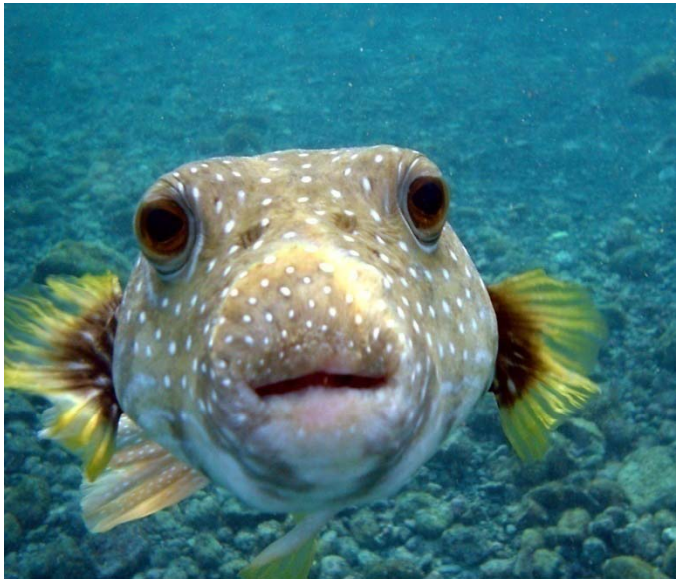
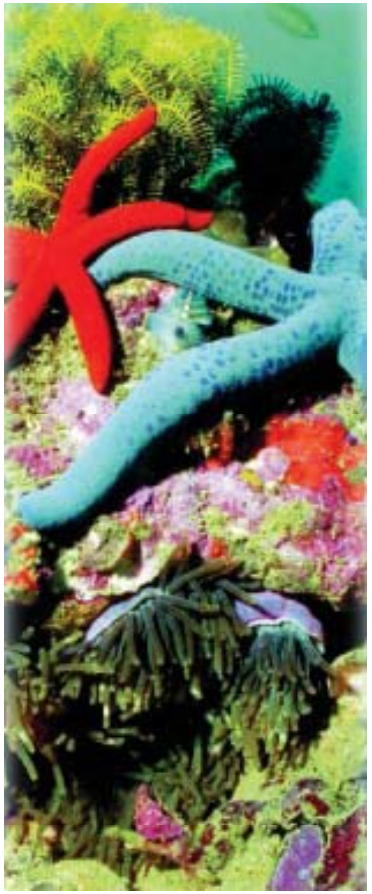
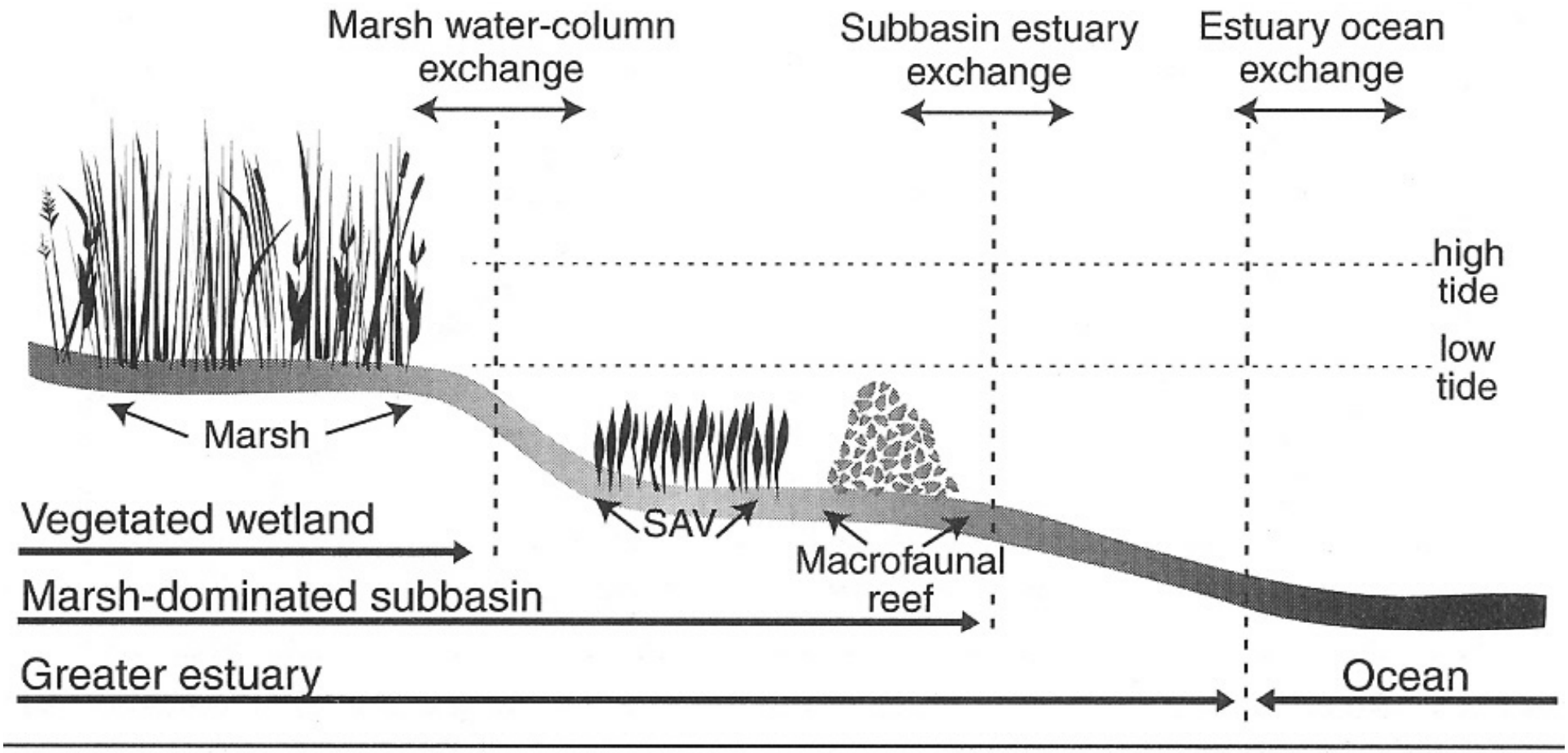


Coral Reefs
NREM 665




Marsh water-column exchange
Subbasin estuary exchange
Estuary ocean exchange
high tide
low tide
Marsh
SAV
Macrofaunal reef
Vegetated wetland
Marsh-dominated subbasin
Greater estuary
Ocean

I. Coral Reef (CR) Formation & Development

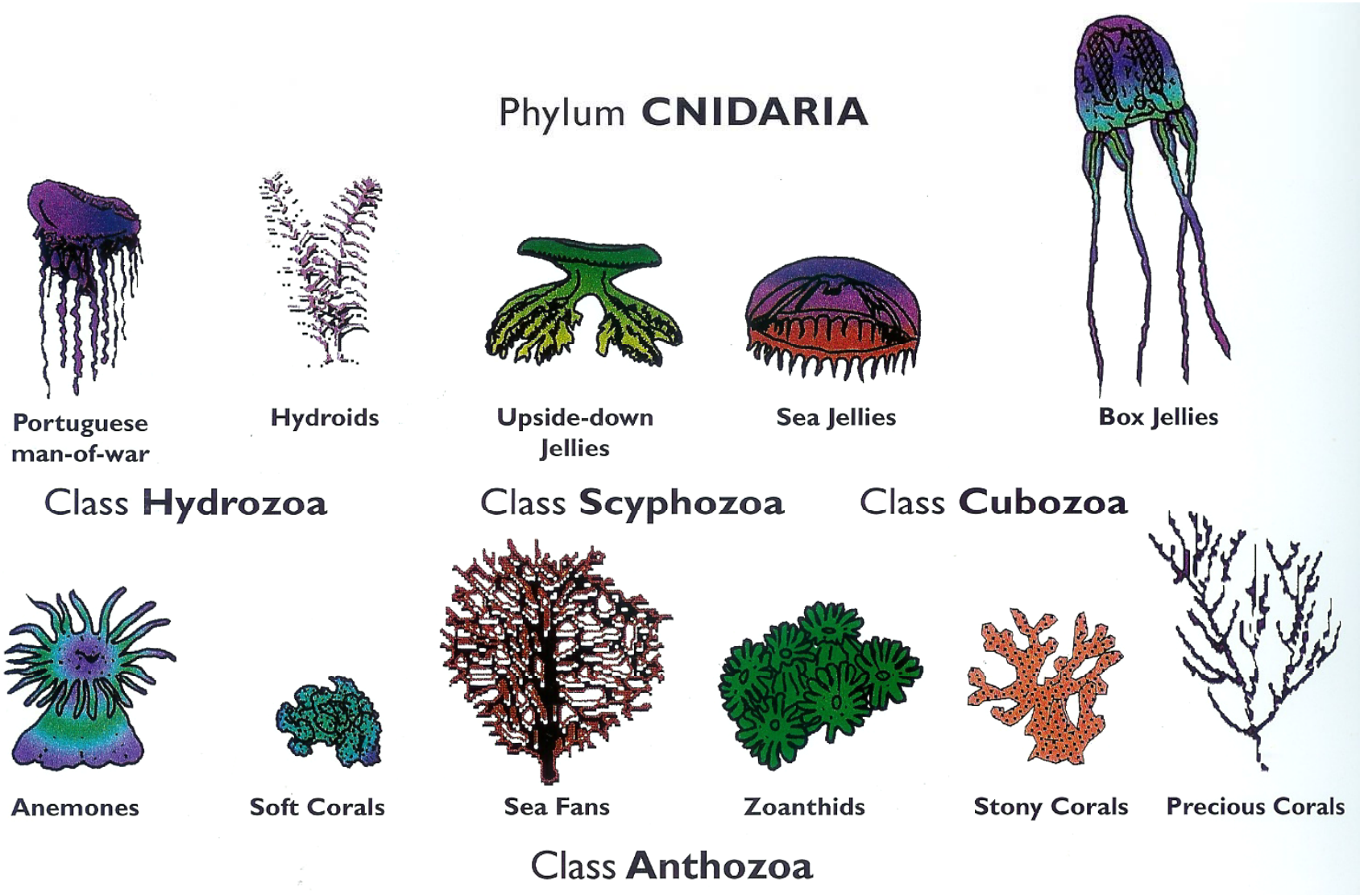
A. CRs are complex, 3-D, wave-resistant structures built by bio-activity

1. Dominant CR forming organisms = **scleractinian** corals, grow by means of accretionary exoskeleton

2. Structure consists of skeletal $CaCO_3$ deposited over yrs of accretion

3. Living coral forms thin layer over surface of skeletal matrix

B. Coral polyps are of Phylum: Cnidaria



(Gulko 1998)

1. Corals use nematocyst-laden tentacles to capture zooplankton, clear debris, & for defense (Boaden & Seed 1985)

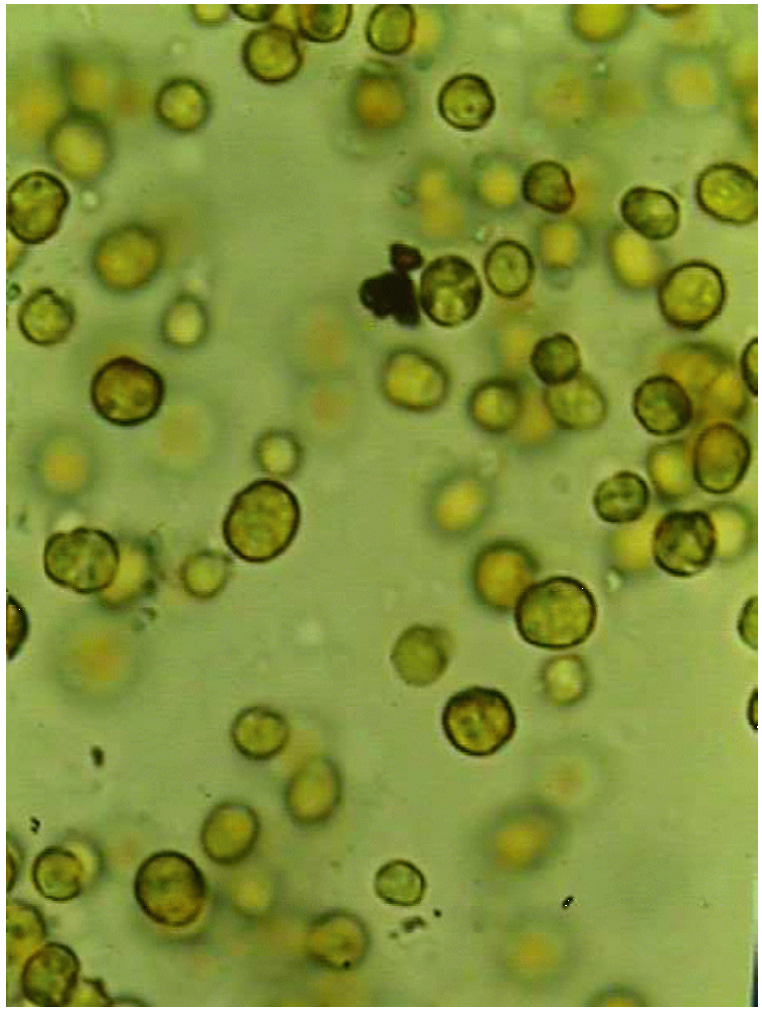
2. Individual polyps are small, collectively present vast feeding surface

