Ch.9 Tropical Communities

9.1 Coral Reefs

Tropical marine environment.

- **Hematypic corals:**
  produce reefs; distribute in tropic with small symbiotic plant cells (Zooxanthellae)
- **Ahermatypic corals:**
  Not produce reefs; worldwide without Zooxanthellae

9.1.1 Coral Reefs

Reef Distribution and Limiting Factors

(1.) **Temperature :** 20℃ surface isotherom

< 18℃ no reef develop (annual mean min. temp.)

23-25℃ optimal temp. (mean annual temp.)

36-40℃ some coral reef can tolerate

South American: ∵Peru Current

West Africa: ∵Benguela Current

宜蘭: ∵黑潮

West coast of continents: absent of corals ∵ strong upwelling of cold water

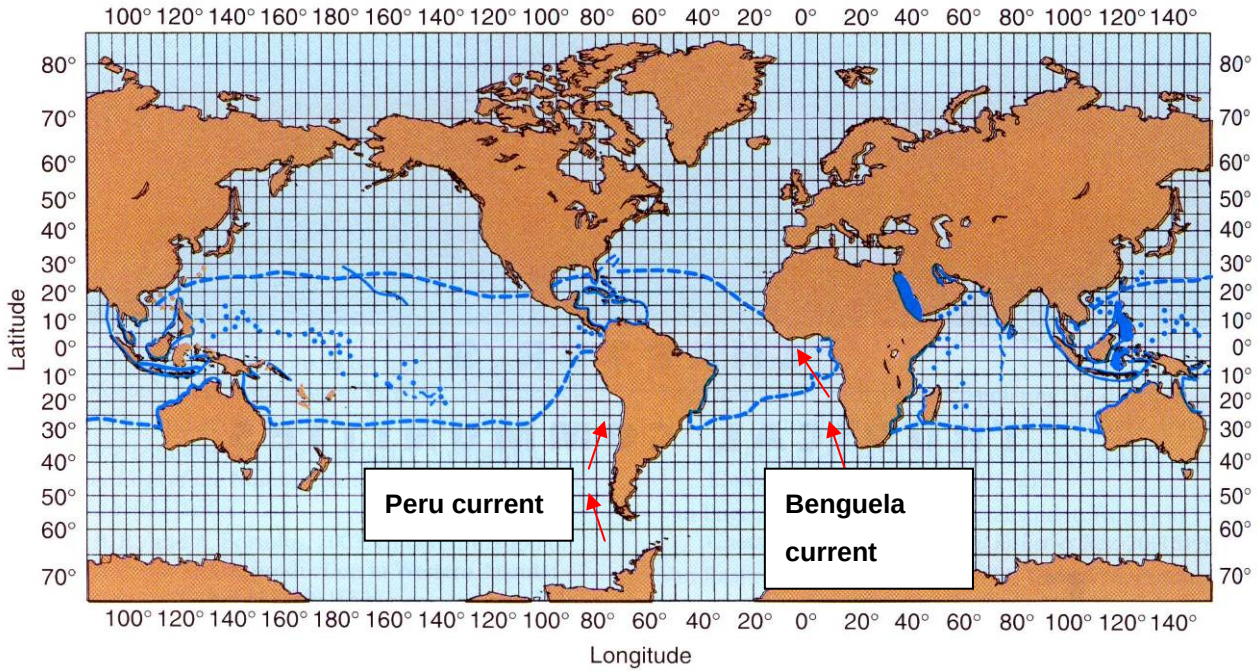


FIGURE 9.1 Distribution of coral reefs in the world; dashed lines indicate the 20°C isotherm.

(2.) **Depth :** < 50-70m (< 25m most case)

∴ margin of continents or islands. ∵ 珊瑚共生藻行光合作用

= 印尼 70-100m 有珊瑚 ∵貧營養鹽，少浮游生物 ∴水清澈，適合進行共生藻之光合作用

(3.) Light : depth ↑, light ↓, photosynthesis ↓
compensation point ~ 1-2% of surface intensity

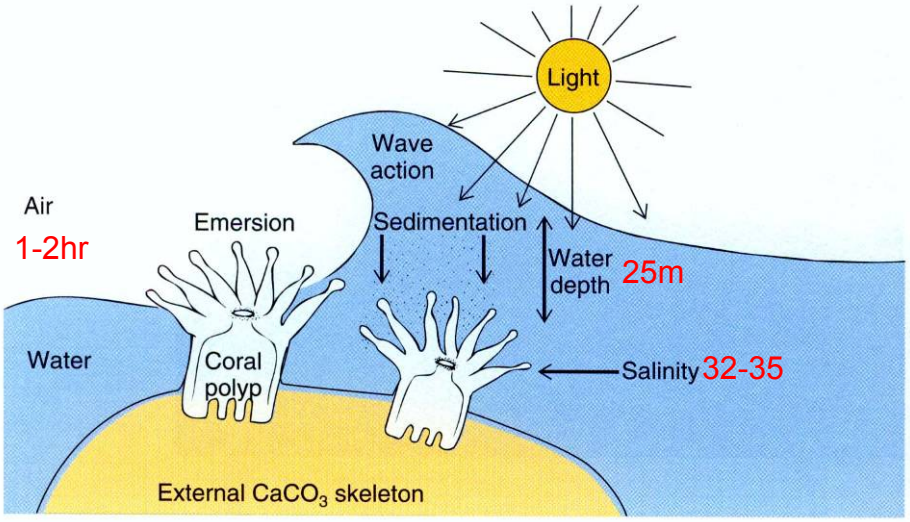
(4.) Salinity : 32-35 ; true marine organisms
∴ rivers and steam run off → absent of corals
i.e. Atlantic coast of S. America,
∵Amazon and Orinoco River, 42　Persian Gulf, reefs develop

(5.) Sedimentation : sediment ↑, light ↓, photosynthesis ↓,
feeding structure clogged
∴海邊若有工程進行，會影響珊瑚成長

(6.) Wave action : wave ↑, O_2 ↑, sedimentation ↓, corals ↑

(7.) Exposure to air : 1-2hrs, few hrs → survive

FIGURE 9.4 Summary of physical factors acting on coral polyps and coral reefs that may limit their distribution.



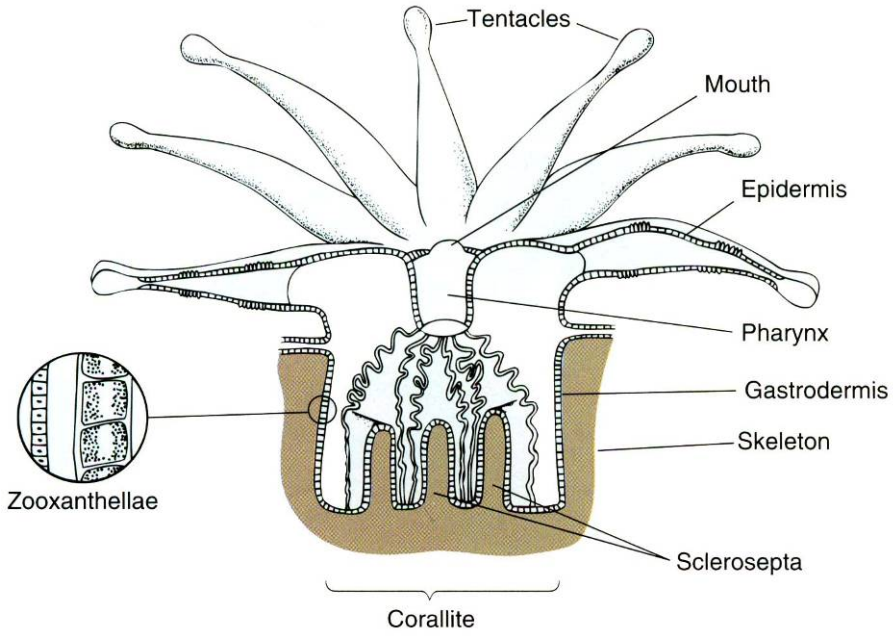


FIGURE 9.5 Anatomy of a coral polyp.

