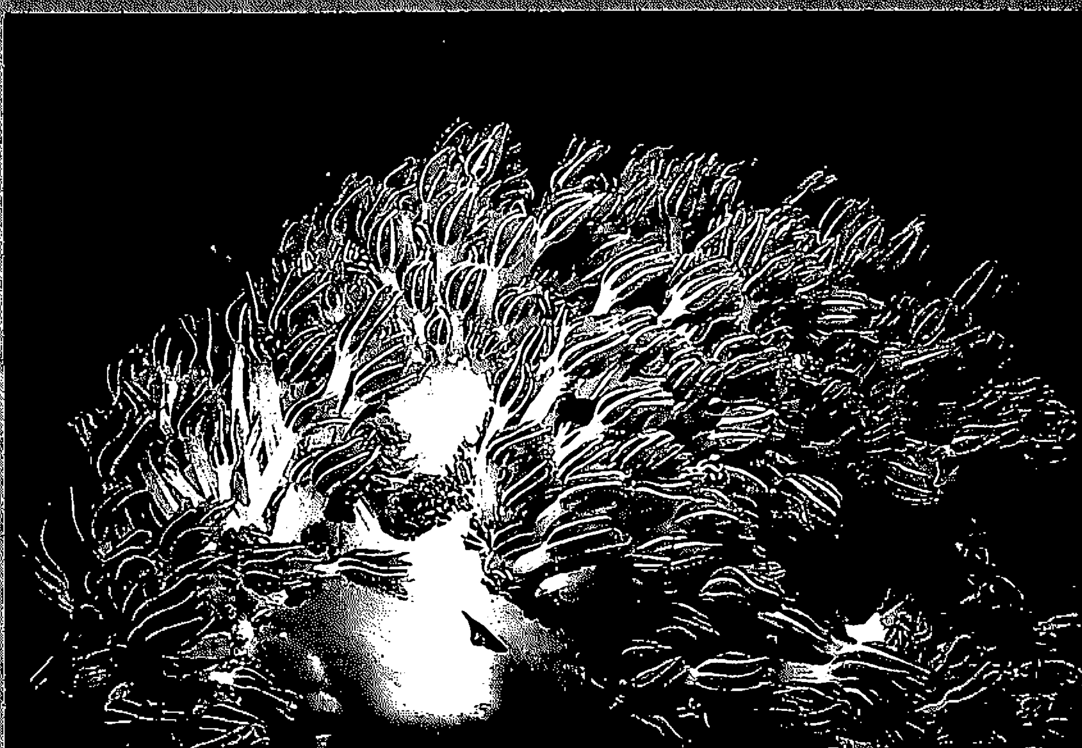
CORAL REEFS

Valuable Resources of Southeast Asia



Alan T. White

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1990

**Association of Southeast Asian Nations/United States
Coastal Resources Management Project Education Series 1**

Coral Reefs: Valuable Resources of Southeast Asia

ALAN T. WHITE

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Cover: Xenia *is a common soft coral. Unlike hard corals, it has no calcium carbonate skeleton and is soft to the touch. Brown Rocks, Philippines.*

Color photos are by A.T. White, unless otherwise noted.

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Contents

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Acknowledgements

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Foreword

The coastal waters of Southeast Asian countries have some of the world's richest ecosystems characterized by extensive coral reefs and dense mangrove forests. Blessed with warm tropical climate and high rainfall, these waters are further enriched with nutrients from land which enable them to support a wide diversity of marine life. Because economic benefits could be derived from them, the coastal zones in these countries teem with human settlements. Over 70% of the population in the region live in coastal areas which have been recently characterized by high-level resource exploitation. This situation became apparent between the 1960s and 1970s when socioeconomic pressures were increasing. Large-scale destruction of the region's valuable resources has caused serious degradation of the environment, thus affecting the economic life of the coastal inhabitants. This lamentable situation is mainly the result of ineffective or poor management of the coastal resources.

It is essential to consider coastal resources as valuable assets that should be utilized on a sustainable basis. Unisectoral overuse of some resources has caused grave problems. Indiscriminate logging and mining in upland areas might have brought large economic benefits to companies undertaking these activities and, to a certain extent, increased government revenues, but could prove detrimental to lowland activities such as fisheries, aquaculture and coastal-tourism dependent industries. Similarly, unregulated fishing efforts and the use of destructive fishing methods, such as mechanized push-nets and dynamiting, have caused serious destruction of fish habitats and reduction of fish stocks. Indiscriminate cutting of mangroves for aquaculture, fuel wood, timber and the like have brought temporary gains in fish production, fuel wood and timber supply but losses in nursery areas of commercially important fish and shrimp, coastal erosion and land accretion.

