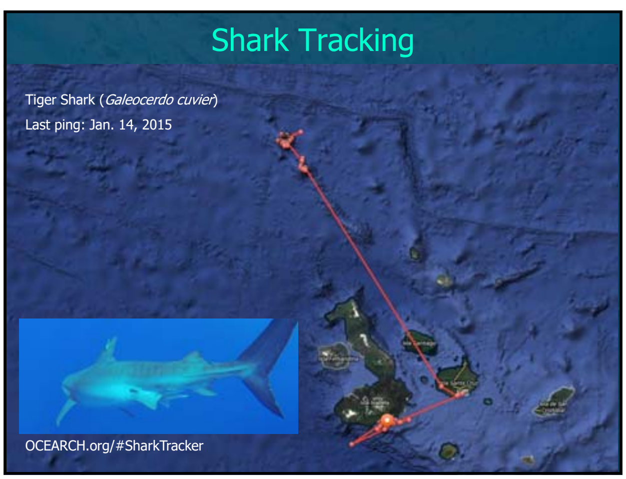
Multiple stressors have virtually eliminated coral reefs from Jamaica's waters. Right: A once vibrant coral reef now smothered with algae and devoid of coral and fish.


Damselfish – a keystone grazer
• algae "farmers"
• exclude other herbivores
• coral cover ↑ outside territories
• contribute to heterogeneity/diversity


Trophic Groups - Corallivores
• specialized "beak" for biting coral
• help to maintain coral diversity
• transfer NPP up the food chain
• Parrotfish create sand
• Pufferfish, Triggerfish, Sea stars


Trophic Groups - Piscivores
Piscivores – eat fish
• 50 - 70% of fish
• solitary
• schoolers - surround prey and avoid predation
• sit-and-wait predators
• import nutrients to reefs


Large Predators
• often migratory & nocturnal
• attracted to reefs for prey
• top-down control of prey
• harmed by overfishing


Shark Tracking
Tiger Shark (Galeocerdo cuvier)
Last ping: Jan. 14, 2015
OCEARCH.org/#SharkTracker

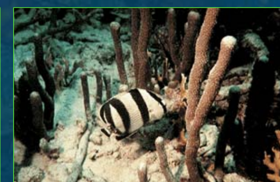

White-tipped Reef Shark
Nocturnal Foraging in Packs

Crypsis: A scorpionfish on a reef

Ecological Interactions - Predation

AVOIDING PREDATION - major pressure!

- schooling (strength in numbers)
- spines (urchins, fish)
- shells (bivalves, crustaceans)
- stinging cells (cnidarians, nudibranchs)
- toxicity + aposematic coloration (nudibranchs)
- disruptive coloration – bold banding
- inflating (pufferfish)



Crypsis: A flounder on a sandy bottom

Ecological Interactions - Predation

CROWN-OF-THORNS STARFISH (COTS)

- natural population booms in **Indo-Pacific**
- devours coral
- natural predator harvested for shell – Triton
- **blast-fishing** inhibits coral recovery
- overfishing takes out grazers
- algae takes over (Alternate stable state)

increased survival of COTs larvae due to nutrient loading and absence of predators