<u>珊瑚的結構</u>
珊瑚是由許多水螅體共生的個體，共生藻住在水螅體的表面
→ 珊瑚分泌 $CaCO_3$
→ 不同的珊瑚的 $CaCO_{3(s)}$有不同的花紋 → 鑑種的依據

Types of Reefs

- **Atolls :** (fig.9.10 right) 環礁
  far from land and enclose a lagoon, lagoon reefs/ patch reefs, Indo-Pacific area
- **Barrier :** (fig.9.10 middle) 堡礁
  adjacent to a landmass but separated from the landmass by a greater distance and deeper water channel
  Largest: Great Barrier Reef of Australia, 2000km along eastern coast of Australia
  Second largest: Yucatan Penisula in Belize
- **Fringing reefs :** (fig.9.10 left) 裙礁
  adjacent to a landmass

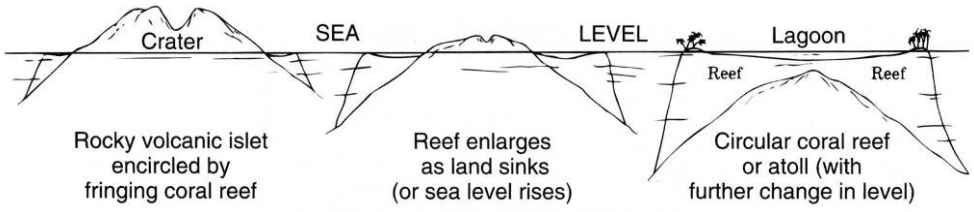


FIGURE 9.10 Geological evolution of a coral atoll according to the subsidence hypothesis of Darwin. (After *General Zoology*, 6th ed., Stoyer et al., 1979.)

Origin of reefs: Subsidence (Compensation) Theory
(Charlee Darwin 提出理論)
(Ladd et al. 1953, found guyots, flat-topped submerged mountains 而確認)

Fringing → Barrier → Atoll
1-1.5 萬年前 1283m of limestone at Eniwetok 6 千萬年前

Composition of Reefs: The most diverse and species-rich areas

- Fig 9.11:
  死掉的珊瑚個體之 $CaCO_3$ 仍可供其他生物利用生長

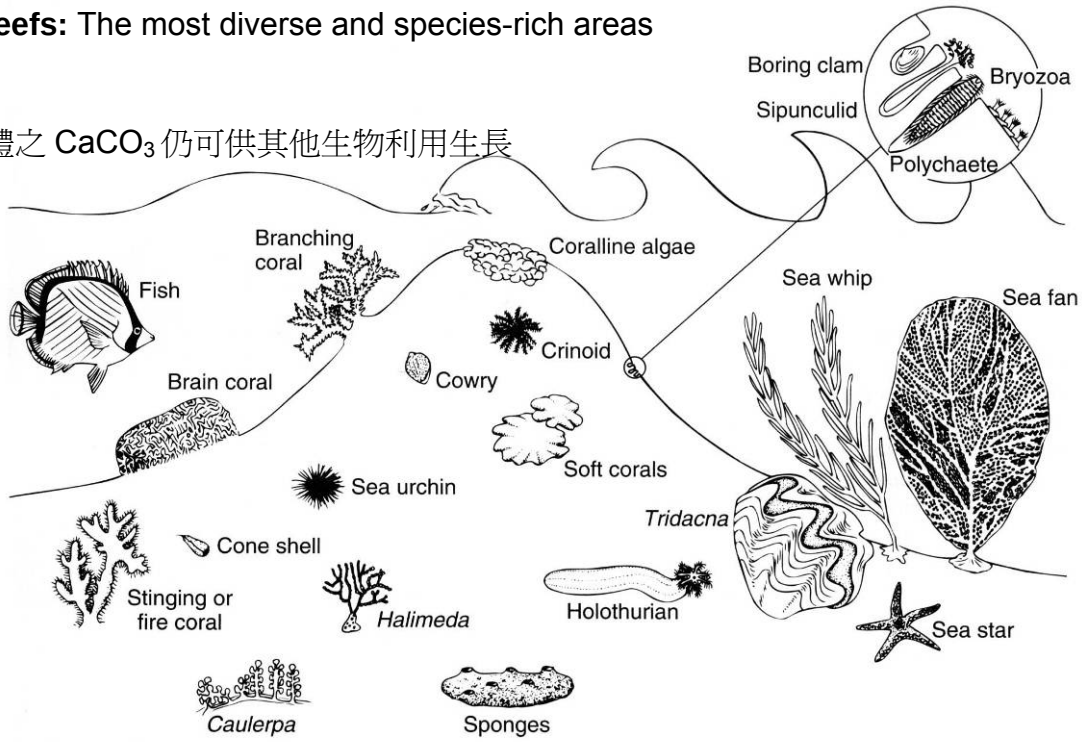


FIGURE 9.11 Some of the dominant and conspicuous components of a coral reef.

Coral Distribution and Reef Zonation

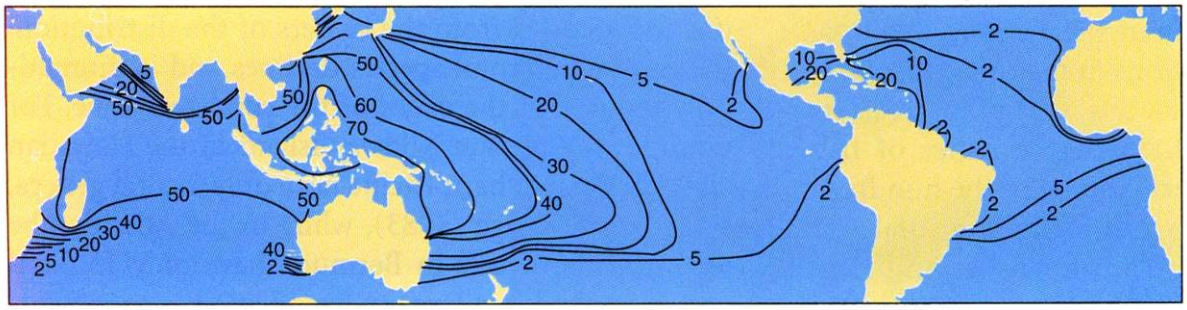


FIGURE 9.19 The number of genera of reef corals occurring in various tropical regions. (After "Distribution of Reef-Building Corals," J. E. N. Veron, *Oceanus,* Vol. 29, No. 2, p. 27, 1986. Copyright © 1986 Woods Hole Oceanographic Institution.)