The coastal zones of most nations in ASEAN are subjected to increasing population and economic pressures manifested by a variety of coastal activities, notably, fishing, coastal aquaculture, waste disposal, salt-making, tin mining, oil drilling, tanker traffic, rural construction and industrialization. This situation is aggravated by the expanding economic activities attempting to uplift the standard of living of coastal people, the majority of which live below the official poverty line.

Some ASEAN nations have formulated regulatory measures for their coastal resources management (CRM) such as the issuance of permits to fishing, logging, mangrove harvesting, etc. However, most of these measures have not proven effective due partly to enforcement failure and largely to lack of support for the communities concerned.

Experiences in CRM in developed nations suggest the need for an integrated, interdisciplinary and multisectoral approach in developing management plans providing a course of action usable for daily management of the coastal areas.

The ASEAN/US CRMP arose from the existing CRM problems. Its goal is to increase existing capabilities within ASEAN nations for developing and implementing CRM strategies. The project, which is funded by USAID and executed by ICLARM in cooperation with ASEAN institutions, attempts to attain its goals through these activities:

- Analyzing, documenting and disseminating information on trends in coastal resources development;
- Increasing awareness of the importance of CRM policies and identifying, and where possible, strengthening existing management capabilities;
- Providing technical solutions to coastal resources use conflicts; and
- Promoting institutional arrangements that bring multisectoral planning to coastal resources development.

One of the information activities of CRMP is to produce or to assist cooperating agencies in producing educational materials on coastal environments which are targetted for general audiences. In the form of books, booklets or leaflets, these materials primarily purport to create public awareness on the importance of rational exploitation of living coastal resources, environmental conservation and integrated CRM and planning.

Coral reefs: valuable resources of Southeast Asia is the first of the titles in the education series of the ASEAN/US CRMP and of ICLARM. This book is intended to introduce coral reef ecosystems as valuable and vulnerable resources which contribute significantly to the economic well-being of coastal people. But because coral reefs are plundered and rapidly destroyed, like many coastal resources, a case is made for rational and sustainable use to ensure their long-term survival and viability.

Chua Thia-Eng
Project Coordinator
ASEAN/US Coastal Resources
Management Project

Introduction

For color, sheer beauty of form and design, and tremendous variety of life, perhaps no natural area in the world can equal coral reefs. Their beauty has fascinated generations of people, both scientific and lay, down through the years.[26]

Coral reefs cover an estimated minimum area of 600,000 km^2 and, with a few exceptions, are located between latitudes 30° north and south of the equator. They are a dominant feature of shallow waters throughout the tropics, and the World Conservation Strategy[14] identifies reefs as an essential ecological and life-support system necessary for human survival and sustainable development[37].

Coral reefs constitute one of the earth's most productive and diverse ecosystems. They benefit people directly by providing food, medicine, construction materials and other valuable items. More importantly, coral reefs provide support and sustenance to the other coastal ecosystems upon which people depend.

Humans have always used reefs, although until recently their exploitation has been tempered by traditional tenures and beliefs. As coastal populations in Southeast Asia have grown, they have brought increased pressure to bear on the reefs. At the same time, traditional management strategies have been discarded. The result is that large areas of coral reef throughout the region have been seriously depleted. This process will continue until new ways are found to protect and manage coral reefs.

This book highlights the value of coral reef resources to people and exposes those threats to reefs caused by humans. An attempt is made to emphasize *process* in the coral reef ecosystem which is a seemingly static environment. When we speak of conservation, we refer to the preservation of this process in its complex natural state of equilibrium. This equilibrium may be upset through unsound, unsustainable uses of natural products produced during this continuing ecological process. When one ingredient is severely depleted or even eliminated inappropriately from the system, unpredictable changes will occur. This may have long-term negative effects on other living components of the system. The inevitable result is a decrease in stability and productivity within the system.

It is hoped that this book will promote public interest in the coral reef environment and its preservation by providing a glimpse of the intricacy, value and problems of this unique ecosystem. Such interest may in turn generate greater concern and active participation aimed at maintaining coral reefs in their natural state.