The triton snail eats COTS

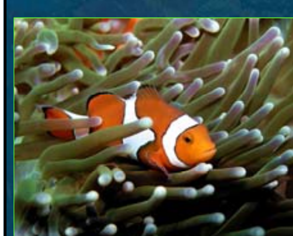
Ecological Interactions - Mutualisms

Many, many on the reef

corals + zooxanthellae

anemonefish

cleaning stations: wrasses, barberfish



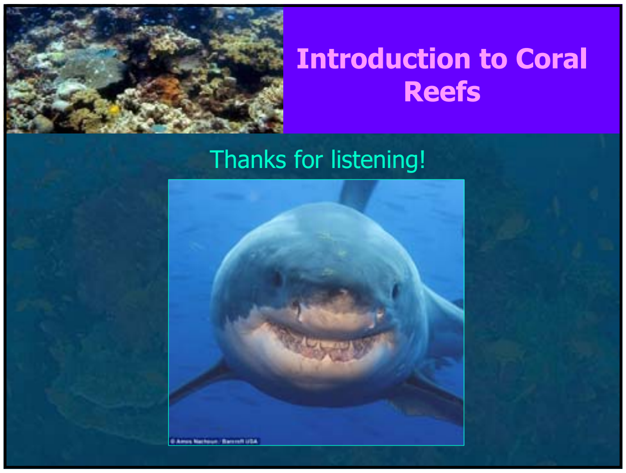
Maintenance of Diversity – Reefs vs Rainforests

Competition leads to niche-partitioning

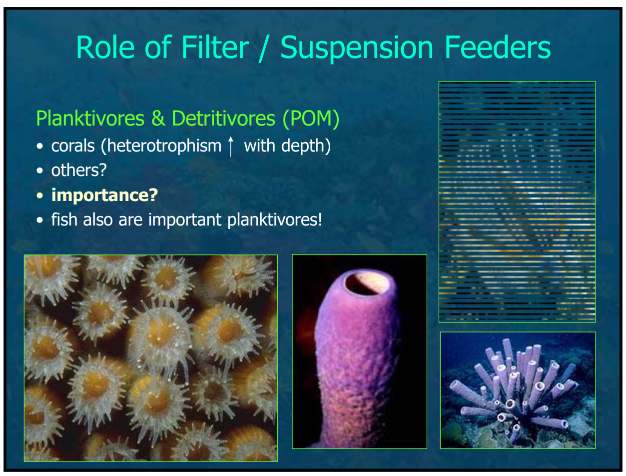
Grazing and predation prevent competitive exclusion

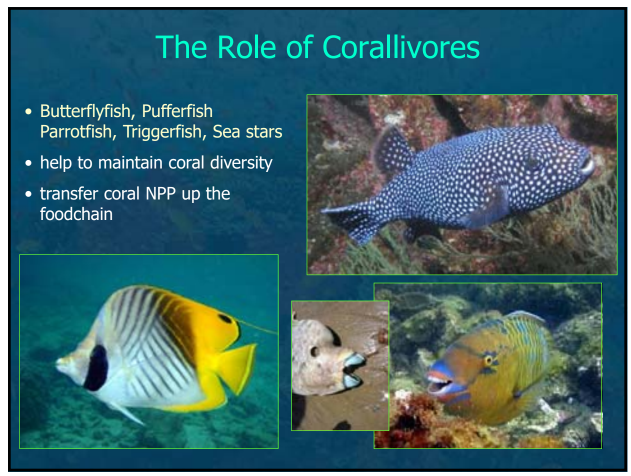
Natural disturbance plays a role

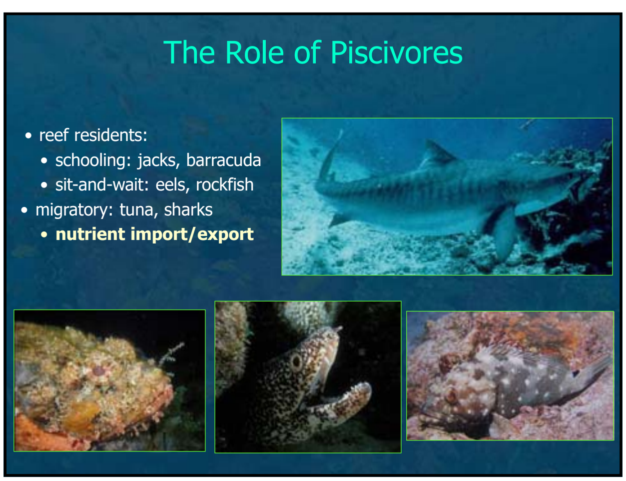
Reefs are resilient, but vulnerable


Introduction to Coral Reefs
Thanks for listening!