■ Fig.9.19 珊瑚礁種類在印度洋最多 (總庫源)

Zonation

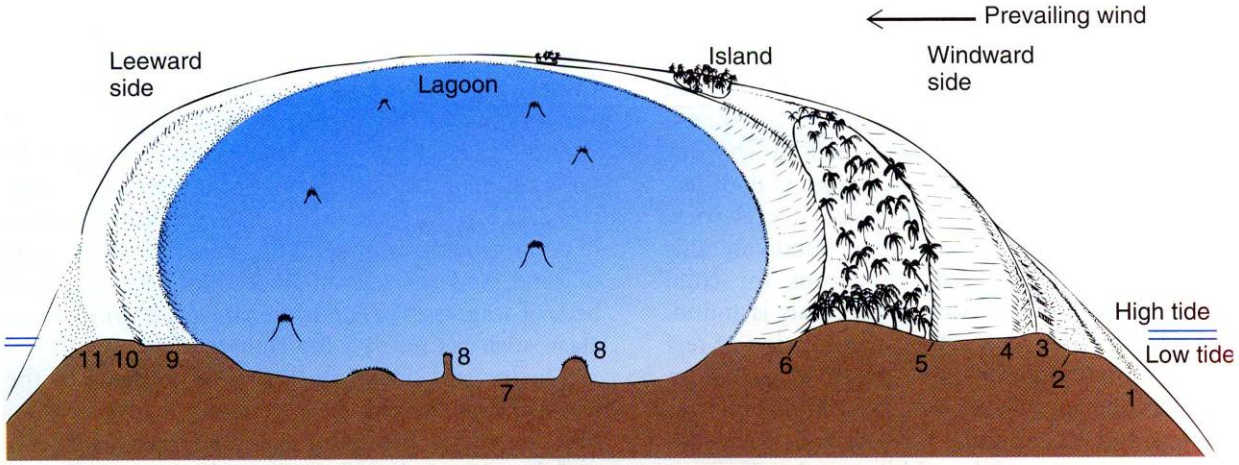
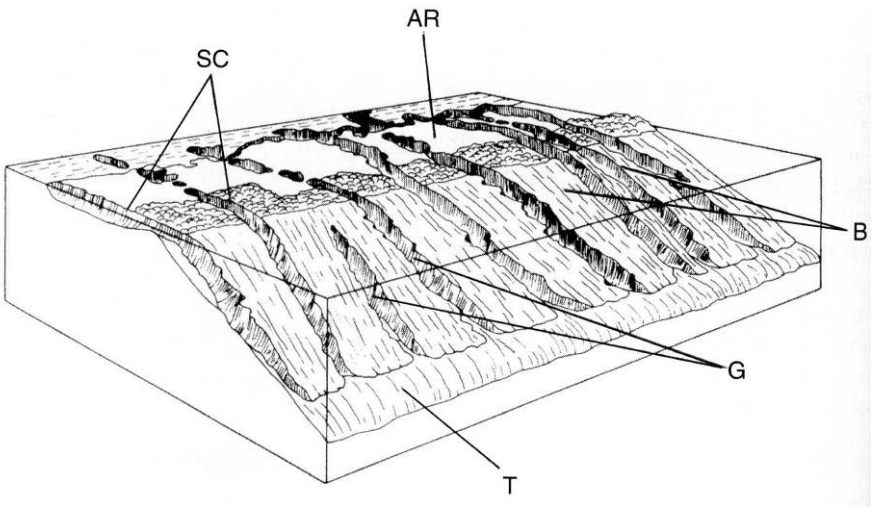


FIGURE 9.20 Diagrammatic cross section of a typical atoll: (1) outer seaward slope; (2) windward reef margin with spur-and-buttress zone; (3) algal ridge; (4) the reef flat; (5) seaward beach of the island; (6) lagoon beach of the island; (7) lagoon floor; (8) lagoon reefs; (9) leeward reef flat; (10) leeward reef margin; (11) leeward reef slope. (Modified from "The Biology of Coral Reefs," C. M. Yonge, 1963, *Adv. Mar. Biol,* Vol. 1, pp. 209–260. Copyright © 1963 Academic Press, Ltd. Reprinted by permission.)

FIGURE 9.21 Generalized sketch of the spur-and-buttress zone of a windward reef. (AR) Algal ridge; (B) buttresses or spurs; (G) grooves; (SC) surge channels; (T) 18-m terrace. (After "The Biology of Coral Reefs," C. M. Yonge, 1963, *Adv. Mar. Biol,* Vol. 1, pp. 209–260. Copyright © 1963 Academic Press, Ltd. Reprinted by permission.)



Productivity

Coral reef:
gross primary productivity = 1500-5000 gC/m^2/yr
Open tropical ocean:
gross primary productivity = 18-50 gC/m^2/yr

TABLE 9.1

Primary Productivities of Component Autotroph Types on Coral Reefs and the Distribution of These Communities on Reefs

AUTOTROPH TYPE	RANGE OF PRODUCTIVITY (g C/m^2/day)	APPROXIMATE AREA/ COVER ON REEFS %
Benthic algae	0.1–4	0.1–5
Turf algae	1–6	10–50
Zooxanthellae	0.6	10–50
Sand algae	0.1–0.5	10–50
Phytoplankton	0.1–0.5	10–50
Seagrasses	1–7	0–40

Source: From Larkham, 1983.

Biology of Hermatypic Corals

- **Nutrition** : grazing → 5-10% food requirement
  zooxanthellae → >90%

- **Phototrophic** (dependent on zooxanthellae)
  1. Directly transmitted during the asexual fragmentation and to the eggs / brooded larvae
  2. 16 spp.
  3. Grow rapidly and fix C at rapid rate till certain density
  4. N limited
  5. Host factor, causing zooxanthellae release C

Sexual Maturity, Reproduction and recruitment

Cnidaria; i.e. jellyfish, hydroids

Class Anthozoa { sea anemones, coral reefs

1. **Asexual reproduction:**
   budding, growth of colony

   Sexual reproduction:
   planula(浮浪幼蟲), develop a new colony
2. **Sexual maturity:** 7-10 yrs
3. **Primarily hermaphroditic,**
   a few dioecious (gogochoric)

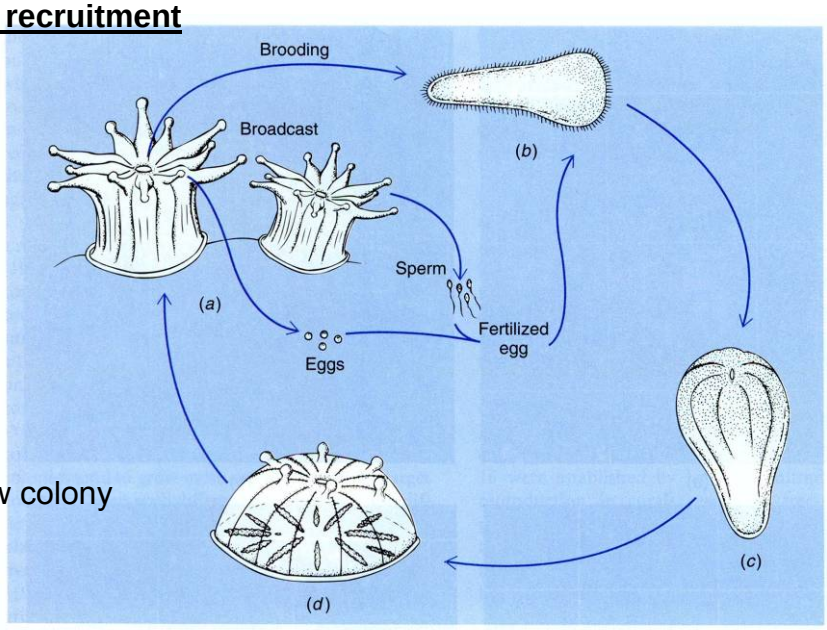


FIGURE 9.28 Reproduction of corals. (a) Adult polyp. (b) Planula (larva). (c) Later planula with developing septa. (d) Young polyp after attachment. (Not to scale; planula and young polyp are much smaller than the adult.) (Modified from *The Invertebrates*, Vol. 1, L. Hyman 1940.)

