Coral Reefs

sponges and corals are familiar to most people as main components of **coral reefs**

Coral Reef Diversity

coral reef communities are the most luxuriant, complex and diverse of all aquatic communities

while they are dominated by coral species practically all animal phyla are represented

an abundance of sponges, clams, snails, octopi, squid, worms, fish, eels, sea stars, sea urchins, shrimp, crab, etc

also seaweeds, algae, bacteria, protists, etc

each species of life has developed ways to cooperate and compete within a myriad of nooks and crannies

reef ecosystems are characterized by **high diversity**

→ lots of competition especially for space & food

eg. algae, sponges and corals are constantly growing over and killing each other

eg. most reef fish are very localized with specific feeding preferences

eg. reef fish even differ between day and night

coral reefs cover 0.1% of earth's surface area

all kinds of reefs cover 1.5 M sq miles (=568,600 km^2)

(the most productive *shallow water reefs*, ie. reefs in <30m of water, cover ~0.75 M sq. miles (=284,300 km^2) = area ~ size of Italy)

coral reefs contain about 200,000 known species (~15% of all species)

tropical rainforests
6% of earth's surface; **14 M sq mi**, support ~**50%** of all species

coral reefs
0.1% of earth's surface; **1.5 M sq mi**, support **~15%** of all species

→Diversity per unit area: coral reefs are 400-500 times more diverse than rain forests

→ but estimates range from 600,000 to 9 M species worldwide

eg. 32 of the 34 animal phyla are found on coral reefs compared to only 9 of the 34 found in the rainforests

eg. >1/4th of all marine fish species are associated with coral reefs

Reefs are unique ecosystems:

1. reefs are the largest biological structures on the earth

2. their structure is created by biological activity
→ they create their own ecosystem

massive deposits of calcium carbonate
→ esp by corals
→ also coralline algae, mollusks, and a few other groups

3. coral reef communities have survived for 1000's or 10,000's of years

relatives of corals appeared over 500 MY ago
→ mainly solitary individuals

modern colonial reef building forms appeared and diversified in the last 25 M years

eg. one reef (Eniwetok) is ~ 4000' thick (1283 m) and estimated to be over 60 M years old

oldest reefs are in the pacific; youngest in the atlantic (10-15,000 years old)

the extensive vertical growth of reefs is the result of changes in sea level &/or subsistence of the seabed

→ virtually all modern reefs have grown upward due to recent sea-level rise beginning ~18,000 BP (rate of 3-15 M (10-40')/1000yrs)

→ some of the thickness may also be due to subsistence (especially at atolls and some barrier reefs)

Where are Coral Reefs

individual corals are found in all oceans from the poles to the equator

but coral reefs are only found in warm, clear equatorial waters

→ waters >68º F (20º C)

tropical reefs are most common in the western Pacific and Indian Oceans

many are **brightly colored**

numerous symbioses occur between reef organisms

yet most reefs grow in areas of ocean with fewest nutrients

→clear clean water = nutrient poor water

Reef Requirements & Structure

to become established a reef has some essential requirements:

1. hard substrate

initial growth requires a **hard surface** (firm base) on which to start construction

reef forming organisms are mainly **sessile, benthic animals**

= animals that live in or on a substrate (don't swim in open ocean)

2. warm tropical temperature

reef communities are also restricted by water **temperature**

→ most occur only in tropical and subtropical seas (±30º latitude)

where average water temperature ~23º - 25º C

none are found below 18º C

few on W coast of N America or Africa due to upwelling of cold water

3. shallow

most reefs grow depths of 75 ft (25 M) or less

limit is 50-70 M

they are therefore restricted to coastal areas or seamounts

most reef building corals contain **symbiotic photosynthetic algae** that require sunlight

→ form basis of reef food chain

not too deep (to 60M)
→ light is quickly filtered out
→ depth of active reef is restricted by light penetration

the growth and health of the coral community is directly dependent on the amount of light reaching the reef