C. Reef-building corals contain a dinoflagellate algae called?

1. line polyp digestive cavity

2. Play key role in reef building via influence on coral growth & calcification

3. Sunlight penetrates polyp tissue, zoo. carry out PSN & growth, obtaining CO_2, nutrients from polyps



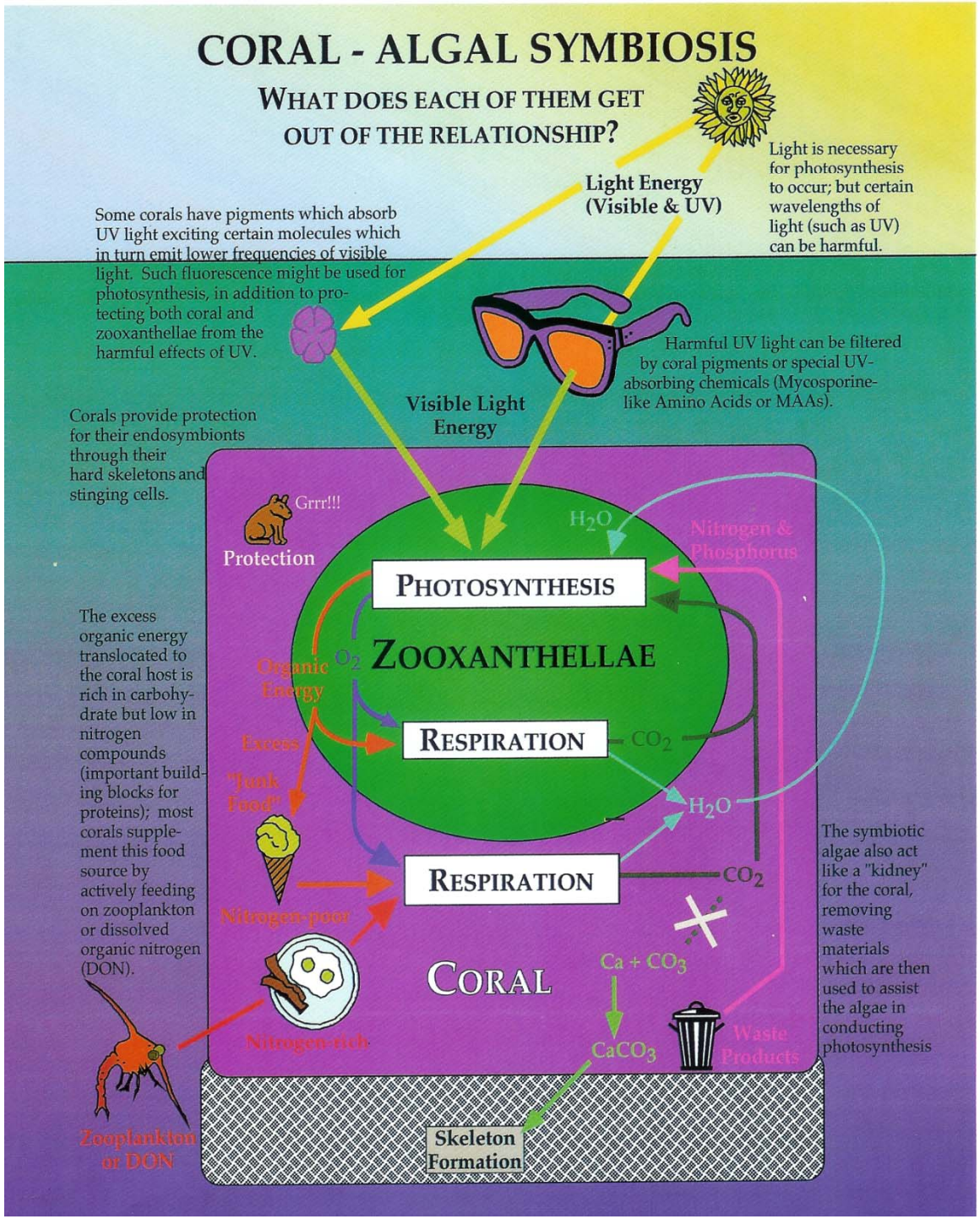
4. Zoo. prod. O_2, remove wastes, transfer excess C to polyps

   a. W/ high temp, salin, polyps expel zoo ~ bleaching ~

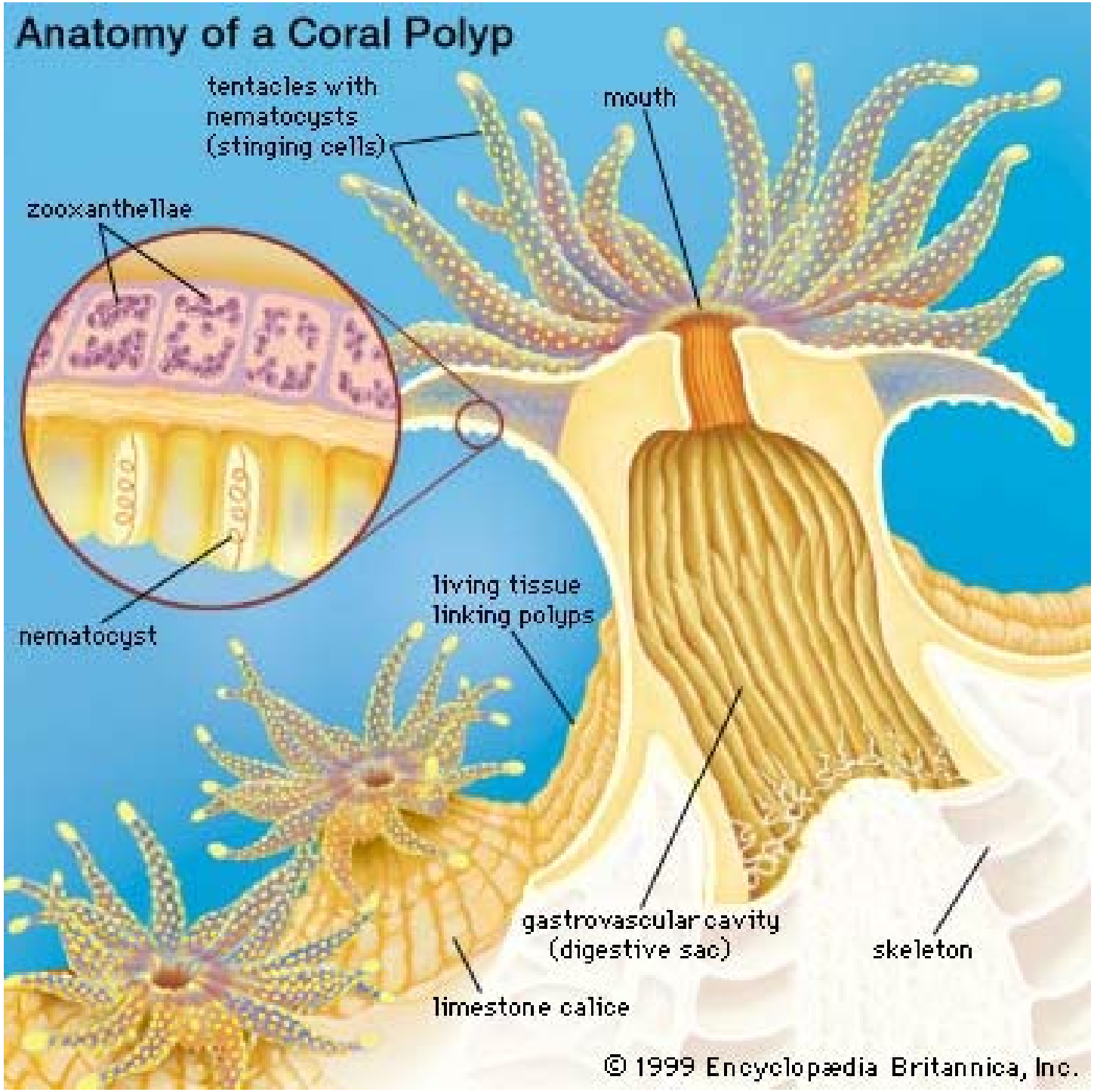
   b. polyps can host >1 spp of zoo w/ diff toler to light, temp.

   c. strong seasonal var iation in zoo. pops.

   d. w/o zoo. corals could not form large reef structures;


CORAL - ALGAL SYMBIOSIS
WHAT DOES EACH OF THEM GET OUT OF THE RELATIONSHIP?
Light Energy (Visible & UV)
Light is necessary for photosynthesis to occur; but certain wavelengths of light (such as UV) can be harmful.
Some corals have pigments which absorb UV light exciting certain molecules which in turn emit lower frequencies of visible light. Such fluorescence might be used for photosynthesis, in addition to protecting both coral and zooxanthellae from the harmful effects of UV.
Harmful UV light can be filtered by coral pigments or special UV-absorbing chemicals (Mycosporine-like Amino Acids or MAAs).
Visible Light Energy
Corals provide protection for their endosymbionts through their hard skeletons and stinging cells.
Grrr!!!
Protection
H_2O
Nitrogen & Phosphorus
PHOTOSYNTHESIS
ZOOXANTHELLAE
Organic Energy
O_2
RESPIRATION
CO_2
Excess
"Junk Food"
H_2O
The excess organic energy translocated to the coral host is rich in carbohydrate but low in nitrogen compounds (important building blocks for proteins); most corals supplement this food source by actively feeding on zooplankton or dissolved organic nitrogen (DON).
RESPIRATION
CO_2
Nitrogen-poor
CORAL
$Ca + CO_3$
Nitrogen-rich
$CaCO_3$
Waste Products
The symbiotic algae also act like a "kidney" for the coral, removing waste materials which are then used to assist the algae in conducting photosynthesis
Zooplankton or DON
Skeleton Formation

(Gulko 1998)


Anatomy of a Coral Polyp
tentacles with nematocysts (stinging cells)
mouth
zooxanthellae
nematocyst
living tissue linking polyps
gastrovascular cavity (digestive sac)
skeleton
limestone calice
© 1999 Encyclopædia Britannica, Inc.

D. CR Formation Theories

1. Subsidence Theory (Darwin 1830)**:** atolls formed on fringing reefs of subsiding islands, upward growth of reef keeps pace w/ island subsidence

2. Glacial Control Theory (Daly 1915)**:** lagoon bottoms were wave cut platforms that formed during ice age when SL was lower than present, reefs have colonized platforms & kept pace w/ SL rise

3.

Subsidence Theory

E. **Water column requirements of CRs?**

2. Sensitive to low salinity & sedimentation

a. No reefs w/i 100s of km of

3. Thrive in regions of strong H_2O movement. *Why?*

    a.