4. **Broadcast spawner,** a few brooder (fertilized eggs in the gastrovascular cavity)
5. **Spawning with a single brief annual event**
6. **Synchronously spawn:** Late spring to early summer
   Nonsynchronously spawn: July – September
   Brooder: Nocturnal illumination (α lunar cycle)
7. **Settlement:** Days-week or more

8. **Rate of recruitment:** 0-13 new colonies/m^2/year

9. **Growth rate:** Broadcast coral < Brooding coral

9.1.2 Ecology of Coral Reefs

Species interaction between corals

Competition

1. **Exploitative competition**
   Growth rate: branching coral > massive and encrusting corals
2. **Interference competition**
   Slow growing coral extend digestive filaments from their gastrovascular cavities to kill the tissues of adjacent, competing coral

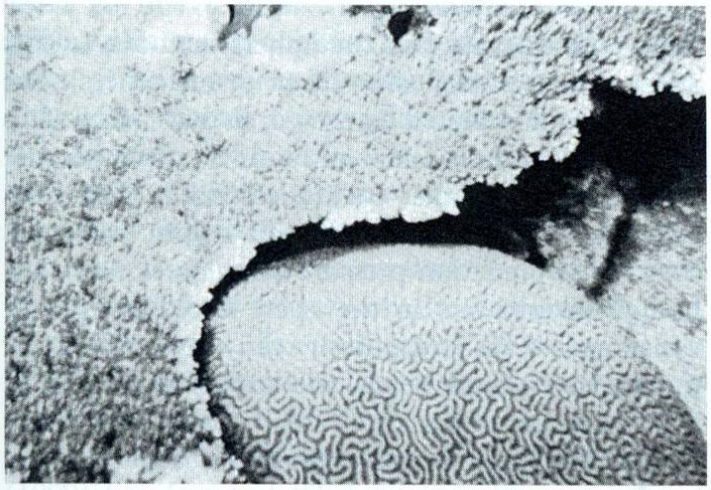


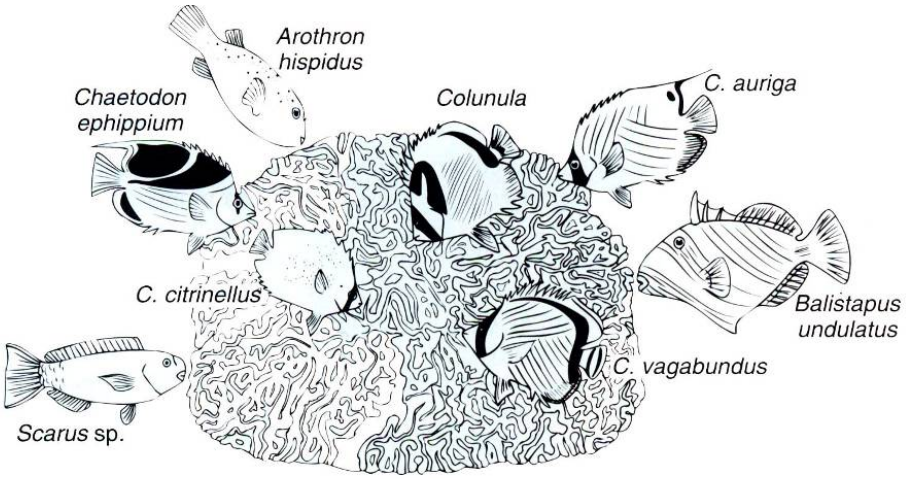
FIGURE 9.29 Photo showing the killing of portions of a tabular *Acropora* colony (left) by the brain coral *Ctenella chagius* (right), thereby preventing overgrowth by the faster growing *Acropora*. (Photo from C. R. C. Sheppard, 1979, Interspecific aggression between reef corals with reference to their distribution. *Mar. Ecol. Progr. Ser.* 1:237–247.)

FIGURE 9.30 Competitive interaction between two massive brain coral species. (Photo courtesy of Dr. Ron Shimek.)

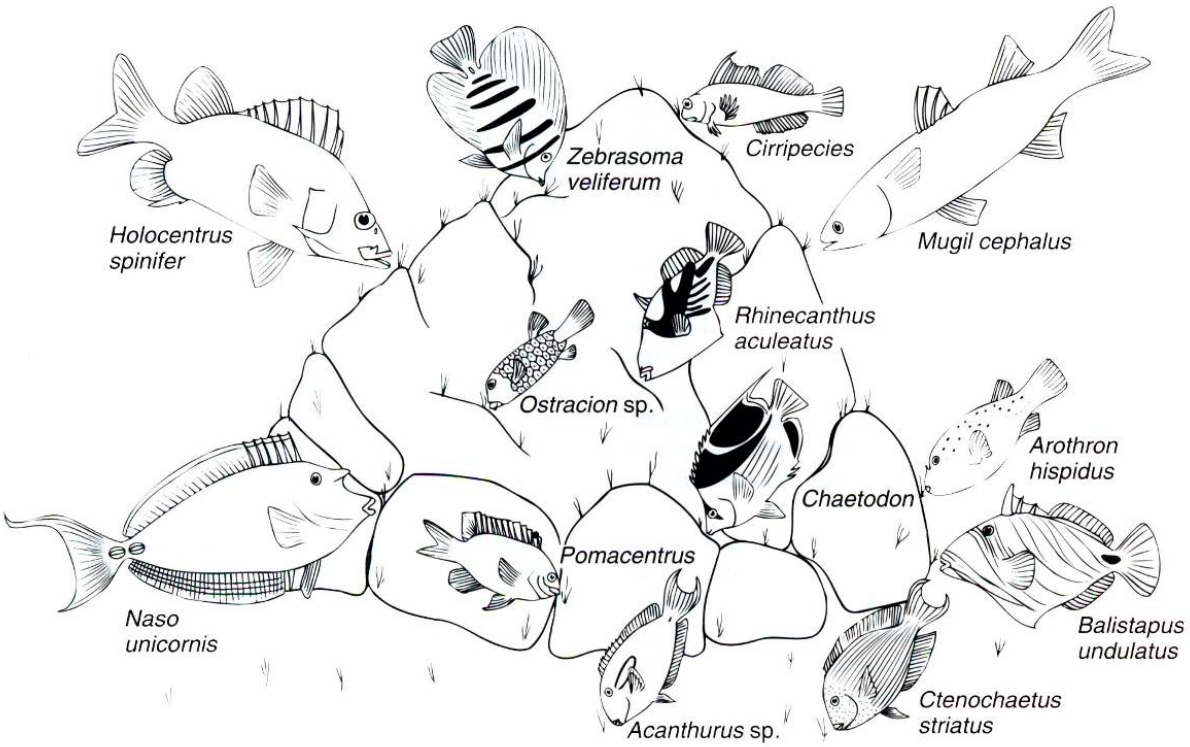
Ecology of Reefs

1. **Predation:**
   Small bits: gastropods, nudibranch, polychaete, crabs
   Destroying reef: starfish and fish