4. salinity near 33_{ppt}

normal salinity of sea water
→ can't withstand lower salt concentrations

eg. don't see any near E coast of S America because of outflow of Amazon River

5. clear

reef organisms require **clear waters** to allow their photosynthesis

→ low amounts of dissolved materials and few nutrients
→ not at mouth's of large rivers

if the water is shallow, but murky (turbid) sunlight will not get through for photosynthesis

also, too much sediment will smother the polyps

another reason why they are not usually found near outlets to large rivers

6. Prefer areas with Strong Wave Action

wave action oxygenates waters, brings in nutrients, and reduces sedimentation

<u>Established Reefs</u>

once established, **reefs create their own environment**:

coral colonies form the main framework of a reef

→ may be over 100 species of corals alone

the coral colonies are able to extract **calcium carbonate** from sea water to form the reef structure

→ they use sugar produced by the algae that live inside their tissues to do this

→ without the algae the corals cannot grow

most reef building corals contain **symbiotic photosynthetic algae** (=zooxanthellae)

present in enormous populations
provides a vital energy source for the reef organisms
base of reef food chain

this symbiosis is beneficial to both organisms:

<u>corals</u>	**<u>algae</u>**
provide CO_2	provide O_2
N, P	remove wastes
	make organic nutrients

some corals also have symbiotic nitrogen fixing cyanobacteria

→numerous crevasses and holes provide excellent hiding places

→ create numerous habitats

→any exposed surface created when organisms die, is quickly attacked by boring organisms especially sponges. worms and clams

→as organisms live and die get build up of coral skeletons, encrusting algae, shells, etc

→waves also break up and destroy old reef material

→fine materials settles into crevasses and holes
→ fills spaces
→ cements reef together

coral reefs show very **rapid recycling of nutrients** (similar to rainforests)

→ virtually all the nutrients the algae create are cycled to corals and the rest of the food web

→ prevents nutrients from sinking out of productive sun lit zone and lost

→produce several times more organic material/area than phytoplankton communities

reef communities show **numerous symbioses and interactions**

eg. zooxanthellae, sponge symbionts, crabs, molluscs, cleaner fish, etc

a common characteristic of many reef organisms is **mass spawning events**

most corals are **hermaphrodites**

take 7-10 years to reach sexual maturity

corals don't have complex nervous systems or sense organs yet many coordinate their release of sperm and eggs within the same few evenings each year, sometimes timed to within minutes of each other

each year, at late-spring full moon, 100's of coral species simultaneously spawn

→ synchronized by a light sensitive pigment in the coral animals

Kinds of Reefs

Two general types of reefs:

1. Fringing Reefs or Barrier Reefs

most common type
surround islands and border continents
grow in shallow waters and border the coast closely or may be separated by a shallow stretch of water
project seaward directly from shore
subdivided into several zones:
reef crest – part of reef the waves break over

forereef – medium energy
buttress (spur & groove) – rows of coral with sandy canyons or passages between rows

eg. Great Barrier Reef is longest in world ~1000 miles

2. Atolls

at summits of submerged volcanoes (seamounts)
usually circular or oval with a central lagoon

Reef Zonation

Both reef types show similarities in profile (vertical zonation)

these differences due mainly to differences in wave energy and water depth

a. Reef Face

seaward side
inclined from gentle to steep slopes
often with terraces creating more zonation

10-20M: (30-60') high energy – help to dissipate wave energy
grooves drain off sand
masses of large dome shaped and columnar corals, large fish

20-30M: (65-100') little wave energy
only 25% of surface light reaches here
more delicately branched corals

30-40M: (100-130') gentler slope
very reduced light
sediments accumulate here
corals become patchy

>50M: (>165') slope drops off sharply

b. Reef Crest

highest point of reef front
exposed at low tide, covered by waves at high tide
elkhorn coral and shelf coral

c. Reef Flat (back reef)

sheltered, lagoon side
highly variable
short to several 100 meters
lowest energy, coral sand
delicate corals, eg. staghorn
becomes shallower and supports sea grasses

Reef communities are characterized by a coordinated reproductive frenzy at specific times of the year often late spring: "spawning"

→ one species after another will discharge reddish clouds of eggs and milky white sperm into the water