4. Optimal conditions: Red Sea, Caribbean, Indo-Pacific, east coast of Australia

II. CR Classification

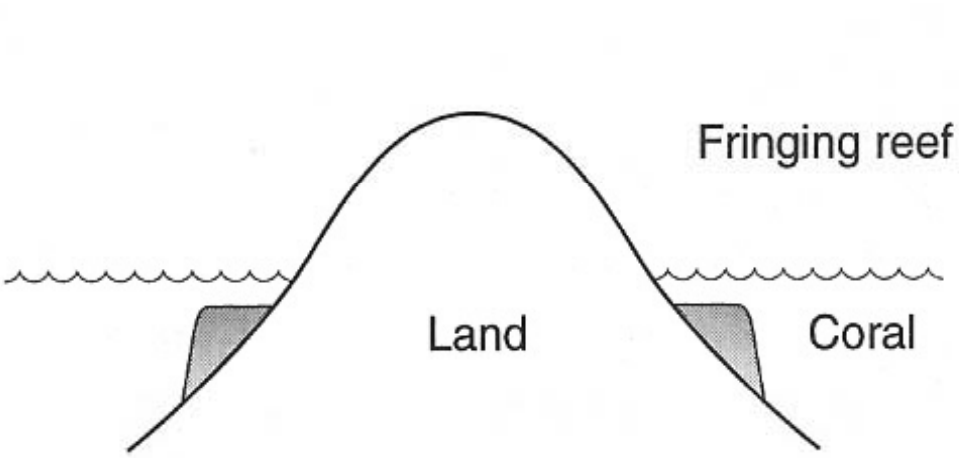
A. 3 main CR types

1. **<u>fringing reef</u>**: found growing as a fringe attached to land mass

   a. longest?

   b. aridity ↓ sediment & FW inputs

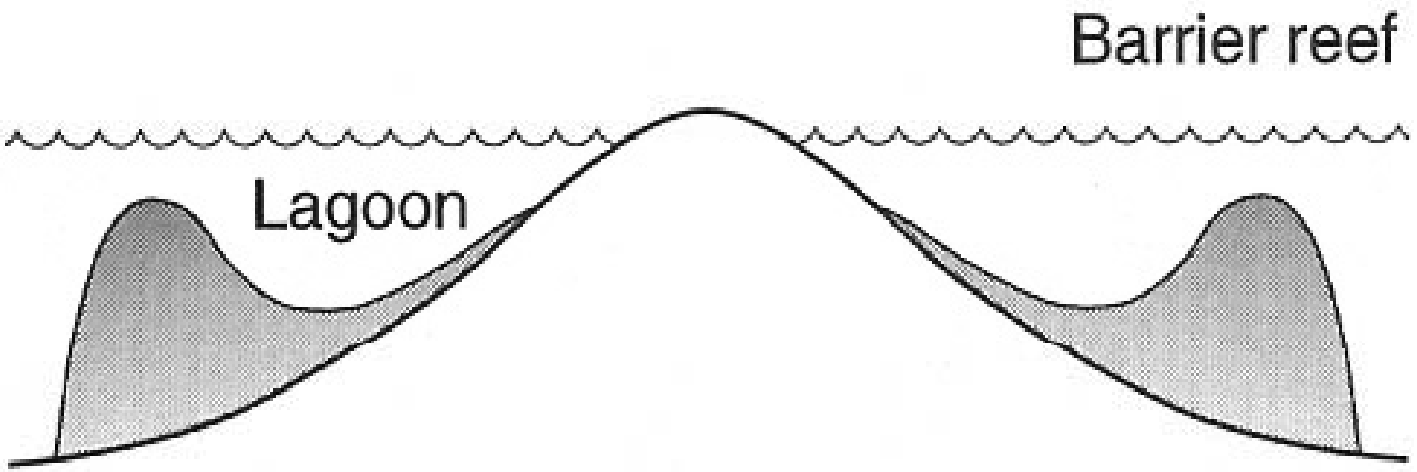
   c.



2. **<u>barrier reef</u>**: occur @ some distance out to sea, create a shallow lagoon bet reef & land

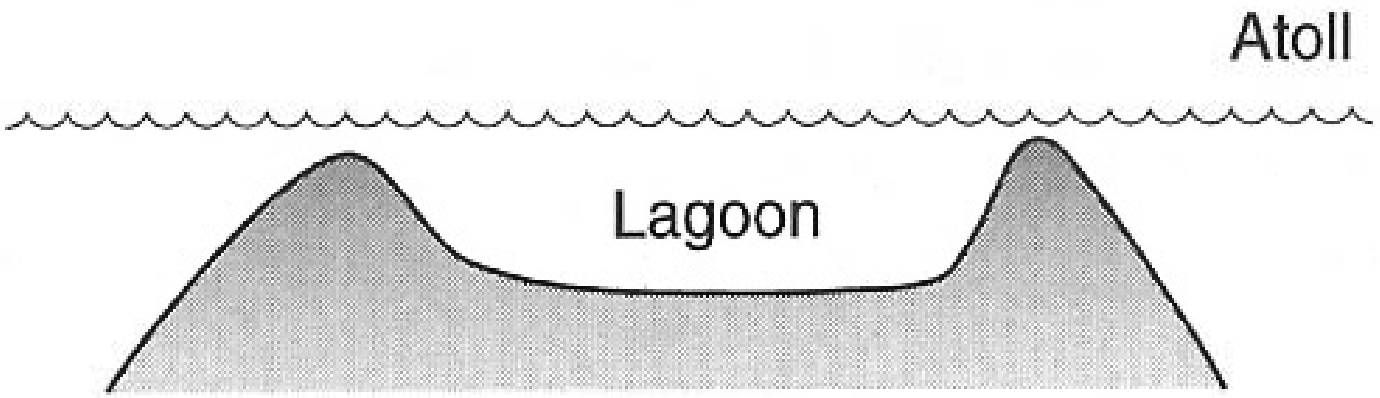
   a. best know ex = Great Barrier Reef, 2,000 km on east coast of Australia

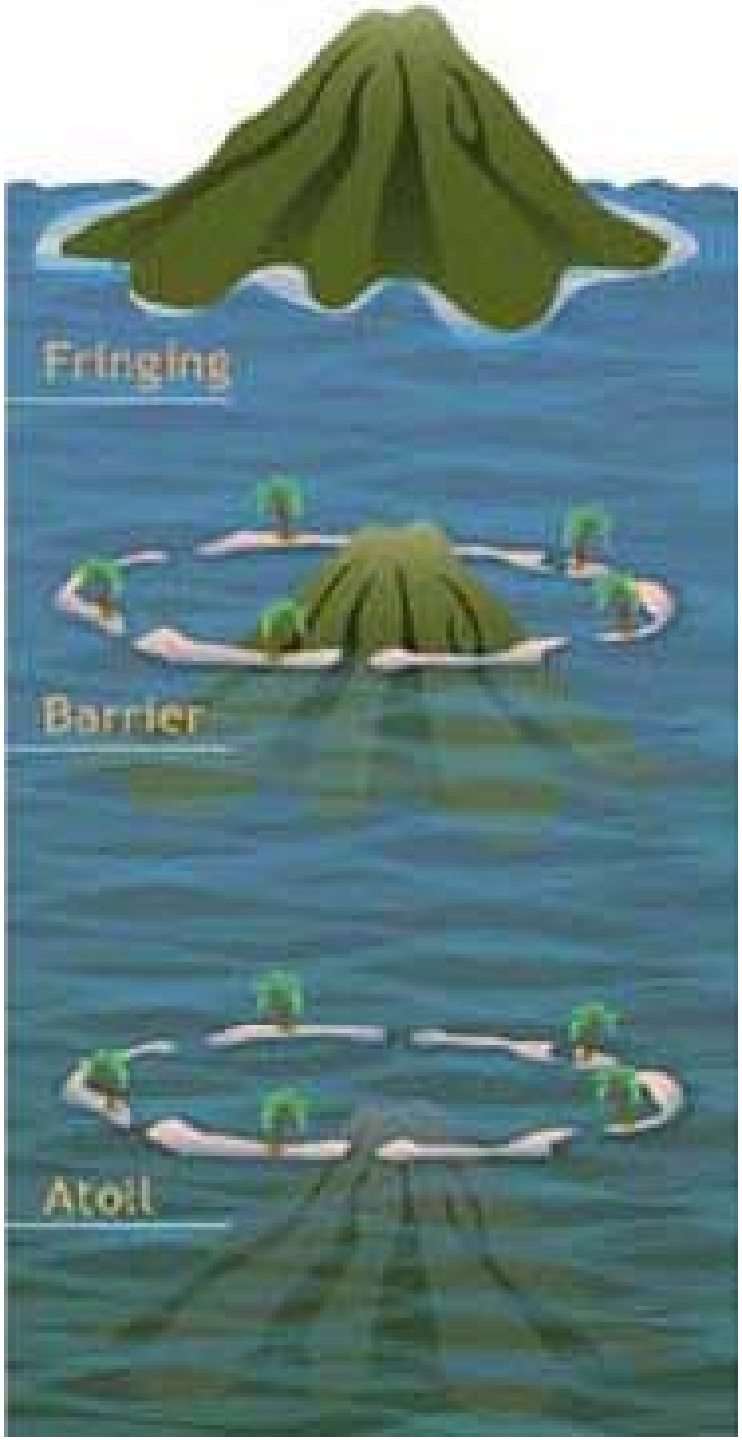
   b.

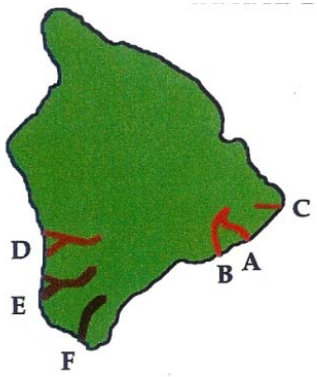


3. **<u>atoll</u>:** isolated structure surrounded by deep H_2O that forms a ring of coral w/ central lagoon

   a. Ex:




Fringing
Barrier
Atoll



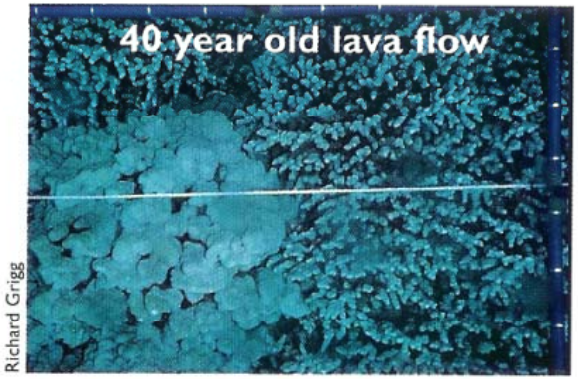
Reef Succession Case Study: Hawai‘i

A. Three month old lava flow. No visible coral colonies present, primarily diatomaceous slime.

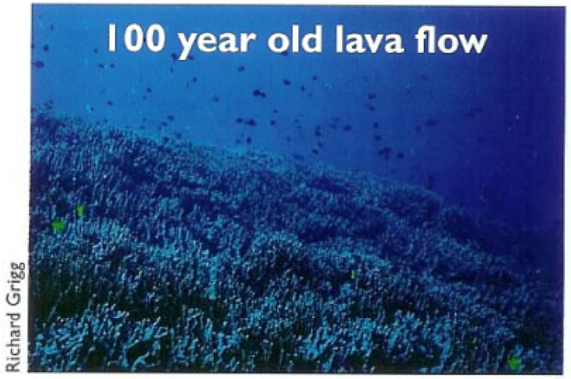
B. Ten year old lava flow supporting a coral colony roughly ten years old.

C. Fifteen year old lava flow. Coral cover is almost entirely *Pocillopora meandrina*; a fugitive species often found colonizing such flows.

D. Twenty year old lava flow. Reef is made up of 12 species of corals, almost 100% coral cover.



E. Forty-four year old lava flow. At this point coverage is primarily *Porites compressa* and *Porites lobata*.



F. A hundred year old lava flow in a relatively undisturbed area. This very developed reef is is almost 100% *Porites compressa* (finger coral).

(Gulko 1998)

C. Reef morphology

1. Main zones: slope, front, algal ridge, flat, lagoon, patch reef, leeward reef

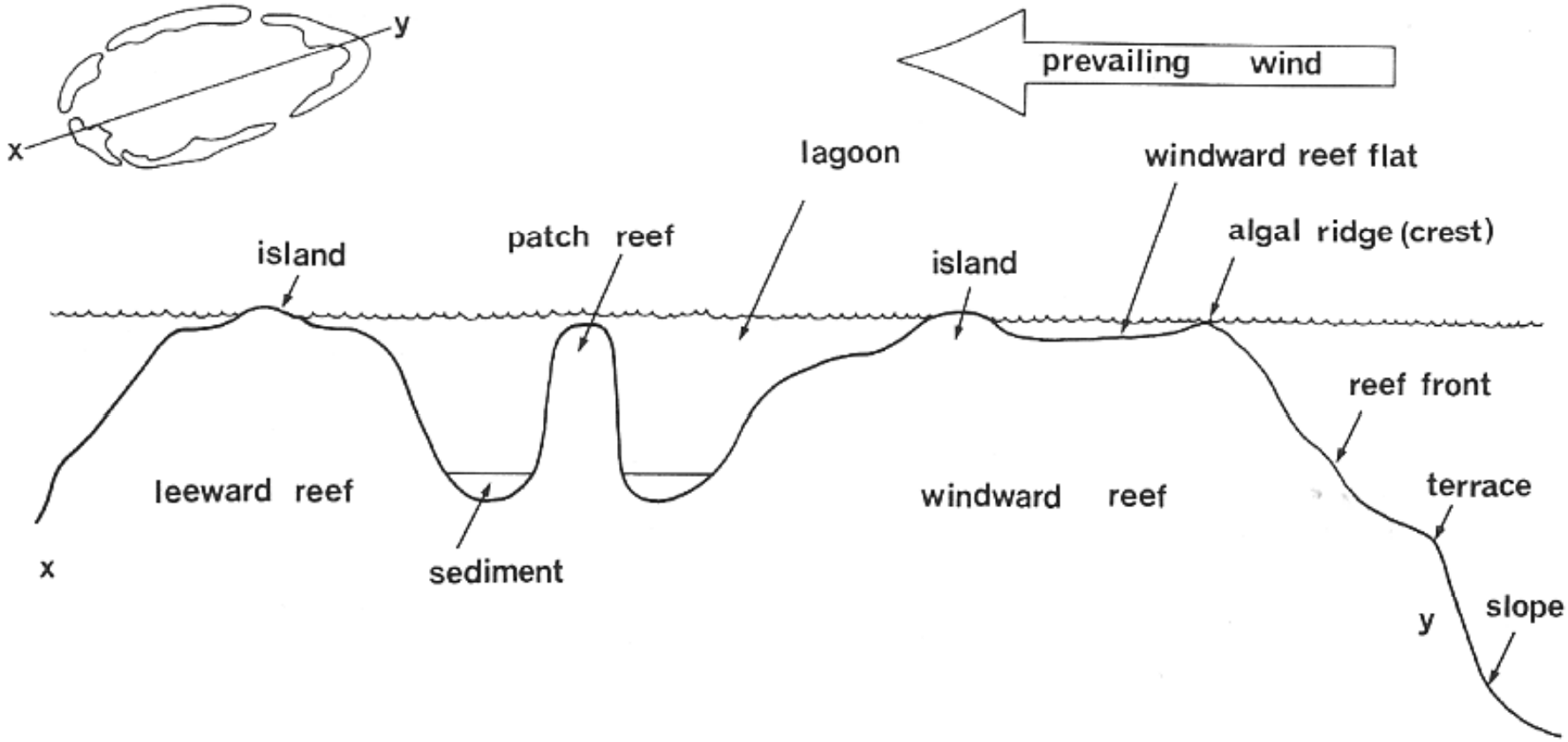


Figure 6.3 Diagrammatic section of a typical atoll showing the major subdivisions of the reef complex.