2. **Grazing of algae:** Herbivorous fishes



(a) Coral eaters



(b) Herbivores

FIGURE 9.32 (a) Fishes that graze coral colonies: butterfly fish (Chaetodontidae), *Chaetodon, Colunula*; parrot fish (Scaridae), *Scarus*; triggerfish (Balistidae), *Balistapus*; puffer (Tetraodontidae), *Arothron*. (b) Herbivorous fishes of the reef: triggerfish (Balistidae), *Balistapus, Rhinecanthus*; squirrelfish (Holocentridae), *Holocentrus*; surgeonfish (Acanthuridae), *Acanthurus, Ctenochaetus, Zenbrasoma, Naso*; damselfish (Pomacentridae), *Pomacentrus*; butterfly fish (Chaetodontidae), *Chaetodon*; puffer (Tetraodontidae), *Arothron*; mullet (Mugilidae), *Mugil*; boxfish (Ostraciontidae), *Ostracion*; blenny (Blenniidae), *Cirripecies*. (Not to scale.) (Modified from "Ecological Relationships of the Fish Fauna on Coral Reefs of the Marshall Islands," R. W. Hiatt & D. W. Strasburg, *Ecological Monographs*, Vol. 30, pp. 65–127, 1960. Copyright © 1960 Ecological Society of America. Reprinted by permission.)

TABLE 9.2

Number of Fish Species in Several Coral Reef Areas

GEOGRAPHICAL AREA	NUMBER OF FISH SPECIES
Philippine Islands	2,177
New Guinea	1,700
Great Barrier Reef	1,500
Seychelles Islands	880
Marshall and Mariana Islands	669
Bahama Islands	507
Hawaiian Islands	448

Source: After Goldman and Talbot, 1976.

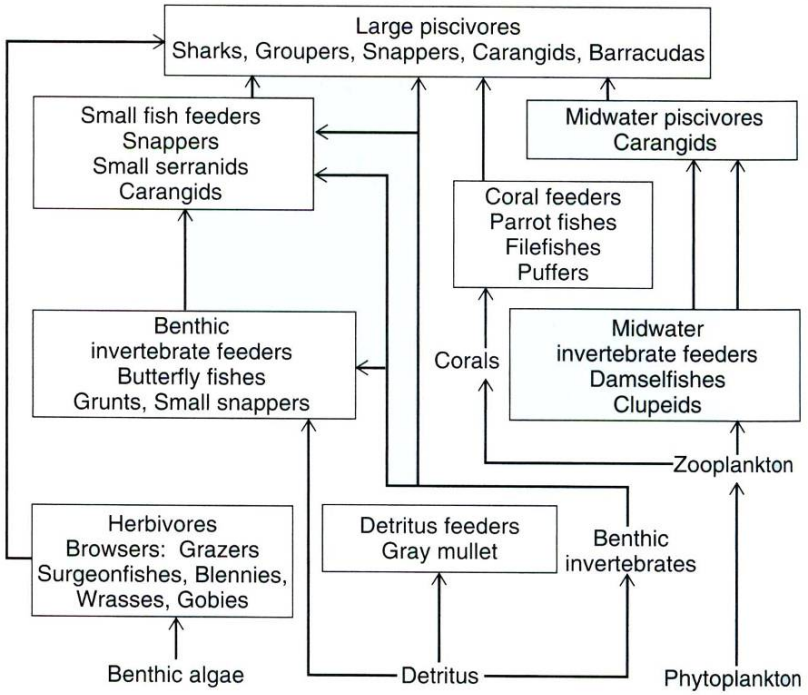


FIGURE 9.42 The trophic relationships of coral reef fisheries. (After "Ecology of Fishes in Tropical Waters," R. H. Lowe-McConnell, 1977, *Studies in Biology*, No. 76, 1977. Reprinted with the permission of Cambridge University Press.)

TABLE 9.3

Proportion of Fish Species in Different Trophic Categories from Seven Tropical Studies[a]

TROPHIC CATEGORY	H & S[b]	RAND[c]	G & T[d]	HOBSON	W & H	SANO	T & C
Herbivores	26	13	22	7	15	18	20
Planktivores	4	12	15	18	20	15	38
Benthic invertebrate feeders	49	44	27	56	53	41	33
Coral feeders	6	1		9	5	9	
Sessile animal feeders	8	6		13	3		
Mobile invertebrate feeders	35	37		34	45		
Omnivores	13	7		10	4	19	
Piscivores	10	25	38	7	8	4	8
Others (e.g., cleaners)				2		2	1

[a]Figures given are percentages of the number of species surveyed, unless otherwise noted. The category of benthic animal feeders is the sum of the three subcategories following and indented from it. The seven studies were H & S, Hiatt and Strasburg (1960); Rand, Randall (1967); G & T, Goldman and Talbot (1976); Hobson, Hobson (1975); W & H, Williams and Hatcher (1983); Sano, Sano et al. (1946b); and T & C, Thresher and Colin (1986).

[b]Hiatt and Strasburg (1960) classified some species into more than one category.

[c]Randall (1967) indicated that the survey was biased toward important sport and commercial species.

[d]Goldman and Talbot (1976) used only the four categories shown. Herbivores were placed into a category of grazers that included coral feeders. Figures given are percent weight of all groups, averaged over three types of habitat: fore reef, lagoon, and back reef.

Zonation patterns on Reefs

Exp. Fringing Reef (Caribbean)

1. **Reef flat (back-reef)**
   few cm – few m depth
   few ten – few thousands m width

   Substrate: coral rock (lining corals are very scarce)
   Loose sand (seagrasses)
   lot of microhabitats → greatest no. of spp.

2. **Reef crest (algae ridge)**
   Highest point of the reef, exposed at low tide
   few – few ten m width, encrusting red coralline
   algae are dominant or brown algae
   living corals are very scare (1 or 2 spp.)