Importance of Grazers
GRAZING
• fish, urchins, sea turtles
• 50 - 100% algae removal
• prevents competitive exclusion of coral by algae
• ↓algal cover, ↑ algal diversity,
• removal of herbivores (fishing) = ↑ algae cover


Role of Filter / Suspension Feeders
Planktivores & Detritivores (POM)
• corals (heterotrophism ↑ with depth)
• others?
• importance?
• fish also are important planktivores!


The Role of Corallivores
• Butterflyfish, Pufferfish Parrotfish, Triggerfish, Sea stars
• help to maintain coral diversity
• transfer coral NPP up the foodchain


The Role of Piscivores
• reef residents:
• schooling: jacks, barracuda
• sit-and-wait: eels, rockfish
• migratory: tuna, sharks
• nutrient import/export


Video Census of Fish

Rainforests vs. Coral Reefs

"Coral reefs are rainforests of the sea" – is this a good analogy?

SIMILARITIES

High productivity
Nutrient poor substrates
Diversity disproportionate to total area
Structurally diverse
Complex food webs
Globally threatened

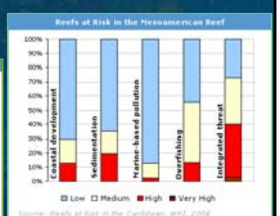
DIFFERENCES

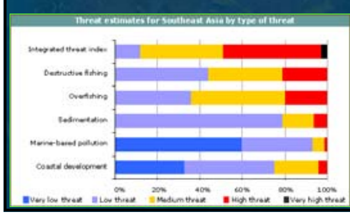
More species in rainforest, more phyla in coral reefs.
Rainforests: beetles, plants and birds.
Reefs: molluscs, fish and algae

Human Impacts & Threats

REEFS AT RISK…Overfishing is #1

- 88% of SE Asian reefs threatened
- 66% of Caribbean reefs threatened
- 50% coral loss on U.S. reefs
    - major cause = coastal development
- Climate change now major threat…





Ecological Interactions & Synergisms

CASE STUDY – *Diadema antillarum* urchin

- 1980 hurricane killed coral
    - usual algae proliferation
- 1984 – *Diadema* die-off
    - 93 - 99% mortality in Caribbean
- overfishing: reduced other grazers
- overgrowth of algae
- >75% coral mortality in Jamaica
- **Alternate stable state**
    - Essentially irreversible

Ecological Interactions & Synergisms

CASE STUDY: Crown-of-Thorns seastar

- *Acanthaster planci* corallivore
- increasing outbreaks in **Indo-Pacific**
    - humans harvest predators
    - increased larval survival
- blast-fishing / sedimentation inhibits coral recovery
- overfishing: algae takes over

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Sarah Brooker

The Great Barrier Reef has lost half of its coral in the last 27 years

2 OCTOBER, 2012
MARINE

Can we save the Reef by controlling crown of thorns starfish?

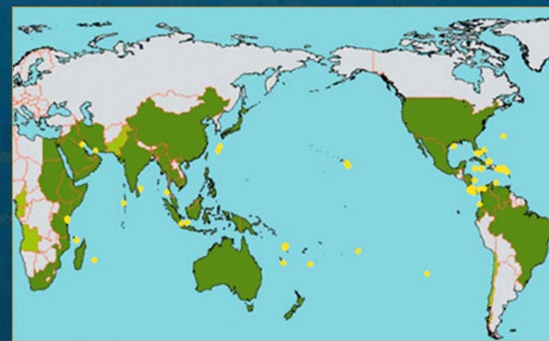
The Great Barrier Reef has lost half its coral cover in the last 27 years. The loss was due to storm damage (48%), crown of thorns starfish (42%), and bleaching (10%) according to a new study published in the Proceedings of the National Academy of Sciences today by researchers from the Australian Institute of Marine Science (AIMS) in Townsville and the University of Wollongong.