a. **Slope**: occurs in deepest H_2Os (depth > 5-15 m), zone of most active growth, exposed to max wave energy

b. **Front**: above slope, in shallower H_2O, from depth of 5-15 m to surface

c. **Algal ridge**: above slope, formed of crustose coralline algae

d. **Reef flat**: elevated area bet. front & lagoon

e. **Lagoon**: deepwater area bet. windward and leeward reefs, substrate = sediment, Carrib depth = 5-15 m, Indo-Pac depth < 70 m

f. **Leeward reef**: coral growth less rapid, algal ridge weak or absent

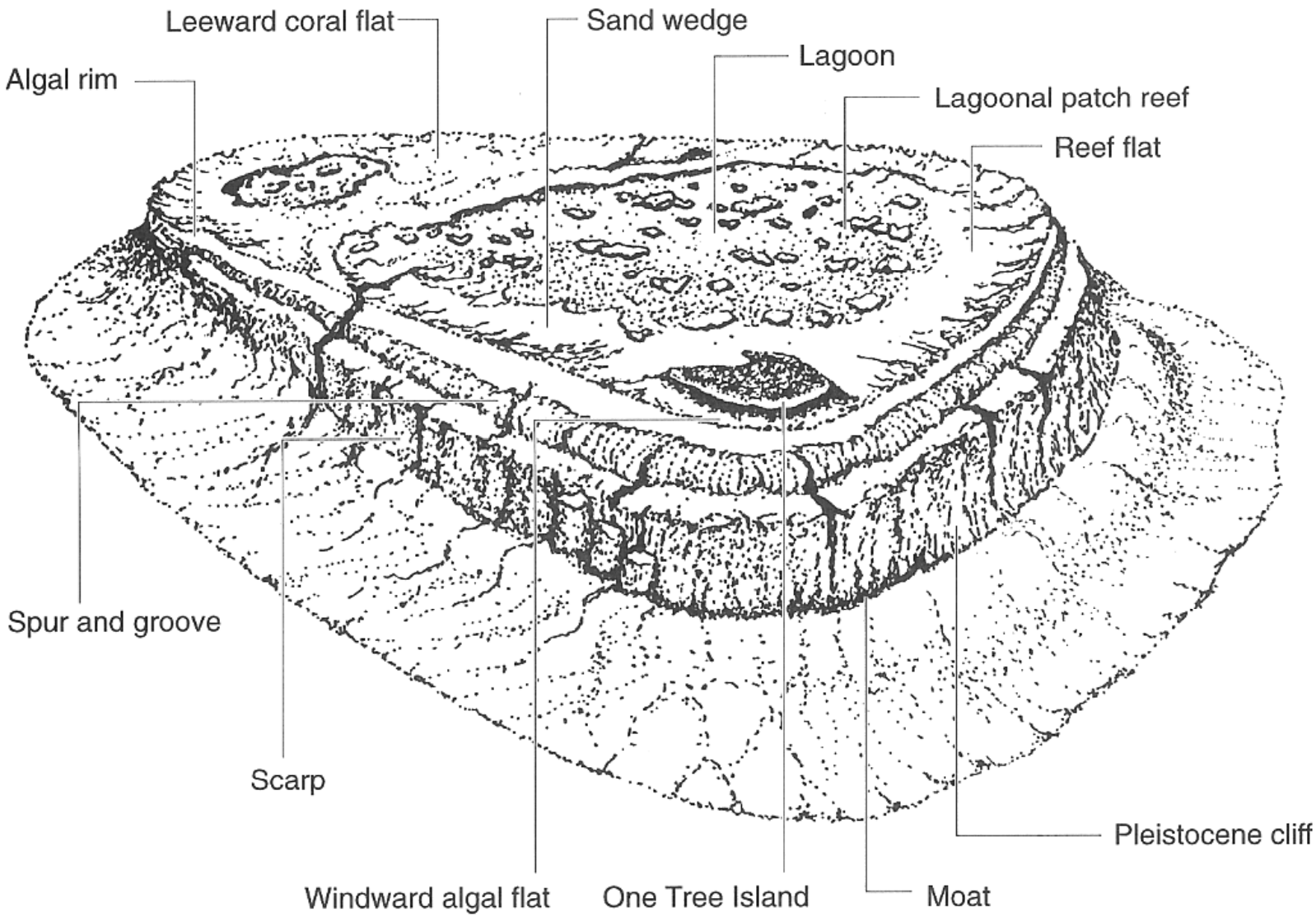


Figure 16.3 A three-dimensional representation of One Tree Reef, part of the Great Barrier Reef. Note that One Tree Island is a very small part of the reef complex. For discussion of the features, see text. Reproduced from Borowitzka and Larkum (1986) by permission.

III. CR Food Webs

A. <u>Producers</u>: corals, sponges, (benthic/coralline) algae (red & green encrusting), phytoplankton compete for nutrients, light, space

1. Corals fix C, but <½ of C fixed avail to consumers due to resp, recyc, accum

2. Reef algae high productivity,

Porites rus
Plate coral

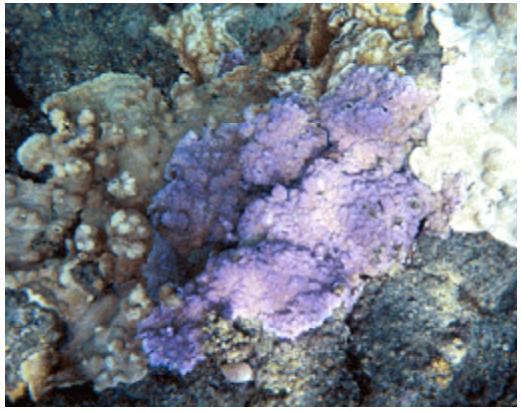
Porites compressa
Finger coral, Pohaku puna

Porites lobata
Lobe coral, Pohaku puna

Acropora cytherea
Table coral

Pocillopora meandrina
Cauliflower coral, Ko‘a

Montipora capitata
Rice coral



Montipora flabellata
Blue rice coral
Encrusting

Montipora patula
Blue rice coral

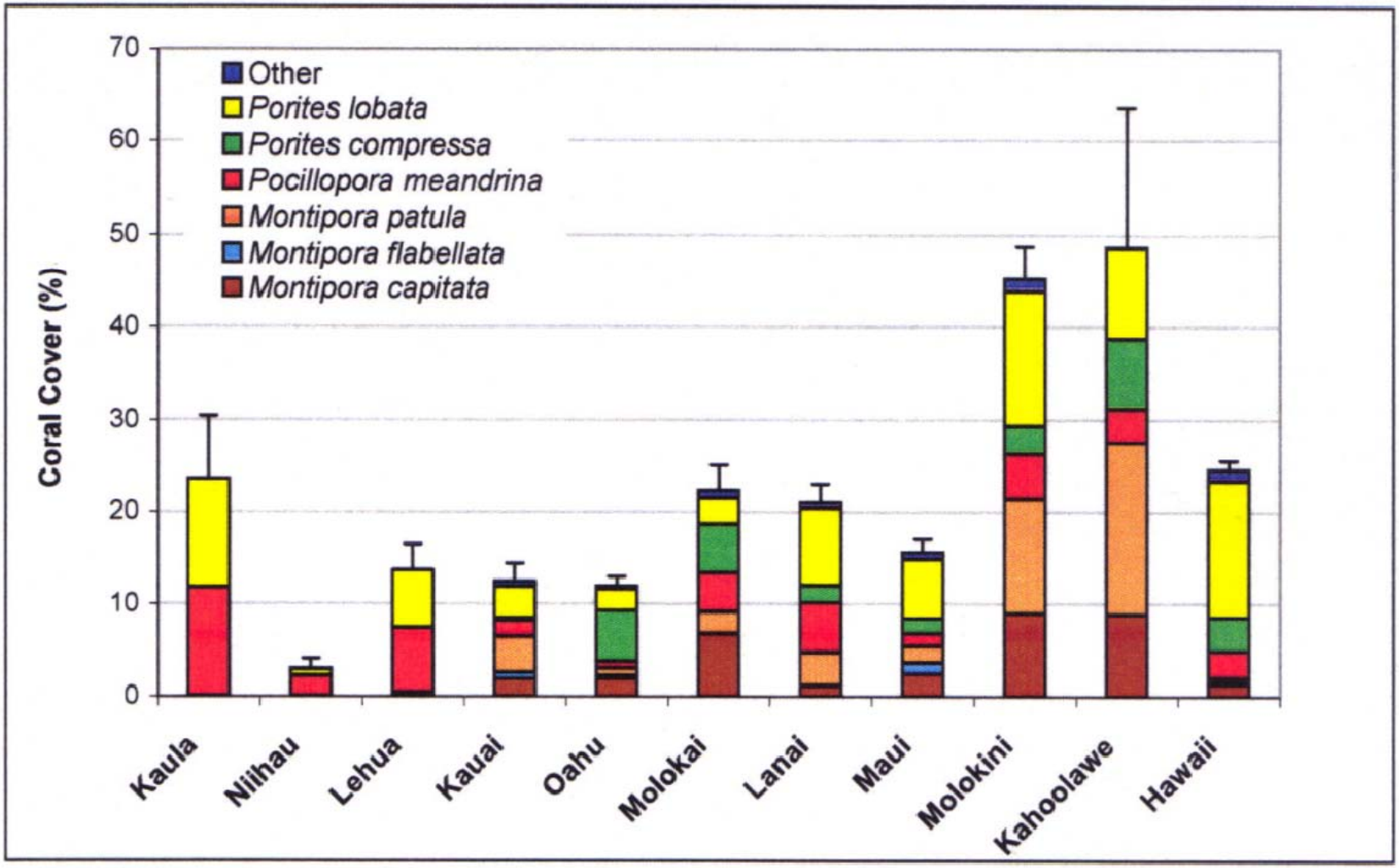
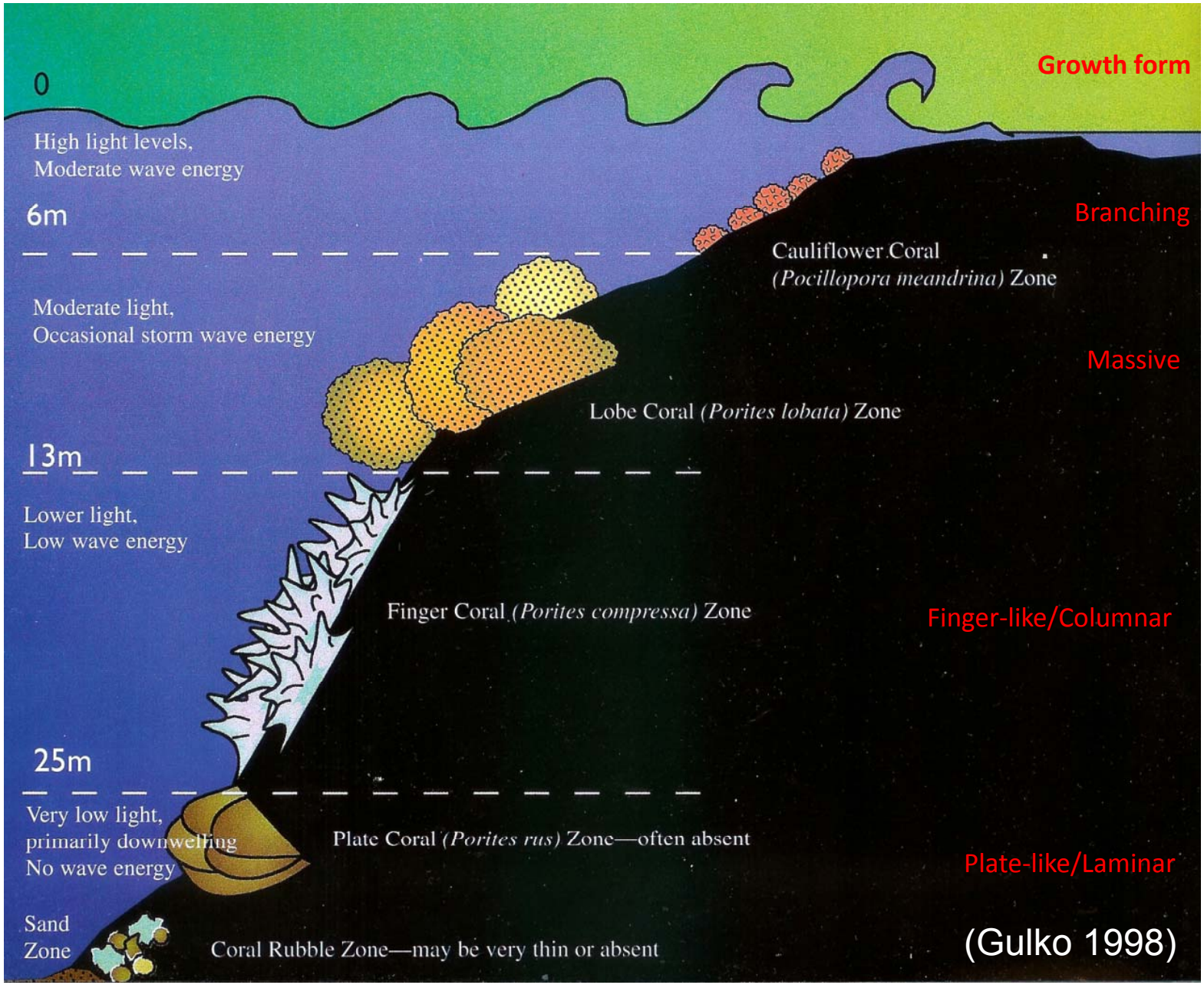