Coral Reef Ecology and Distribution

Physical Limits of Coral Reefs

Coral reefs are unique among marine associations or communities in that they are built up entirely by biological activity. Reefs are essentially massive deposits of calcium carbonate that have been produced by corals (phylum Cnidaria, order Scleractinia) with major additions from calcareous algae and other organisms that secrete calcium carbonate. The limiting environmental factors of reef growth are really those of corals which form the reef framework and immediate foundation (Fig. 1). Conditions favoring the development of reefs include water temperature above 18°C; water depth shallower than 50 m; constant salinity greater than 30 but less than 36 parts per thousand; low sedimentation rates; sufficient circulation of pollution-free water; and preexisting hard substrate[10, 26].

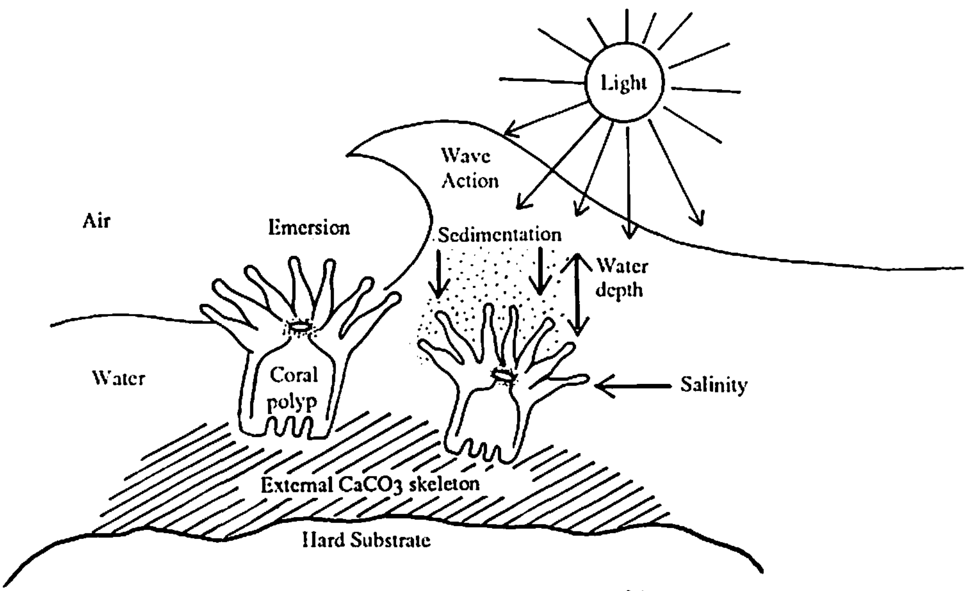

Fig. 1. Reef growth (coral polyp) physical restraints[26].

Types of Reefs and Zonation

Coral reefs are generally grouped into three types: atolls, barrier reefs and fringing reefs. Fig. 2 shows the evolution of an atoll reef from the beginning stages of a fringing reef followed by a barrier reef. This process presupposes either subsidence of the land or a rising sea level or a combination thereof. Such changes are ongoing over tens of thousands of years. Sea level rose by about 100 m or more between 15,000 and 5,000 years before the present, leaving many reefs submerged or simply growing upward. Thus, most modern-day reefs are the result of growth over the past 5,000 years of relative sea level stability.

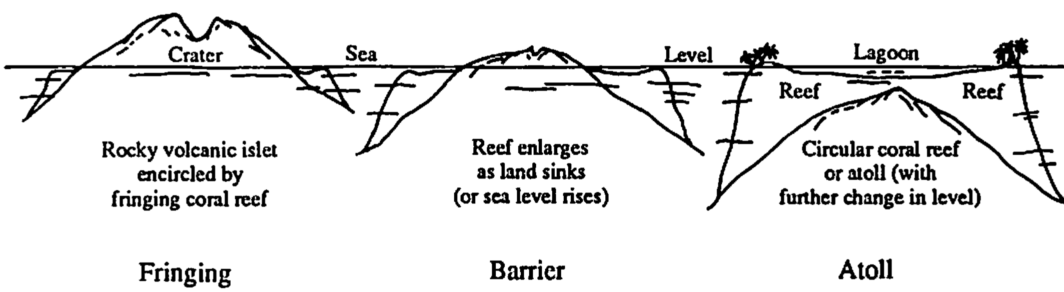

Fig. 2. Coral reef types and their geological evolution. Charles Darwin applied this reasoning to mid-Pacific atolls where subsidence was evident but excluded shelf areas such as much of the Caribbean, the Red Sea, the Great Barrier Reef and Southeast Asia[26].

Fringing reefs are by far the most common type in Southeast Asia where most islands are bordered by coral growth (Fig. 3). Regardless of the general reef type as determined by its original formation, there is a scheme of zonation common to most reefs (Fig. 4). Due to physical constraints, most corals and other animals can live only at certain depths. Some animals have special living places or activities, i.e., niches.