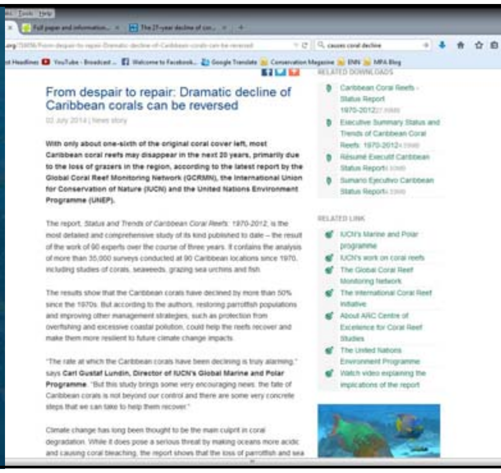
"We can't stop the storms but, perhaps we can stop the starfish. If we can, then the Reef will have more opportunity to adapt to the challenges of rising sea temperatures and ocean acidification, says John Gunn, CEO of AIMS.

Signs of Stress: Coral Bleaching

common response to temperatures >30°C
high temp or low temp
high CO_2
low pH
low O_2
rapid, reversible if short

Bleaching Hotspots





From despair to repair: Dramatic decline of Caribbean corals can be reversed

02 July 2014 | News story

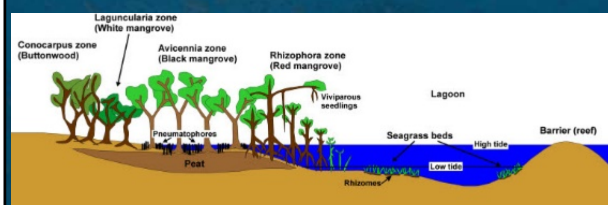
With only about one-sixth of the original coral cover left, most Caribbean coral reefs may disappear in the next 20 years, primarily due to the loss of grazers in the region, according to the latest report by the Global Coral Reef Monitoring Network (GCRMN), the International Union for Conservation of Nature (IUCN) and the United Nations Environment Programme (UNEP).

The report, *Status and Trends of Caribbean Coral Reefs: 1970-2012*, is the most detailed and comprehensive study of its kind published to date – the result of the work of 90 experts over the course of three years. It contains the analysis of more than 35,000 surveys conducted at 90 Caribbean locations since 1970, including studies of corals, seaweeds, grazing sea urchins and fish.

The results show that the Caribbean corals have declined by more than 50% since the 1970s. But according to the authors, restoring parrotfish populations and improving other management strategies, such as protection from overfishing and excessive coastal pollution, could help the reefs recover and make them more resilient to future climate change impacts.

"The rate at which the Caribbean corals have been declining is truly alarming," says **Carl Gustaf Lundin, Director of IUCN's Global Marine and Polar Programme**. "But this study brings some very encouraging news: the fate of Caribbean corals is not beyond our control and there are some very concrete steps that we can take to help them recover."

Climate change has long been thought to be the main culprit in coral degradation. While it does pose a serious threat by making oceans more acidic and causing coral bleaching, the report shows that the loss of parrotfish and sea



Human Impacts & Threats

Destructive fishing

Bottom Trawling

Blasting

- high **bycatch** and collateral damage

Aquarium fish trade

- poorly regulated
- 60% to U.S.
- >90% mortality
- Marine Aquariums Council

Human Impacts & Threats

Tourism

- coastal development
- boat anchors, trampling
- sewage, sunscreen, trash
- 25 out of 30 Caribbean countries

Ex.: Maldives

snorkelers damaged 17% branched coral, 7% of all coral

Human Impacts & Threats

Sedimentation

- deforestation
- coastal development
- dredging
- up to 50 mg/cm^2/day = 50X normal rates

Effects

- blocks light
- physically clogs polyps
- increased disease
- coral bleaching
- **eutrophication**

Signs of Stress: Disease

Black Band Disease

White Band Disease

perhaps due to increased mucus secretion

Human Impacts & Threats

EXACERBATING NATURAL DISTURBANCES

Climate Change

- rapidly increasing sea temperature
- ocean acidification
- increased intensity / frequency of storms
- sea level rise

Effects on Coral Reefs

- **coral bleaching**
- reduced calcification rates
- increased mortality
- reduced growth

1996 - Healthy 1997 - Bleached