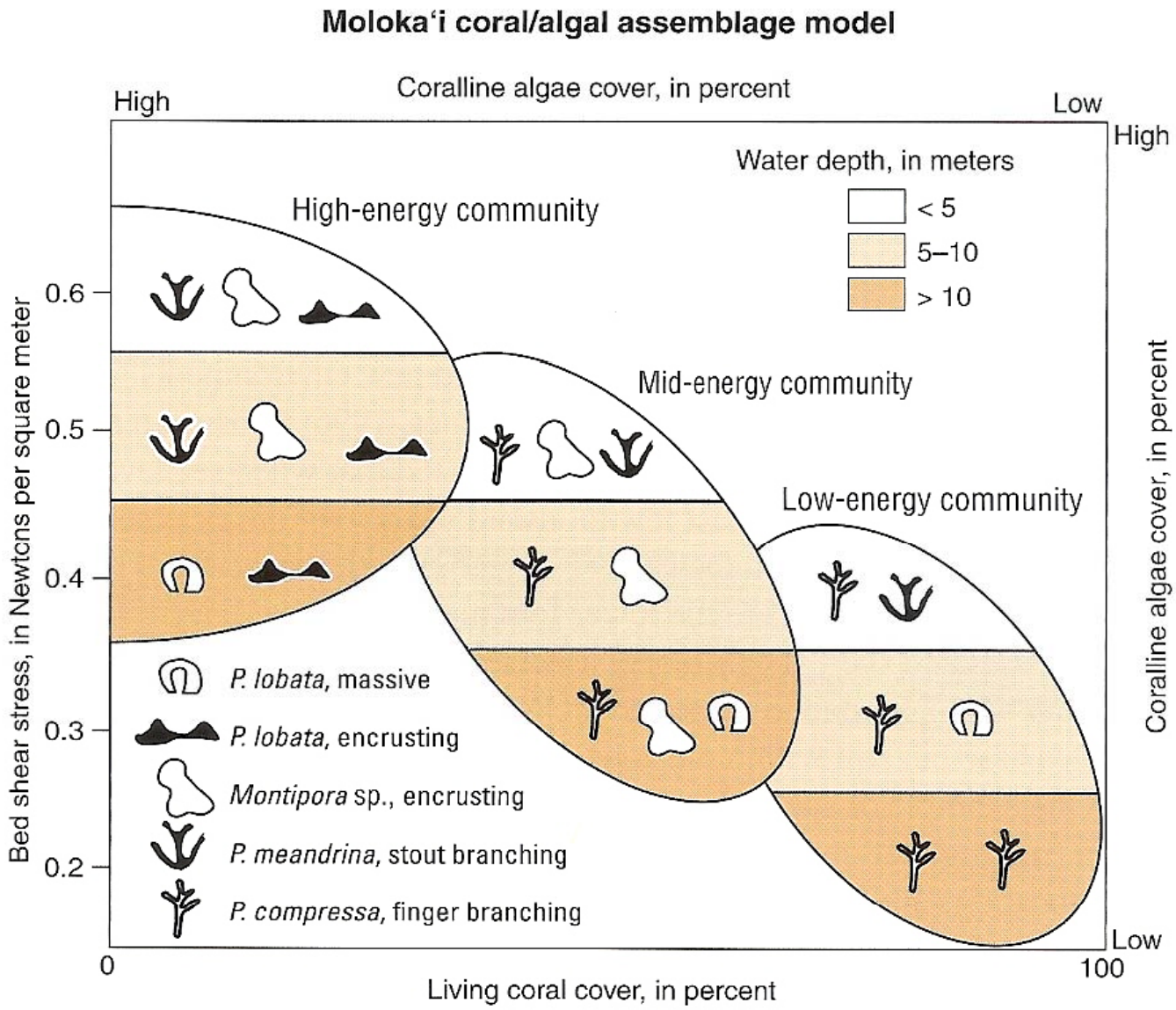
Figure 8.34. Mean percent coral cover at each island in the MHI along a geological (longitudinal) gradient from oldest (west) to youngest (east). Coral cover was calculated from 1,682 transects/sites surveyed between 2001 and 2006. Data sources include CRAMP/DAR (n=692), PIFSC-CRED (n=108), FHUS (n=859) and WHAP (n=23). Mean percent cover ± 1 SE.

(Friedlander et al. 2008)

Coral Reef Zonation in Hawai‘i



Coral assemblage model for south Moloka‘i reefs



(Engels et al. 2004, Field et al. 2007)

B. **Consumers**:

1. Coral polyps: prey on plankton

2. Inverts: diverse → limpets, crabs, lobsters, snails, urchins, starfish graze on algae, browse corals

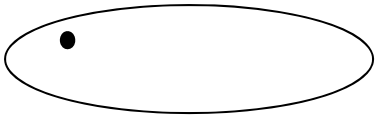
3. Herbivorous fish: damsel, parrot, surgeon, rabbit most important

    a. Damsel: defend small patches of dead coral,

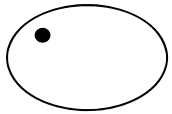
    b. Parrot, surgeon, rabbit: occur in dense schools,

4. Only a few spp, i.e., crown of thorns starfish, some parrot, butterfly, trigger, puffer feed directly on polyps

Reef fish body types

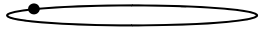


Body type: *tapered* Species: *snapper*

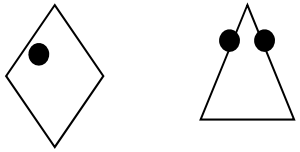


Body type: *compressed oval* Species: *butterflyfish*

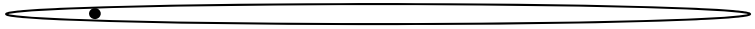
Body type: *spherical* Species: *puffer*



Body type: *depressed* Species: *rays or flatfish*



Body type: *angular* Species: *triggerfish*



Body type: *elongated/long* Species: *cornetfish*

Herbivorous reef fish

Damselfish
Family:
Pomacentridae

Rabbitfish
Siganidae

Redlip parrotfish, pālukaluka,
Scarus rubroviolaceus

Sexually dimorphic, scrape/bite off substrate/coral, extract plant material, produce sand

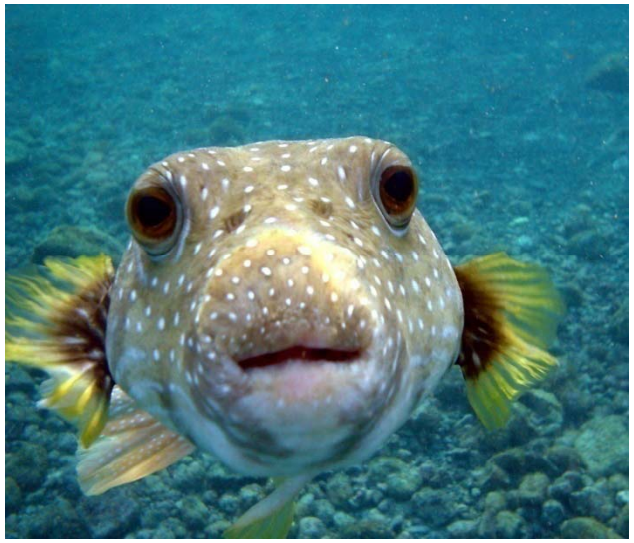
Surgeonfish
Acanthuridae

Achilles tang, pākuʻikuʻi
Acanthurus achilles

Direct coral grazers

butterflyfish, lauhau
Chaetodon quadrimaculatus

Spotted puffer, ‘o‘opu hue
Arothron meleagris

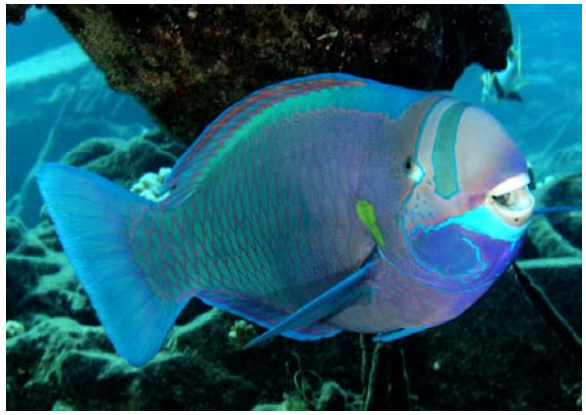


Triggerfish
Balistidae

Titan (Thailand)

Lagoon triggerfish

Spectacled Parrotfish
Chlorurus perspicillatus



Reef triggerfish, humuhumu-nukunuku-ā-pua‘ā, *Rhinecanthus rectangulus*

Other Hawaiian reef fish

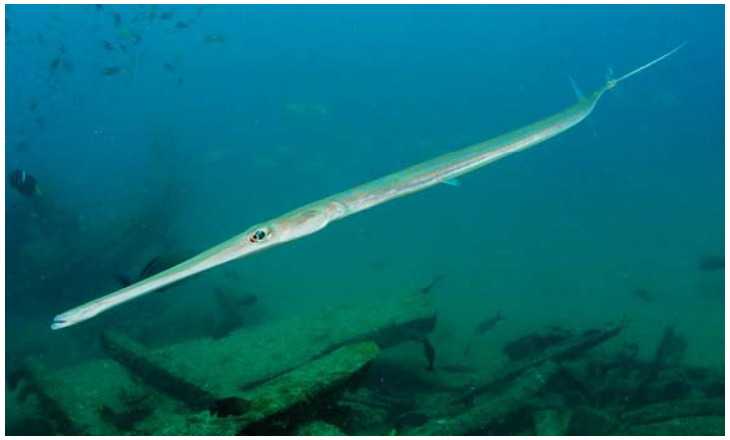
Hawaiian cleaner wrasse,
Labroides phthirophagus