3. **Seaward slope (fore-reef)**
   low tide to deep water
   15 – 25m many large fish
   20 – 30m fish no. ↓, small branched from corals
   30 – 40m patchy coral, sponges, sea whips, sea fans, ahermatypic coral
   50m ┐ Pacific
   100m ┘ depth limit for reef-building coral Caribbean

Nutrition and Production in reefs

Hermatypic corals ←→ ahermatypic corals = Reef – building corals
With photosynthetic dinoflagellates ~ Zooxanthellae
Symbiodinium microadriaticum diff. strains, specific to particular coral species

The coral-zooxanthellae Symbiosis

- Maintain over time and distance in coral larvae before leave parent polyp
- Zooxanthellae present in other reef inhabitatants
  i.e. other cnidarians, shell-less snails some tunicates, giant clam, *Tridacna*
- Internal nutrient cycling → (Coral-Zooxanthellae symbiosis) primary importance in maintaining the productivity of reef in oligotrophic tropical water
- Live within cells in the living of gut of corals 30000 cells/mm^3
- **Bleaching** ∴zooxanthellae expelled from coral
  ∴coral colour ← pigmentation of zooxanthellae (Coral- zooxanthellae symbiosis)
- **Zooxanthellae**
  1. Protected environment
  2. certain chemical compounds i.e. CO_2, NH_4,NO_2,NO_3

Coral

1. O_2
2. Removes wastes
3. Nutrients, i.e. glucoses, glycerol, amino acids
4. Synthesize of $CaCO_3$

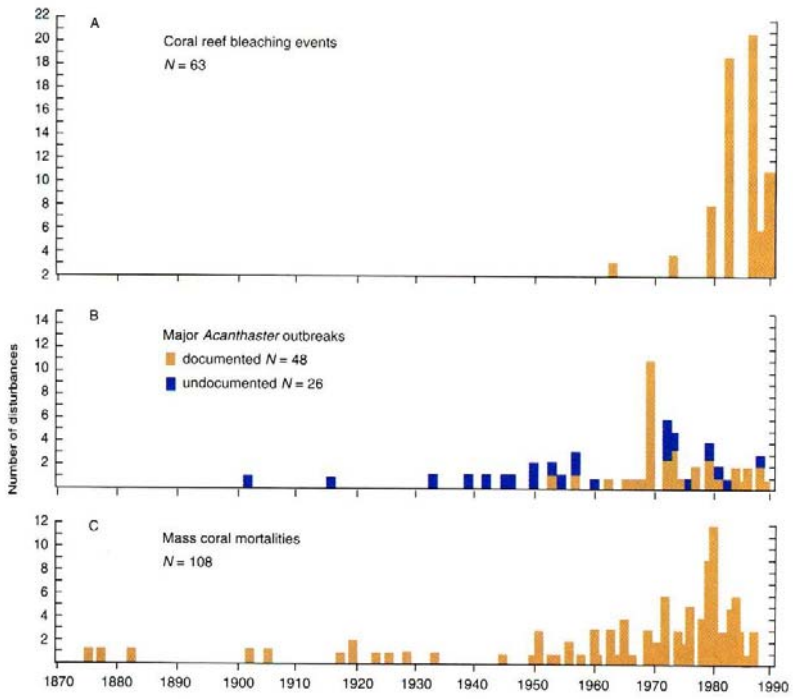


FIGURE 9.48 Reported coral bleaching events, *Acanthaster* outbreaks, and mass coral mortalities from 1870 to 1990. (From *The Life and Death of Coral Reefs*, C. Birkeland, editor, © 1997 Chapman and Hall, p. 355, Figure 15.1, with kind permission from Kluwer Academic Publishers.)

Energy requirement in Great Barrier Reef:

71% - photosynthesis fixation by the zooxanthellae

17% - predation on zooxanthellae

12% - absorption of dissolved organic matter and ingestion of bacteria

Diversity

Extraordinary rich

~ 3000 animal species + micro and Meiofauna

~ Representative spp. of almost all phyla and classes

Richness(species):

Indo0Pacific spp. > Atlantic spp.

Ref-building Coral	500	62
Mollusc	5000	1200
Fish	2000	600
∵ Age of the Oceans	200 萬年 (Great Barriers Reefs)	1-1.5 萬年
	6000 萬年 (Pacific Atoll)	

Reef Community

1. Other reef organisms contribute to the carbonate reef structure
   i.e. Hard, coralline red algae (cementing the reef fragment together)
   Green algae, benthic algae, seagrass – sandy area within or arrounding the reef
2. Other types of Cnidarians
   i.e. Non-reef-building corals ~ fire coral, pipe coral, soft coral, sea whips and sea fans
3. Other major invertebrate groups
4. Echinodrems : starfish, sea urchins, sea cucumbers
5. Mollucs : limpets, snails, clams
6. Polycharte worms, sponges
7. Crustaceans : spiny lobsters, small shrimp
8. Encrusting spp.
   i.e. bryozoans, tubes of polychaete, giant clam (1m length, 300kg width)
9. Fish : 25% of world's fish spp.
   Herbivores, plankton-feeders, piscivores, predator of benthic reef invertebrates

Growth of reefs

A balance between the growth rates (budding) and calcification of the coral polyps and the rates of destruction of the limestone framework.

~ growth rates; growth upward toward light
  sunlight > darkness
  shallow water > deeper water
  sediment-laden water ↑ , chemical ↑ , age ↑ , growth rate ↓ , increasing size of colony ↑

Rates of growth < 1-10cm/yr, few mm-30cm/11yr

*predation (starfish), competition (mesenterial filament), light intensity

Destruction of the reef

1. Physical erosion ; wave action and currents, storms
2. Bioerosion ;
   a. Boring: algae, clams, sponges, urchins, polychates
   b. Grazing: limpets, snails, parrotfish
   c. Consumed: sea cucumber (deposit-feeder)

Production

Gross primary productivity ~ 1500-5000gC^{-2}/yr

P/R = 1.0-2.5 for coral reef community
  = 10 for healthy phytoplankton

Food chain longer then upwelling.

Catastrophic mortality of reefs

1. Hurricanes or typhoons

2. Explosion of the sea star, *Acanthaster planci*
   ex. In Guam, cheater (1969), 90% 38km coral, destroyed in 2.5 years
   Great Barrier Reef, Endean (1973), 8 km^2 coral, 12months
   i. Natural phenomena, Acanthaster problem
   ii. Human removed an important predator.
   ∴ survival rate ↑ i.e. large gastropod, *Charonia tritoris* (shell collectors)
   iii. Tropical storms opened space for juvenile settlement
   iv. **Runoff theory**. Low salinities, high nutrients and temp., larvae growth ↑
   v. A**dult-aggregation theory.** Storms opened space ↑, adult ↑

3. **El Nino Southern-Oscillation (ENSO)**
   A massive flux of nutrient poor warm water into the usually cold, nutrient-rich surface water off the coasts of Ecuador and Peru. 每 100-250 年一次,Temp. ↑2-4℃ ~ 30-32℃, sea levels↓ 44cm, unusual hurricane acticity. Mortality rates for coral 50-98%

4. **Coral Bleaching :** zooxanthellae expel
   ∵Stress, Temp. >30℃, global warming

5. **Human Activities**
   i. Sewage pollution, i.e. Kaneohe Bay, Hawaii
   ii. Mined for building materials, i.e. India
   iii. Dynamiting for fishes; i.e. Philippines

Recovery of Reefs

1. Hurricanes ~ 25-30yrs
2. *Acanthaster* ~ 7-40yrs
3. El Nino (1982-1983) ~ 100 or more

Conservation of Reefs

1. Great beauty (Tourism)
2. Endemic species
3. Remove CO_2 (global CO_2 budget)
4. Protecting coastlines
5. Provided sheltered

Damage and destruction of Coral reefs

∵ Human activities and change in ocean climate

1. Nutrient ↑, algae↑, outcompete corals
2. S.S. ↑ (sewage effluents and pollutants)

3. Deforestation → sedimentation↑
4. Harvest for building material
   i.e. Maldive Islands (Indian Ocean),
   Thailand and French, Polynesia
5. Tourism
6. Crown-of-thorns starfish
7. Storms

9.2 Mangrove Foresta

Mangrove swamp; Tidal forest; Mangal

TABLE 9.4

The Genera of Mangroves

Avicennia	*Aegiceras*
Suaeda	*Aegialitis*
Laguncularia	*Rhizophora*
Lumnitzera	*Bruguiera*
Conocarpus	*Ceriops*
Xylocarpus	*Sonneratia*

Source: After Lugo and Snedaker, 1974.