Reefs fringing most small islands in Southeast Asia are similar in structure and support similar living communities. Most shores are sandy beaches, mangrove forest and rocky cliffs or intertidal areas. Sloping gently away from this shore is a shelflike *reef flat* of variable width and depth. It usually consists of a combination of sand, mud, rocks, sea grass, algae and scattered corals. The mean water depth of the reef flat is often no more than one meter, and extreme low tides can leave large areas of it exposed. At the outer edge of the reef flat is

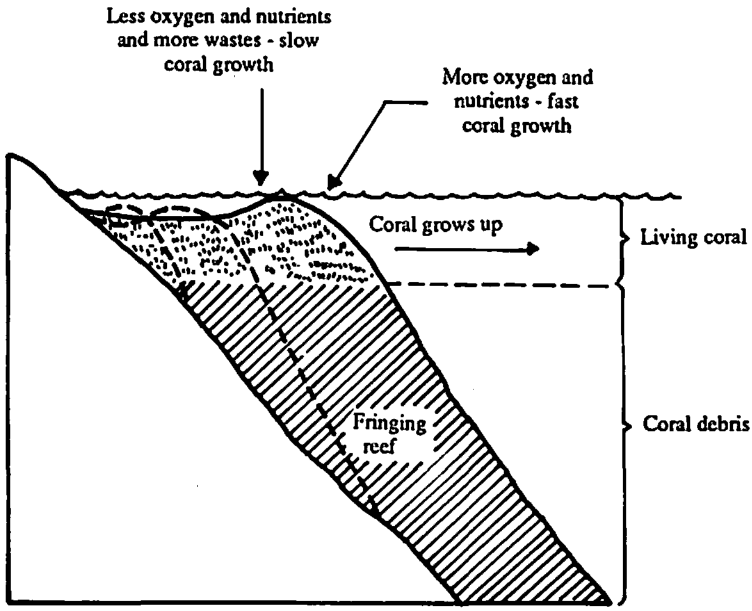

Fig. 3. Formation of a fringing coral reef[42].

the *reef crest* which is often the most diverse and productive zone being exposed to waves, currents, clear and shallow water. Below the reef crest is the more tranquil reef slope.

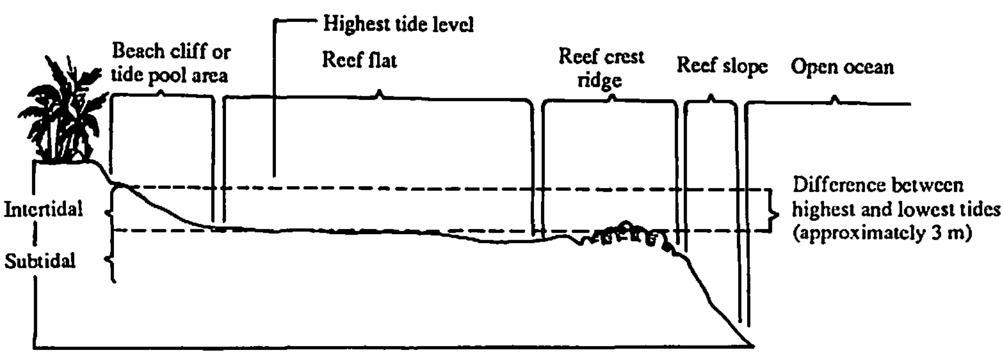

Fig. 4. Zonation of a fringing reef[12, modified].

Reef Productivity and Diversity

The primary productivity of coral reefs equals or surpasses all other natural ecosystems, and one reef may support as many as 3,000 species (Fig. 5). Yet the tropical waters that overlie coral reefs are nearly devoid of life-supporting nutrients such as nitrates and phosphates. It is, thus, remarkable that reefs support a wealth of life under these conditions.

The high primary productivity of coral ecosystems results principally from flowing water over the reef, their efficient biological recycling and high retention of nutrients. The coral polyps have symbiotic algae, zooxanthellae, within their tissues, which process the polyps' waste products before they are excreted, thus retaining such vital nutrients as phosphates[30].

Coral reef communities obtain their supplies of fixed or usable nitrogen, which is essential to phytoplankton and algae for photosynthesis, from algae on adjacent reef flats and bacteria in reef sediments, sea grass beds and mangroves.