Old woman wrasse, hīnālea luahine,
Thalassoma ballieui

Moorish idol, kihikihi, *Zanclus cornutus*

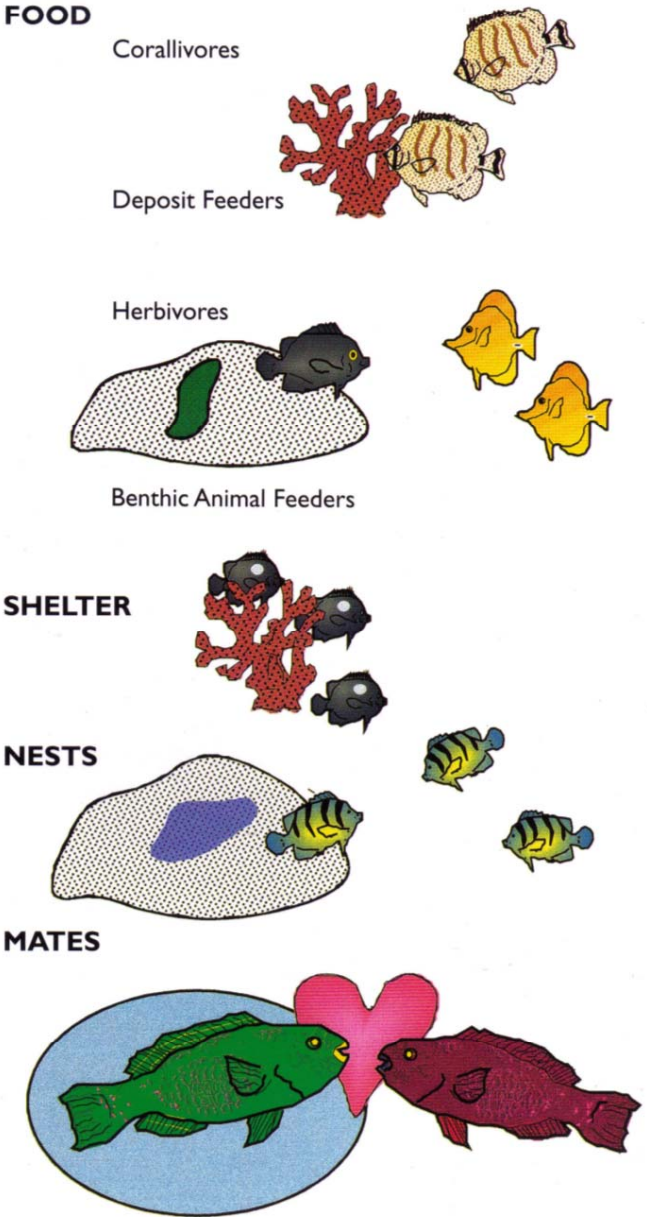
Only spp. in family Zanclidae, sports long graceful filament extending from its back, & pointed snout used for finding food in crevices

Cornetfish, nūnū peke
Fistularia commersonii



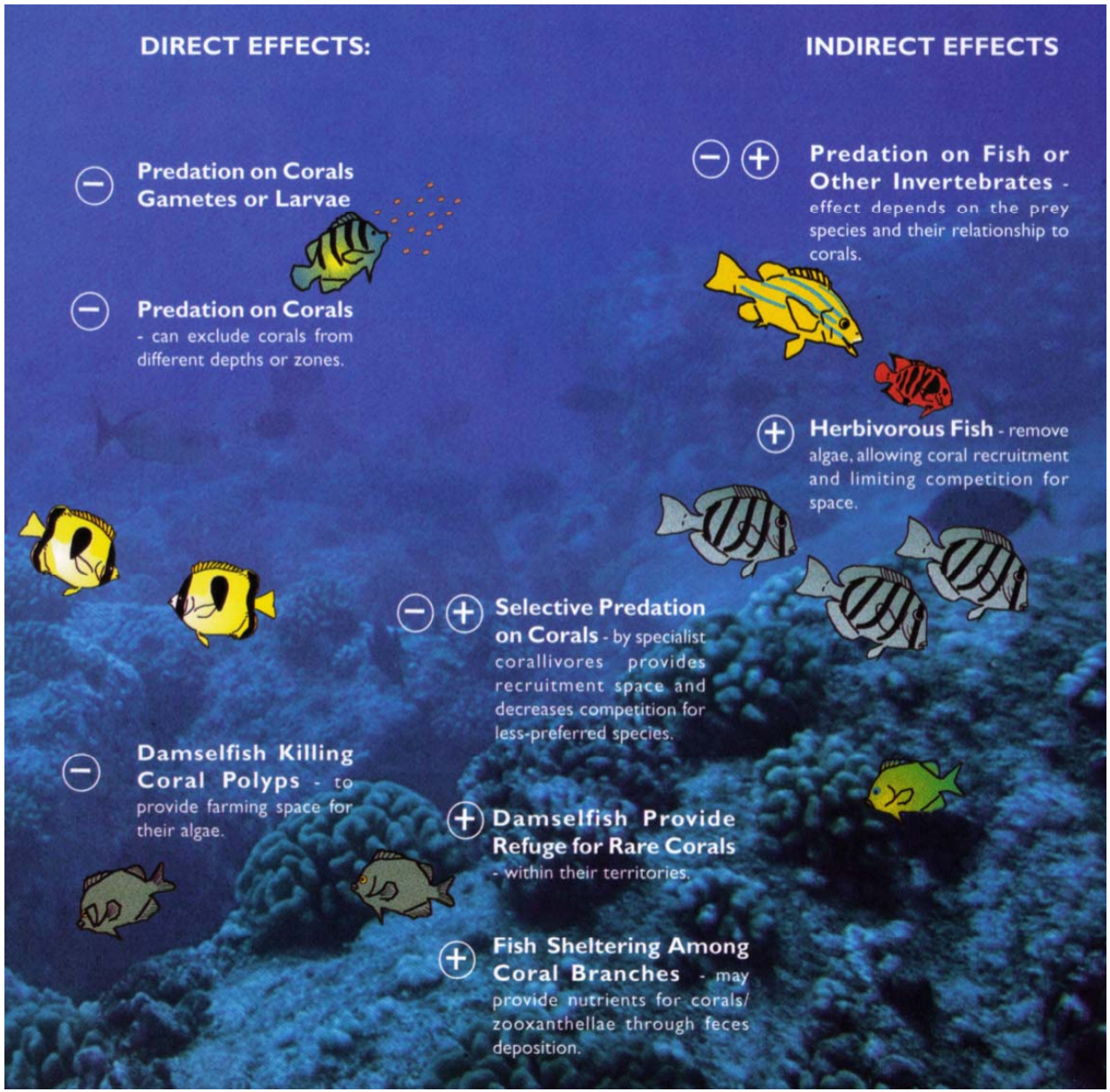
Territoriality in Reef Fishes

TYPE OF RESOURCE		EXAMPLE
FOOD		
	Corallivores	Assorted Butterflyfish Blue-eyed Damselfish Short-bodied Blenny
	Deposit Feeders	Certain Angelfish Blennies
	Herbivores	Angelfish Blennies Damselfish Certain Surgeonfish
	Benthic Animal Feeders	Angelfish Butterflyfish
SHELTER		Damselfish Blennies Gobies
NESTS		Damselfish Gobies Blennies Longnose Hawkfish
MATES		Damselfish Wrasses Parrotfish Groupers & Basslets Hawkfish Gobies



(Gulko 1998)

Effects of Fish on Corals



(Gulko 1998)

C. Carnivores/Secondary consumers: reef fish, bottom fish, crabs, lobsters, seabirds

1. Reef fish—at least 4,000 fish spp found on CRs

D. Apex Predators: Sharks, jacks, goatfish, seals

1. absent or reduced #s & biomass in many CR systems, present in NWHI

F. Symbioses

1. Examples: coral-zoo., fish-anemones, crab-coral head,

Seabirds & Seals

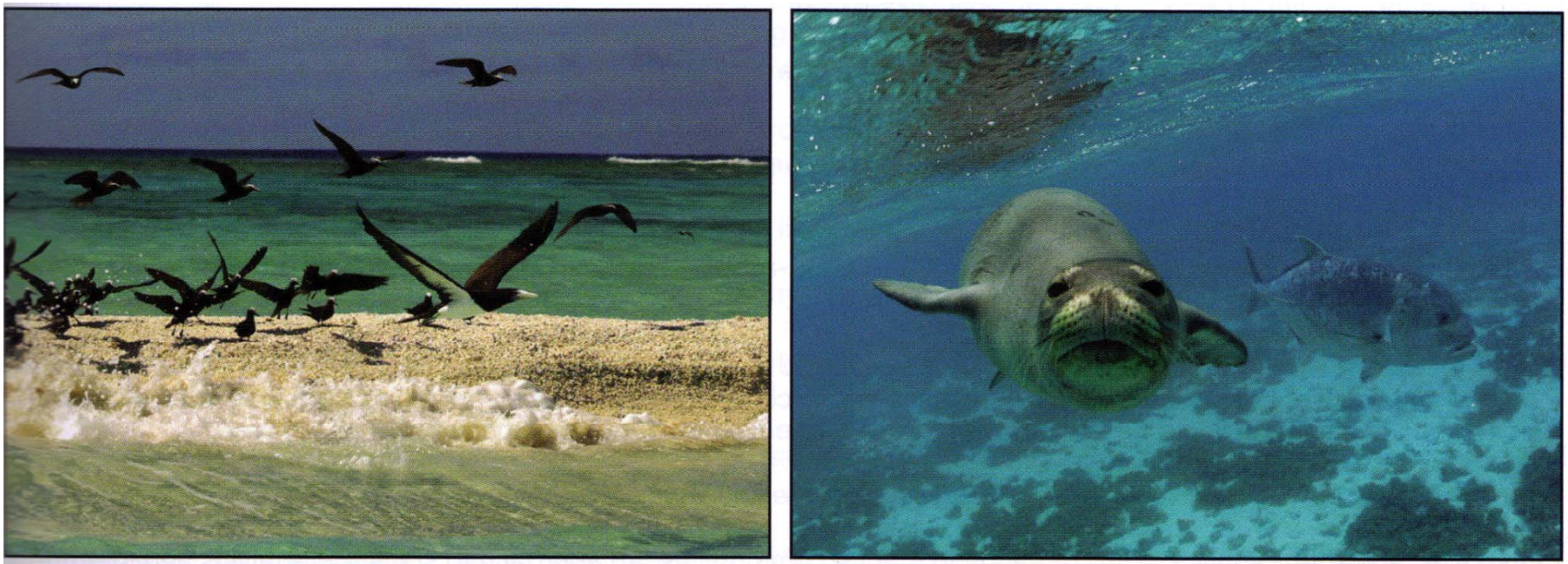


Figure 10.39. Seabirds, such as these Brown noddy terns and Brown booby at P&H (left photo), rely on the NWHI for nesting, feeding and breeding. The critically endangered Hawaiian monk seal (right photo) is an intergral component of the NWHI ecosystem. Photos: J. Watt.

(Waddell 2005)

Apex Predators NWHI

Figure 10.27. Large apex predators, such as sharks (left panel) and jacks (right panel), are abundant in the NWHI and dominate the ecosystem in terms of biomass. Large predators are conspicuously absent from most of the other jurisdictions in this report. Photos: J. Watt.

(Waddell 2005)

Coral Reef Feeding Guilds

Carnivores

Benthic Animal Feeders

Ambushers (hawkfish), *Foragers* (eels, goatfish, wrasses), *Grazers* (butterflyfish)

Corallivores (butterflyfish, damselfish, crown-of-thorns)

Molluscivores (octpus, rays, puffer, wrasse)

Piscivores

Ambushers (scorpionfish), *Stalkers* (barracuda, cornetfish), *Chasers* (jacks, sharks)

Deposit Feeders (sea cucumbers, surgeonfish)

Herbivores

Browsers (angelfish), *Croppers* (surgeonfish), *Grazers* (sea urchins), Grovelers (mullet),

Scrapers (sea turtles, parrotfish)

Omnivores (moorish idols, triggerfish)