FIGURE 9.51 Pneumatophores on the roots of a mangrove tree. (Copyright Dr. Aaron Ellison.)

Structure and Adaptations

1. Peculiar prop roots (pneumatophores)
2. Tough leaves; internal water storage tissue
3. With salt gland; secret salt; osmotic balance
4. Special reproductive strategies
   a. Vivipary; uninterrupted development of the embryo; no “resting” or true “seed” stage
   b. Dispersal by water; ∴living on the fringe of the sea

Distribution

1. Tropical and subtropical sea shores
2. Sheltered from wave action; e.g. estuarine
3. Occur over a larger geographical area than coral reefs, 30°N-30°S
4. Except:
   West coast of central and northern South America and Africa, North island of New Zealand; mouth of Rio de la Plata in Argentina; 300km upstream the Fly River of New Guinea

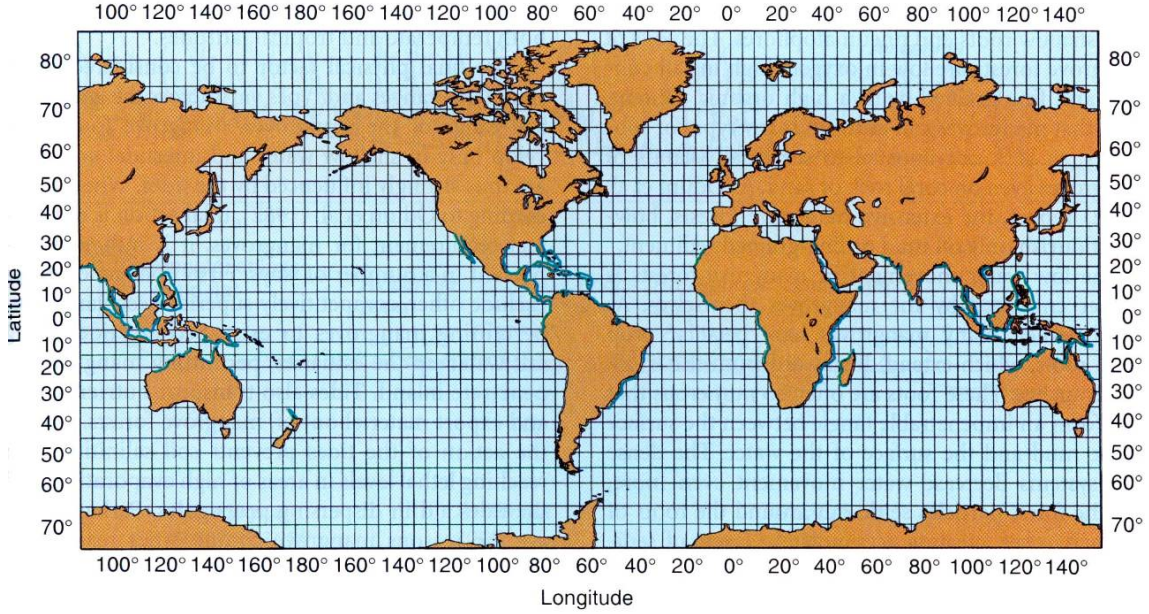


FIGURE 9.54 Distribution of mangrove forests in the world.

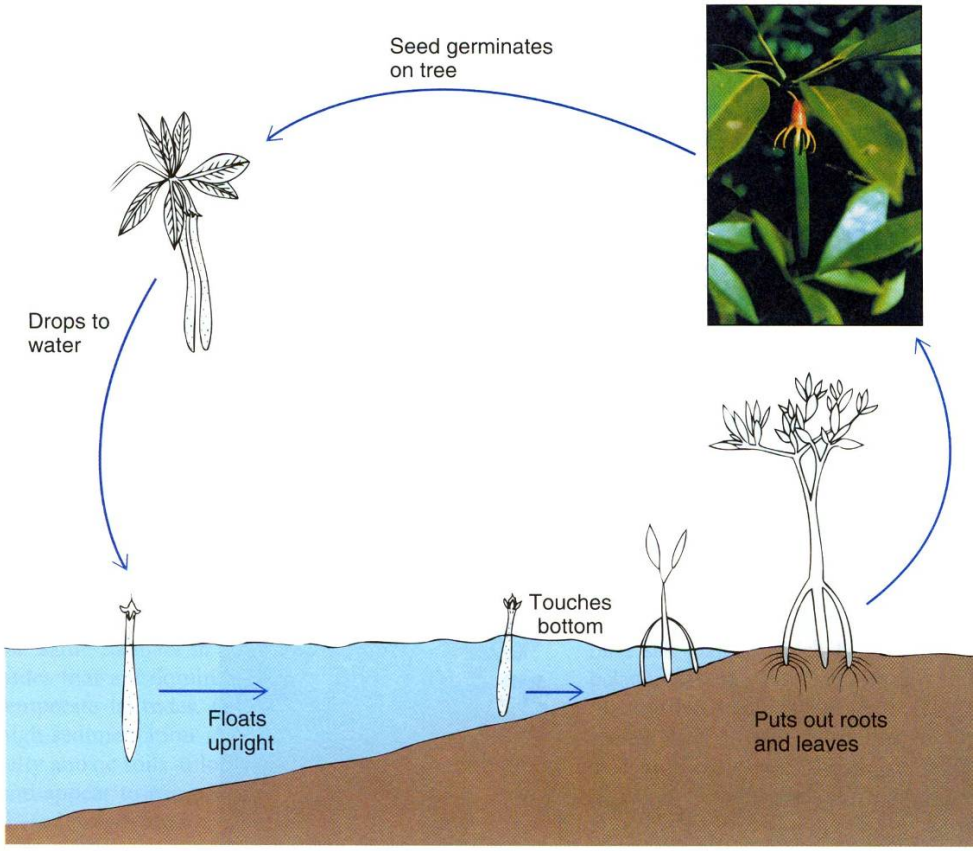


FIGURE 9.52 The life cycle of a typical mangrove tree.

TABLE 9.5

Species Diversity of Mangroves in Different Geographical Regions

REGION	NUMBER OF GENERA	NUMBER OF SPECIES
Australia and New Guinea	16	35
Asia, including Indonesia	17	39
East Africa and Madagascar	8	9
West Africa	3	5
West Atlantic, including the Caribbean	3	6
Eastern Pacific	4	7

Source: Species Diversity, Vol. 1: Ecological Communities, by Ricklefs and Schluter, p. 218. Copyright © 1993 University of Chicago Press. Reprinted by permission.