→ described as an underwater 'snowstorm'

Economic Impacts of Coral Reefs:

reef communities have significant impacts on human economies and activities:
fisheries
tourism
coastal protection
pharmaceuticals

1. Fisheries

eg. worldwide, coral reefs provide 1/4th of the annual commercial fish catch and feed over 1 Bil people in asia alone.

eg. US reefs support millions of jobs and a $200 M annual fishery

on global basis
1/2 sq mile of reef:
→ can sustainably yield 15 tonnes of fish and other seafood/yr
→ $8.6 M in revenue/yr

2. Tourism

eg. reefs of the florida keys generate $1.2 Bil/yr in tourist dollars

3. Biochemicals

many marine animals produce biologically active compounds
the earliest known use of marine resources was for medical uses:

2700 BC – China – medical text

scientists have extracted over 20,000 new biochemicals from marine life, mainly from coral reef organisms over past 20 yrs(04)

perhaps 10% of all marine organism could yield medically important compounds

since the greatest marine diversity is in coral reefs, they offer the greatest possibilities for potential uses

scientists first began looking at softbodied sessile organisms of coral reefs because they thrived under highly competitive conditions with no apparent claws, teeth, etc for defense

→ must use chemical weapons

Some examples:

a. Sponges
antibiotics, antitumor drugs, antifungal drugs

b. Corals
antiinflammatories, painkillers for arthritis, antimicrobials

cardiac stimulant from sea anemone

c. Segmented Worms

insecticides and anticancer drugs
eg. Padan – a powerful insecticide produced from a polychaete worm
eg. dolastatins from sea hare (Dolabella auricularia) has potential anticancer properties

d. Snails & Other Molluscs
muscle relaxants, painkillers
adhesives

e. Bryozoa
potent anticancer chemicals

f. Tunicates
antiviral, antitumor
including possible treatment for malignant melanoma
→ the most dangerous form of skin cancer

by some estimates, coral reefs provide over $30 Billion in benefits (direct and indirect) , worldwide per year

destroying 1/2 sq mi of reef costs $137,000-$1.2 M in loss of fisheries, tourism and shoreline protection over a 25 year period.

<u>Threats to Reefs:</u>

Coral Reefs are among the most endangered ecosystems in the world

recent ('03) assessments of world's reefs show they are globally threatened

→ there are no "pristine" reefs left:
all reefs are impacted by human activities
only reefs in remote areas are generally healthy

→ 30% of reefs are damaged
up to 30% have been lost in last 50 years(06)
another 16% are severely damaged

→ 60% may be completely dead by 2030

generally, coral reefs are very resilient
→ have existed for 1000's to 100,000's of years

but today are being degraded in a matter of decades

the greatest threats to reefs are from human activities

eg. ~1/2 of world's population live in coastal regions

eg. in SE Asia, 70% of population is in coastal areas

<u>Coral Bleaching</u>

one of earliest signs of stress is **coral bleaching**

→ when water gets too warm algae "flee" their coral hosts

therefore lose their color

triggered by disease, pollution, elevated temperatures, salinity changes, increased UV radiation, etc

bleaching is a normal response to short term stresses

while bleached, corals stop growing
→ leaves reef vulnerable to erosion

after one bout the reef can recover,
→but frequent episodes may kill the coral polyps

what is significant about bleaching today is its frequency, severity and extent

Coral Reefs are associated with 109 countries, those in 93 countries show significant damage

reefs at highest risk:

Japan	Singapore	Taiwan
Sri Lanka	India	Indonesia
Asia		

eg. Phillipines
only 5% of reefs are pristine
30% are dead
39% are still healthy

all are areas with dense coastal populations and heavy coastal development

Human Causes of Coral Reef Decline:

while natural events, eg diseases and hurricanes can cause extensive damage to specific reefs

humans are having a global impact on reefs

human causes of reef decline:

1. **sedimentation**
2. **eutrophication**
3. **shipping and oil spills**
4. **exploiting for food (overfishing)**
5. **collecting**
6. **mining**
7. **tourism**
8. **Climate Change**
9. **Ozone Depletion**