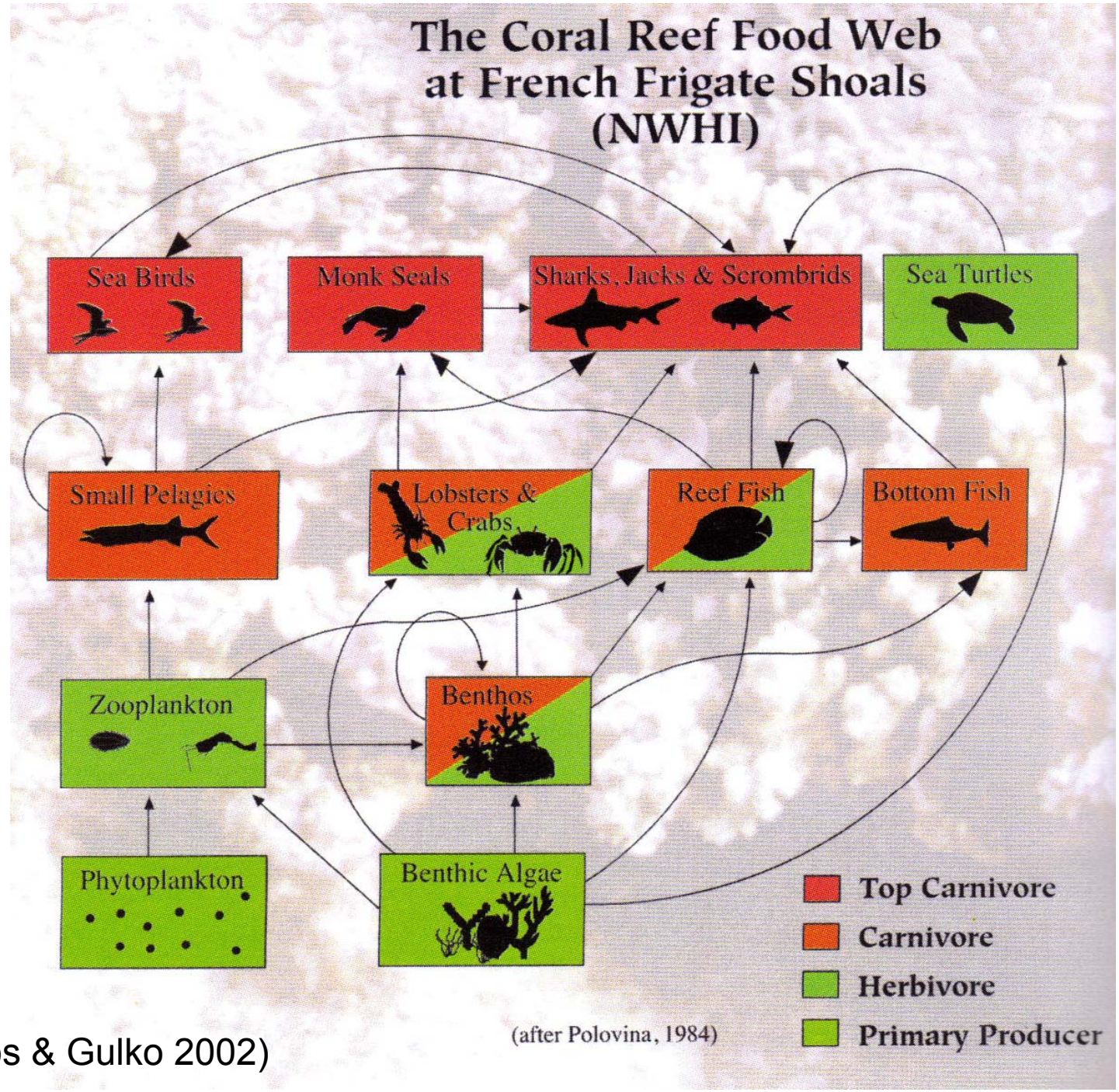
Planktivores

Strainers (manta rays, whale sharks), *Pickers* (butterflyfish, squirrelfish)

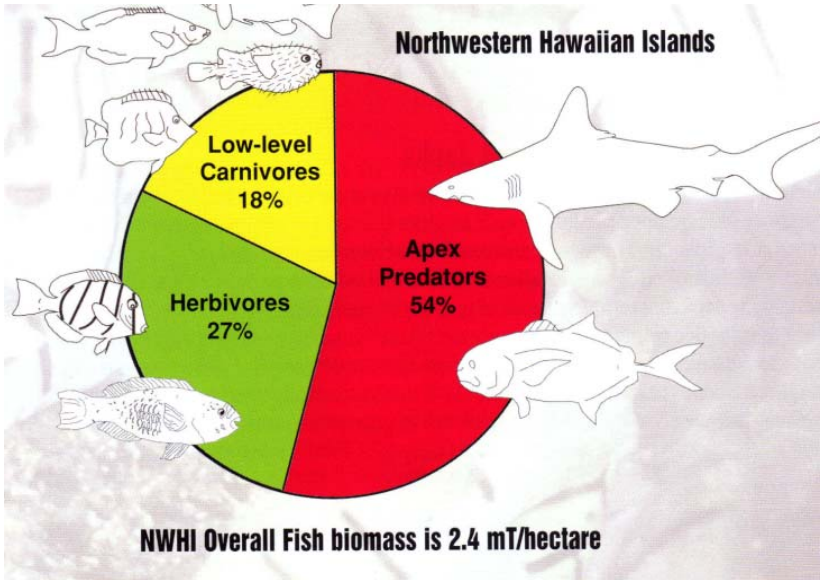
Scavengers (crabs, lobsters, wrasses, sharks)

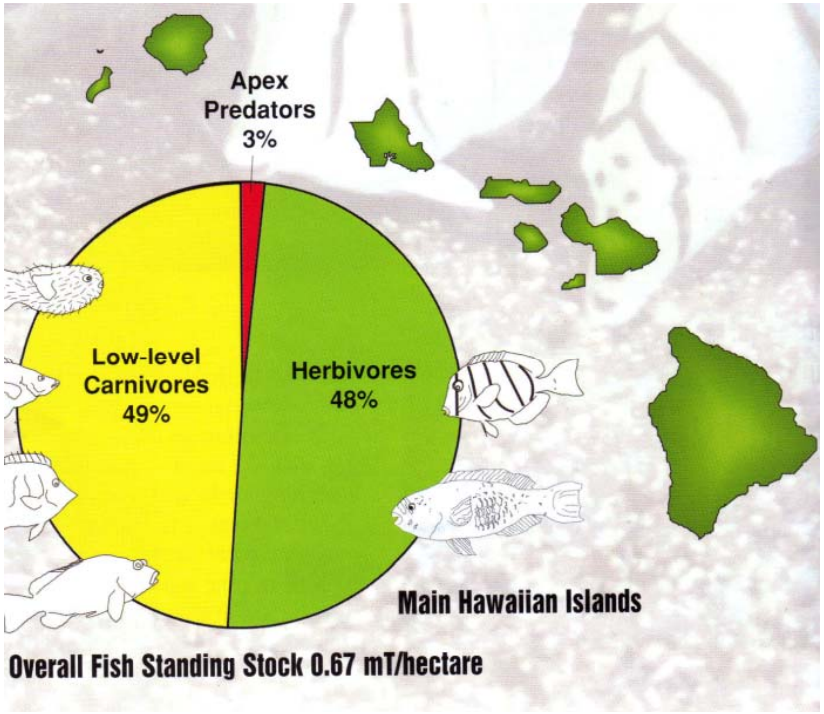
Suspension/Filter Feeders (barnacles, featherduster worms, sponges)

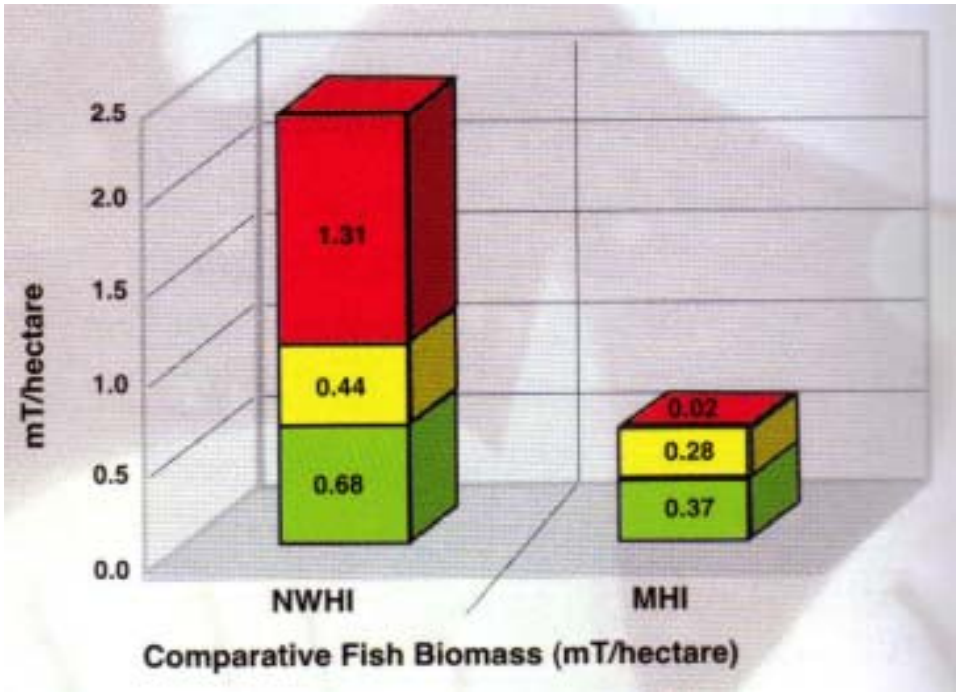
(Gulko 1998)



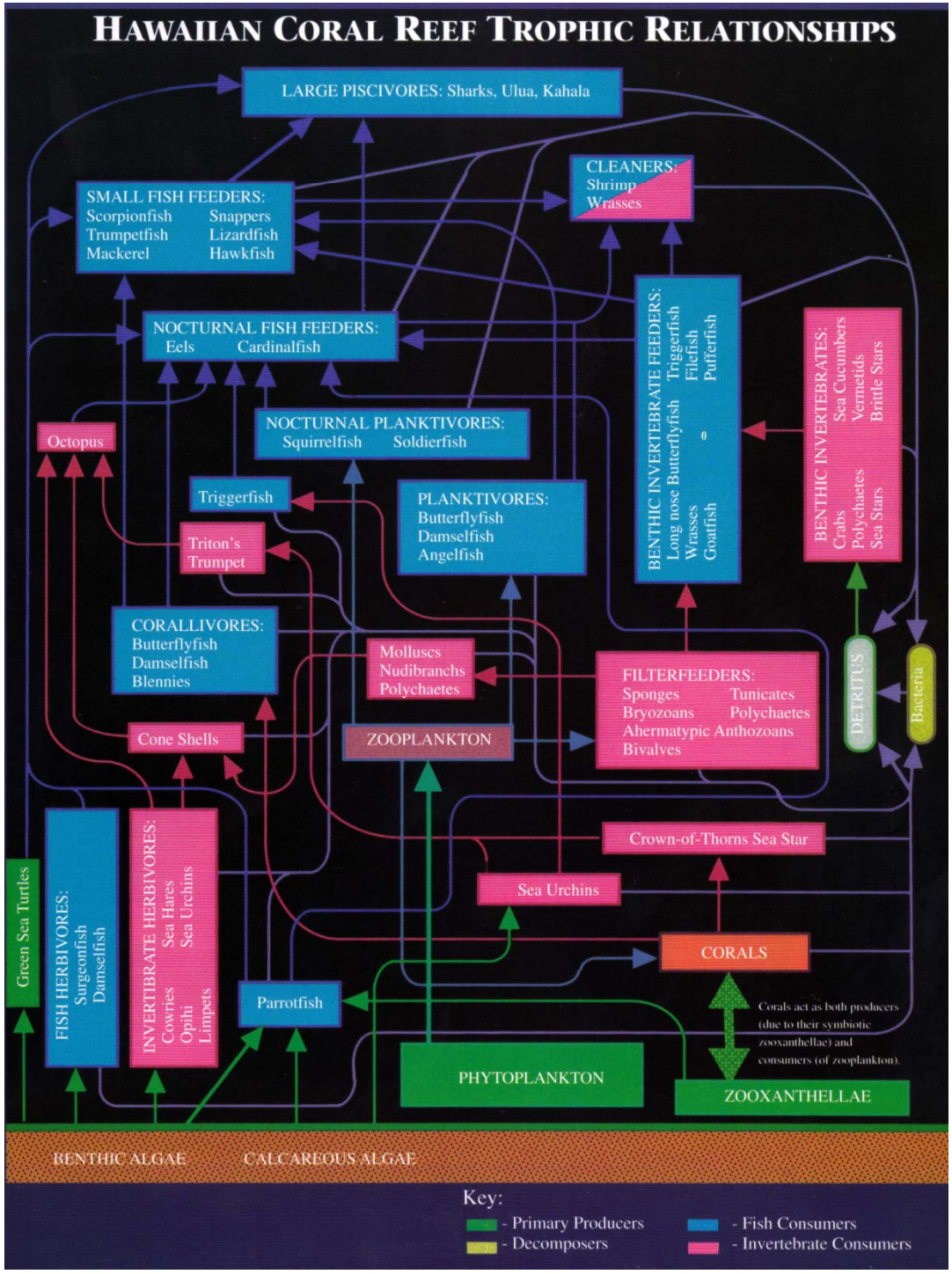
(Maragos & Gulko 2002)







(Maragos & Gulko 2002)


HAWAIIAN CORAL REEF TROPHIC RELATIONSHIPS
LARGE PISCIVORES: Sharks, Ulua, Kahala
SMALL FISH FEEDERS:
Scorpionfish Snappers
Trumpetfish Lizardfish
Mackerel Hawkfish
CLEANERS:
Shrimp
Wrasses
NOCTURNAL FISH FEEDERS:
Eels Cardinalfish
BENTHIC INVERTEBRATE FEEDERS:
Long nose Butterflyfish Triggerfish
Filefish
Pufferfish
Wrasses
Goatfish
BENTHIC INVERTEBRATES:
Sea Cucumbers
Vermetids
Brittle Stars
Crabs
Polychaetes
Sea Stars
NOCTURNAL PLANKTIVORES:
Squirrelfish Soldierfish
Octopus
Triggerfish
Triton's Trumpet
PLANKTIVORES:
Butterflyfish
Damselfish
Angelfish
CORALLIVORES:
Butterflyfish
Damselfish
Blennies
Molluscs
Nudibranchs
Polychaetes
FILTERFEEDERS:
Sponges Tunicates
Bryozoans Polychaetes
Ahermatypic Anthozoans
Bivalves
DETRITUS
Bacteria
Cone Shells
ZOOPLANKTON
Crown-of-Thorns Sea Star
Sea Urchins
CORALS
Green Sea Turtles
FISH HERBIVORES:
Surgeonfish
Damselfish
INVERTEBRATE HERBIVORES:
Cowries Sea Hares
Opihi Sea Urchins
Limpets
Parrotfish
Corals act as both producers (due to their symbiotic zooxanthellae) and consumers (of zooplankton).
PHYTOPLANKTON
ZOOXANTHELLAE
BENTHIC ALGAE
CALCAREOUS ALGAE
Key:
- Primary Producers
- Decomposers
- Fish Consumers
- Invertebrate Consumers

(Gulko 1998)

III. Stressors

A. **Natural**

1. Physical: storms, volcanoes, exceptionally low tides, runoff, uplift from earthquakes, El Niño

2. Biological: disease, predator pop explosions

Figure 3.13. A closeup of a crown-of-thorns starfish, *Acanthaster planci*, on a reef in the PRIAs. Photo: J. Maragos.