Physical conditions of Mangrove Forests

1. No significant wave action
2. Muddy shores
3. Anoxic substrates, Bacteria↑
4. Tide
   → competition with terrestrial vascular plants

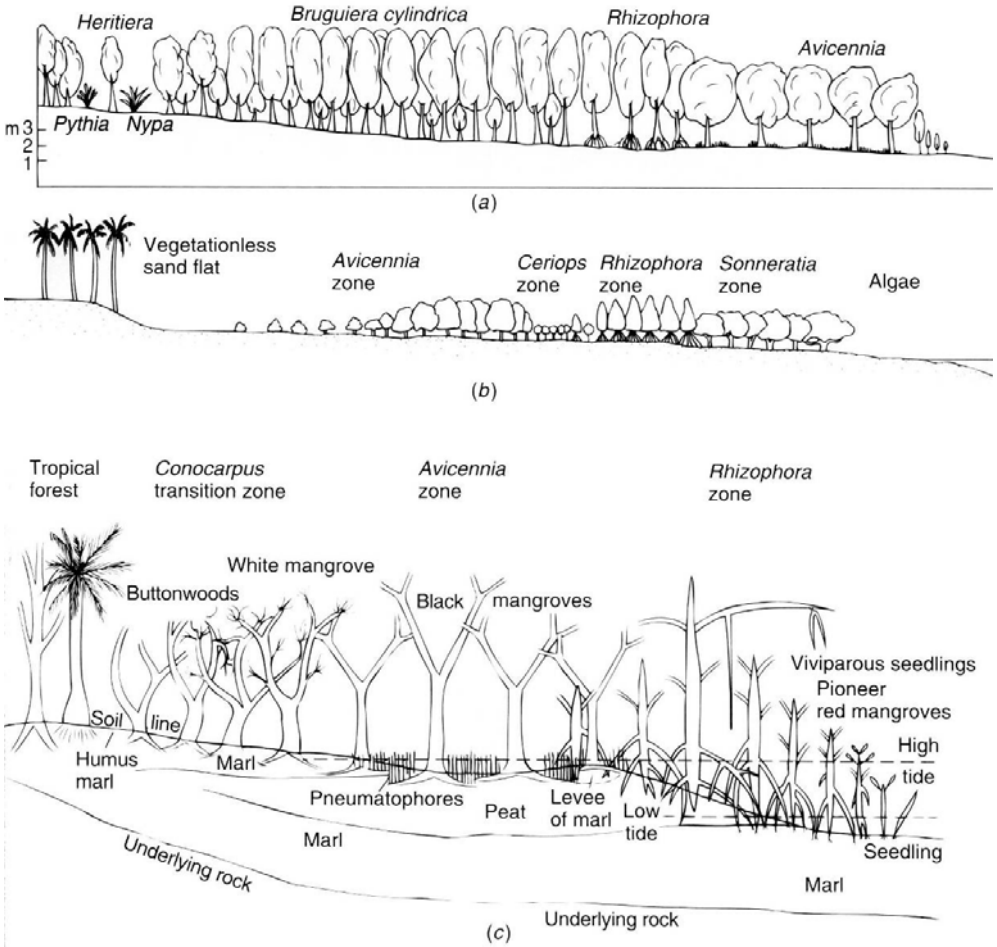


FIGURE 9.55 Diagrams of the zonation of mangroves in several areas. (a) Malaysia. (b) East Africa. (c) Florida. (a, b from *Ecosystems of The World*, Vol. 1, ed., V. J. Chapman, 1977. Copyright © 1977 V. J. Chapman. c, from "The Ecology and Geologic Role of Mangroves in Florida," J. H. Davis, Jr., 1940, Carnegie Institute of Washington, Publication 517, Tortugas Lab, Paper 32. Reprinted by permission.)

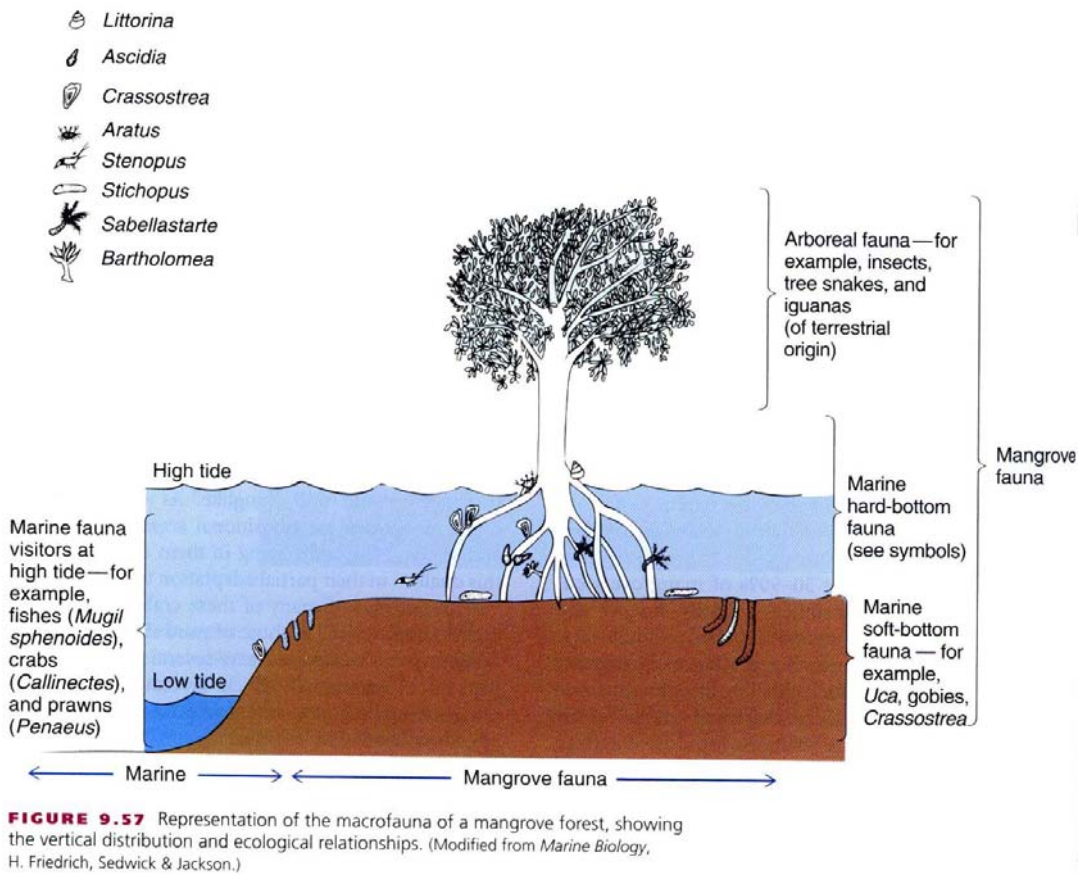


FIGURE 9.57 Representation of the macrofauna of a mangrove forest, showing the vertical distribution and ecological relationships. (Modified from *Marine Biology*, H. Friedrich, Sedwick & Jackson.)

■ Fig 9.57 紅樹林區生物相豐富，根的小縫形成小棲所，矽藻→多毛類→甲殼類→小魚→大魚

Succession and mortality

- Succesion occur when changes of
  1. Sedimentation rate
  2. Water movement
  3. Tidal regime
  4. Slinity of water and soil

- Large-scale motality
  1. Typhoons and Hurricanes
  2. Infected by small isopod, Sphaeroma terebrans
  3. Human activity
     i.e. Herbicide spraying filling,Dredging or channelizing waters,Firewood,Construction, build ponds, etc

- Important values of mangrove forests
  1. Nursery ground
     i.e. blue crab, penaeid shrimp,spiny lobster
  2. Shelter of endangered species,
     i.e. American crocodile, brown pelican, Altantic Ridley sea turtle
  3. Stabilized land