1. Sedimentation

by far the greatest impact
increase in suspended silt, clay, dirt
mainly due to **deforestation** esp. mangroves
due to logging, farming, mining, dredging
doesn't have to occur near coast to have and impact
sediment blankets coral reef
initial plume blocks sunlight→reduces photosynthesis
smothers polyps
as they produce mucus to remove it, depletes their energy reserves; makes them more susceptible to disease
impedes larval settling

2. Eutrophication

food and nutrients usually limit the growth of most organisms

eg. N & P →plants, algae; organics→ bacteria, heterotrophs
reef ecosystems are especially susceptible since they are found in nutrient poor waters
too much food can upset the balance between organisms in the community:
some grow much faster than others and can become toxic
sometimes a new predator gains upper hand
eg. crown of thorns starfish → can clean out entire reefs when its predators are eliminated

some algal infestations caused by eutrophication cause algae to release sugars that fertilize the symbiotic bacteria making them pathogenic and killing their coral hosts

3. Shipping and Oil Spills

eg. oil tankers pollute and kill reefs
eg. 1st gulf war oil release (10M BBL's)
caused extensive damage to reefs in arabian sea
eg. in Mid East a phosphate tanker ran aground on a reef,
releasing phosphates into the water
killing 500 mi^2 of reef

4. Exploiting for Food (overfishing)

reef fish are prone to overfishing because many are slow growing, long lived fish (K-selected; low natural fertility)
when depleted they are slow to repopulate

historical record shows that over the last several 1000 years, large fish and animals have been hardest hit of reef community

blast fishing
use explosives to kill or stun fish
eg ~1/6th of reefs in Phillipines have been damaged this way since 1945

cyanide fishing

some use cyanide and poisons to fish
→ kills other organisms as well

child labor
in Phillipines 40 ships carry 300 children to reef each day
children pound reef with rocks to scare fish into nets
can destroy up to 1 km^2 of reef/day
children killed by needlefish, sharks, barracuda, poisonous snakes, etc

as fish become more scarce, fishermen earn extra income collecting turtles, clams, etc

5. Collecting

1.5 Million kg's (15 tonnes; 3M lbs) of coral & shells/year are harvested
mainly for "shell shops" around the world
~1/3rd from the Phillipines
most is exported
most goes to US gift shops and aquarium shops

live corals were collected and sold in Florida until 1989 when it was outlawed
but some is still traded on black market

shells etc collected by malacologists: prefer killing live specimens rather than dead shells from beach

exotic fish collected from reefs feed a $4 Billion/yr aquarium industry

6. Use as Building Material

in Sri Lanka and parts of India entire sections of reef have been removed to make cement
→there is no other source of rock nearby

7. Tourism (Ecotourism)

walking on reef and touching it kills polyps and kicks up sediment

many break off souvenirs of live reef
beauty of reef stimulates beach front developments

eg. On S Pacific Island of Palau
they mined an area of reef to build a new airport runway
→ to accommodate an increasing number of tourists coming to see the reef

eg. in Grand Caymans a 525' cruise ship dropped a 5 ton anchor and
dragged its chain across 150M of reef
creating a 3M wide path 150M long
uprooted 8M diameter blocks of coral
destroyed an area 1/2 the size of a football field

Indirect Human Effects:

8. Climate Change

global temperatures are increasing 1/2 – 1 degree every decade
this rate is 100x's faster than natural rate at end of last glaciation
most of this accelerated warming is due to human activities
global warming will
alter weather patterns
alter ocean circulation
warm ocean surface waters
cause significant sea level rise up to 6 cm/decade
→ but reefs can grow up to 10 cm/decade
cause acidification (lowering of pH) of ocean waters
→ dissolves coral skeletons; reefs don't grow
→ reduces reproductive success of coral eggs and larvae

9. Ozone Depletion

will continue into next century
→ozone levels decrease .5-5% over the tropics
→this causes a 1-10% increase in UV radiation

shallow marine communities are particularly susceptible to

damage from this additional radiation