(Waddell 2005)

B. **Coral bleaching**: high or low temps; high or low salinity; high UV;

C. **Human-induced**

1. Physical: Sedimentation, anchor damage, reef trampling, dynamite fishing, coastal dvp

2. Chemical: Sewage, NPS runoff, coastal dvpt, sunscreen

3. Biological: coral diseases, overfishing, invasive spp

Plume of fine silts & clays discharging into the sea in Indonesia.

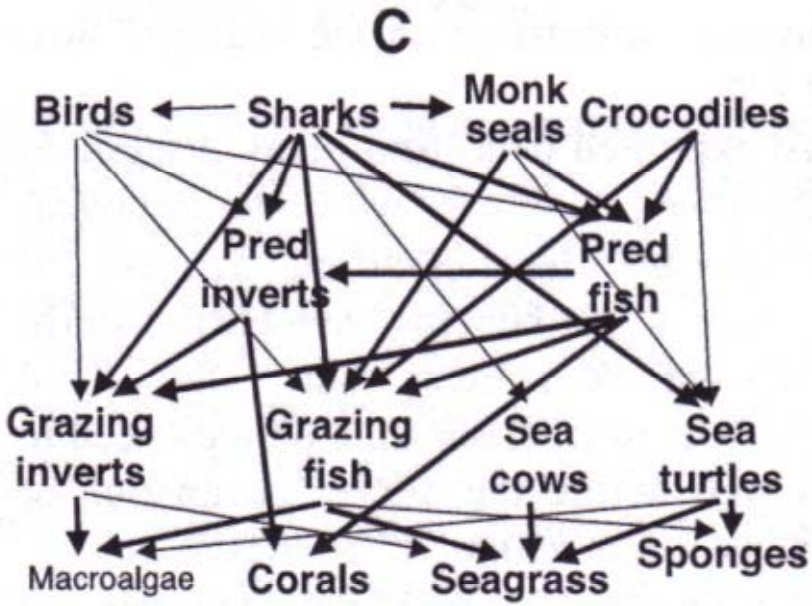
(http://www.dfid-kar-water.net/w5outputs/soil_erosion_slides.htm)

(http://courses.washington.edu/larescue/projects/devin/index3.htm)

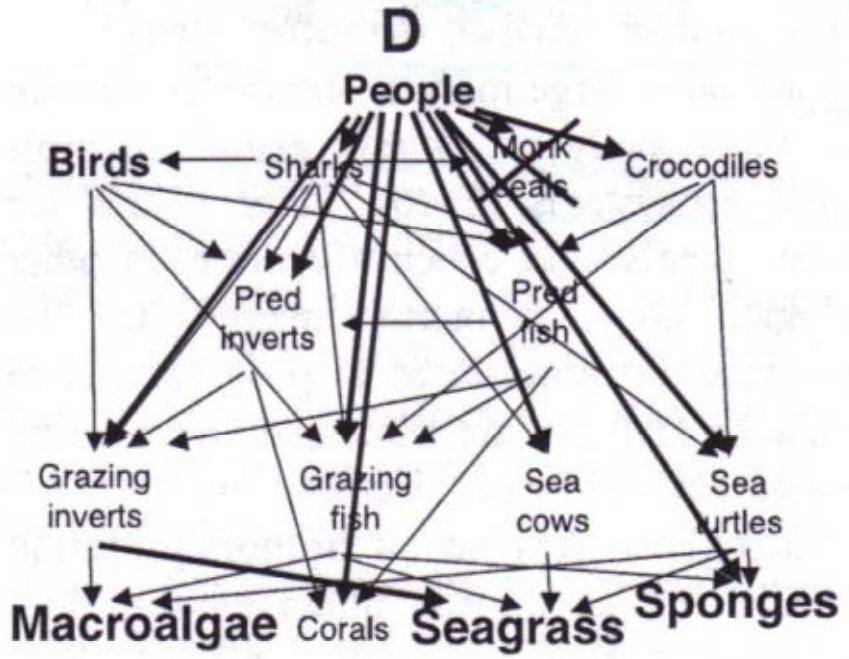
(Photo: Reefbase/T. Heeger)

Natural vs human-modified coral reef food web

Before Fishing



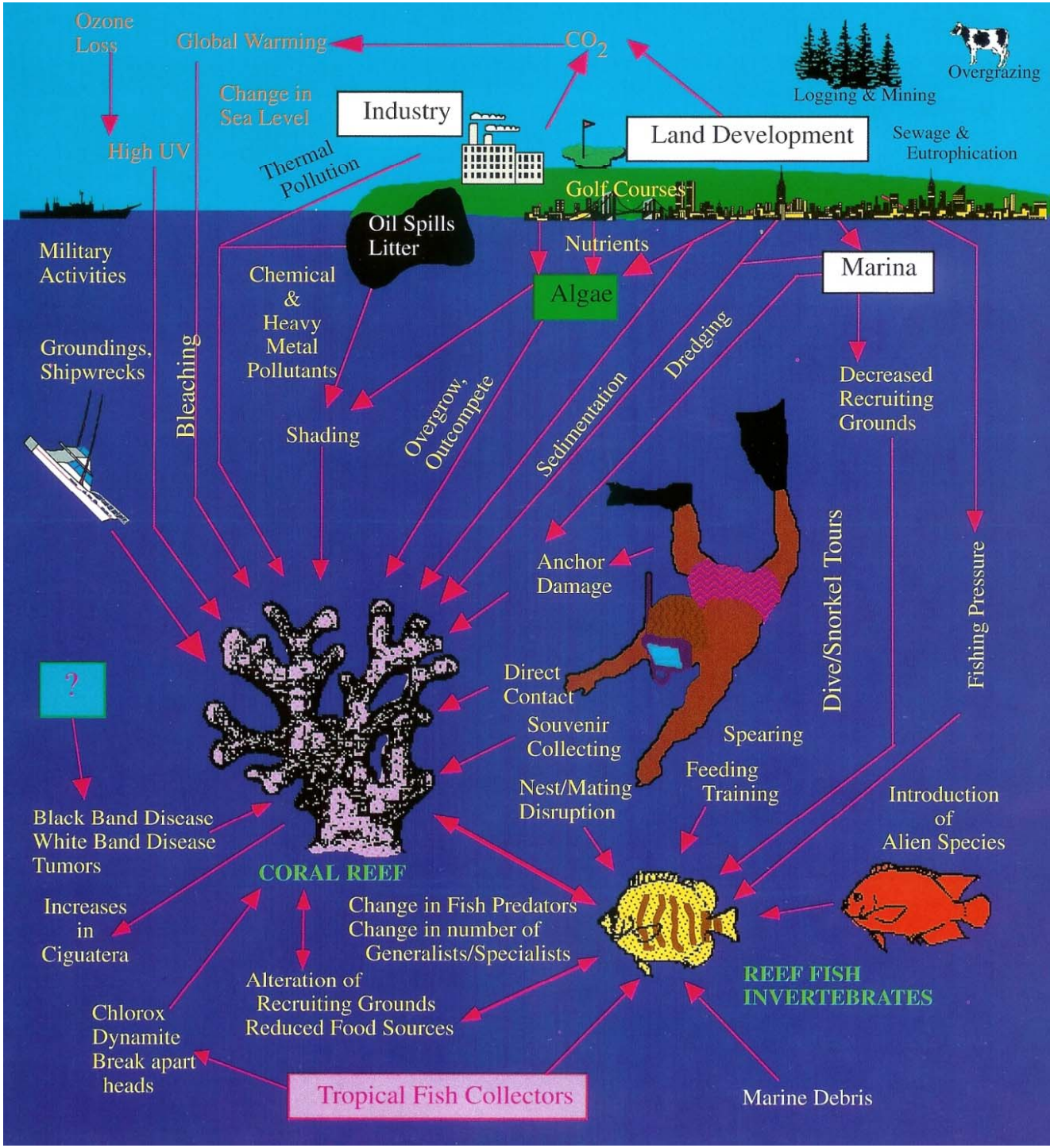
After Fishing



Bold font = abundant

Normal font = rare

(Jackson et al. 2001)

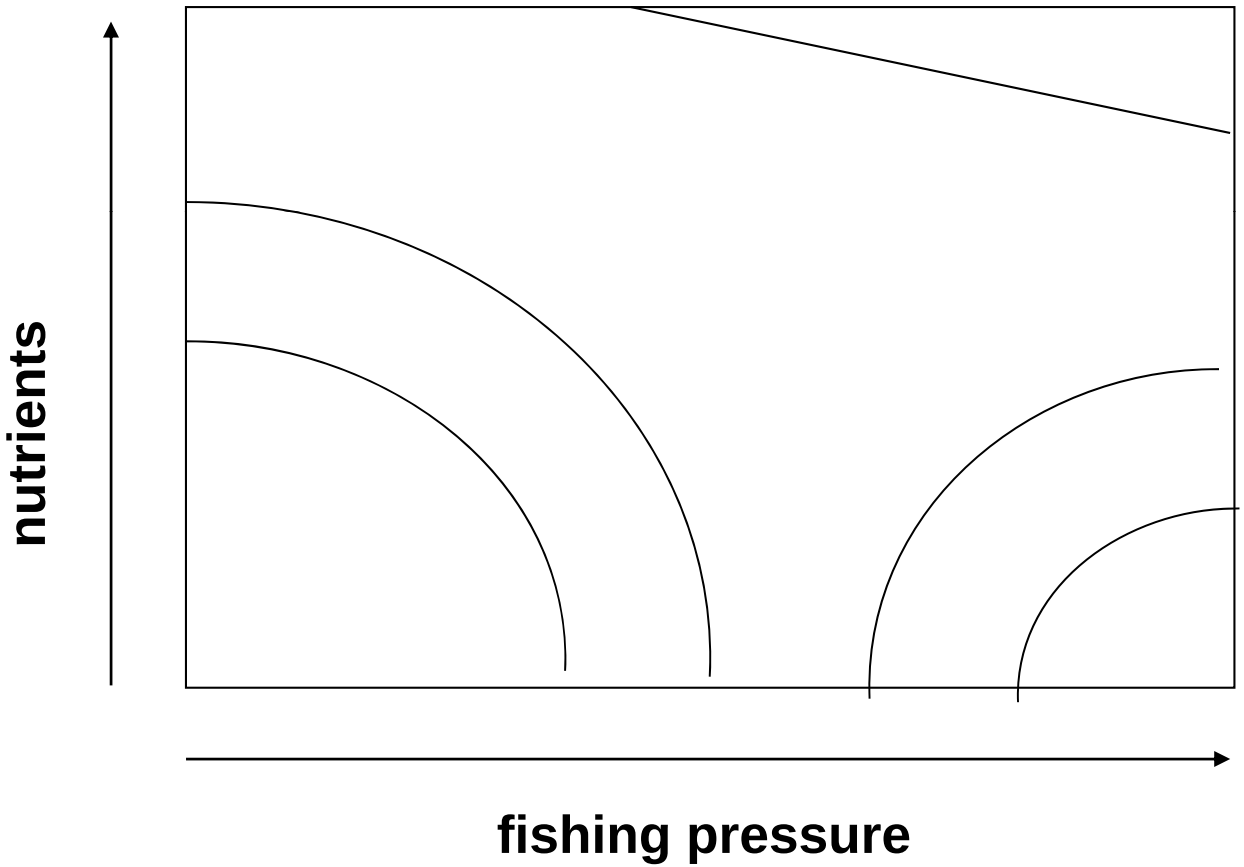


Human Impacts on CRs: Synthesis

(Gulko 1998)

IV. **Alternate stable states** (modified from Bellwood 2004)

Partner activity: Place *6 states* on right in proper location in diagram below



slime

healthy reef

seaweeds

sea urchin barren

stressed reef

rock