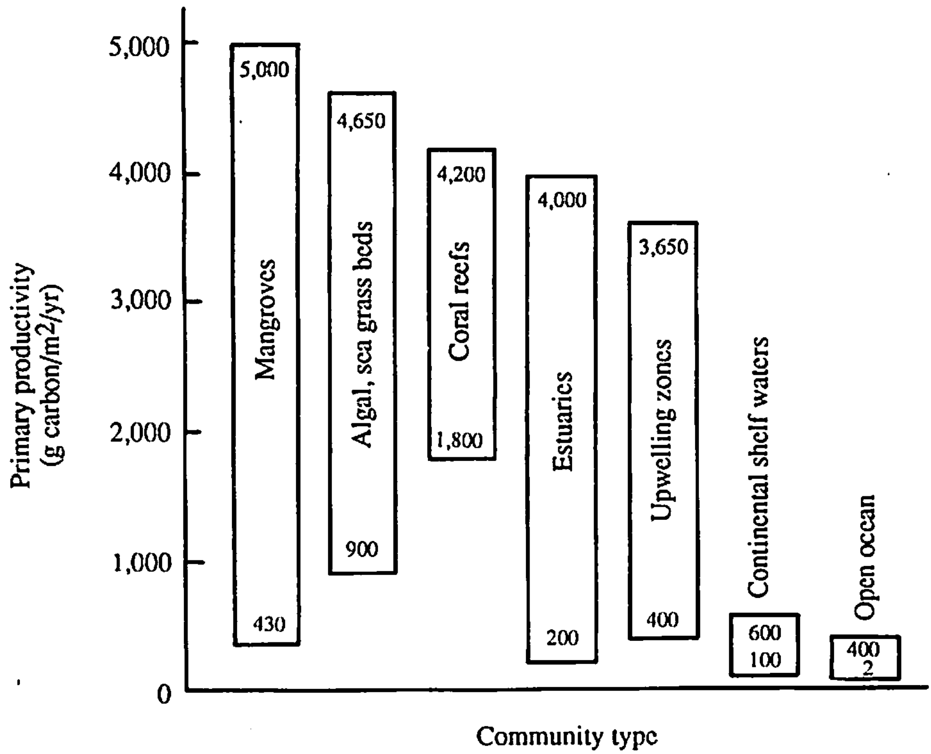

Fig. 5. Ranges of primary productivity of some major marine communities[45].

Blue-green algae fix nitrogen and flourish on the reef flats. Algal mats are grazed by damselfish, surgeonfish and parrotfish that return to the reefs and deposit the nutrient there in the form of feces. Fixed nitrogen produced by bacteria in the sediments of sea grass beds is carried by fish that feed there and return to the reefs for shelter. Often overlooked, the reef flats, sea grass beds and mangrove areas are important in supplying nutrients to coral reefs[30] (Fig. 6).

The physical complexity of a reef contributes to its diversity and productivity. The great number of holes and crevices in a reef provide abundant shelters for fish and invertebrates, and are important fish nurseries. In addition, highly specialized creatures such as parrotfish, butterflyfish and nudibranchs have become dependent for their survival on the reef. The reef provides a solid substrate for many bottom-living organisms (clams, sponges, tunicates, sea fans, anemones and algae) to settle and grow.

The high primary productivity of the coral reef ecosystem results not only in its own survival and complex nature but also in the formation of many products and processes which are useful to people. These are considered below.

Reefs in Southeast Asia

Fringing coral reefs occur throughout the region and conservatively comprise 30% of the world's coral reef area. They are usually associated with small- to medium-sized coastal islands. Larger island and continental coasts support reefs to a lesser extent due to high sedimentation rates, turbidity and low salinity associated with river outlets. Generally, more remote, smaller islands support better quality, more extensive reefs.

The Nicobar Islands, the Mergui Archipelago and the Andaman Sea coastal islands of Thailand all support coral reef growth, some in good condition. The Gulf of Thailand has limited reef areas, mostly in its eastern portion. Coastal islands off the east coast of the Malay Peninsula support coral reefs, but reefs are generally absent from the western coast of the peninsula. The most extensive coral reef areas for any one country is in Indonesia, reflecting its 81,000 km coastline. Coral reefs are well-represented along the southern rim of Indonesia, in the eastern archipelagos, in the Mentawai Archipelago, along many coasts in the Sunda Archipelago, and along most coasts in the Sunda Archipelago, the Banda and Molucca Seas and Halmahera. The Great Barrier Reef and the Torres Strait north of Australia have some of the best developed reefs in the world. Papua New Guinea has extensive reefs along the north coast and offshore islands. Most Philippine islands have extensive reef growth,

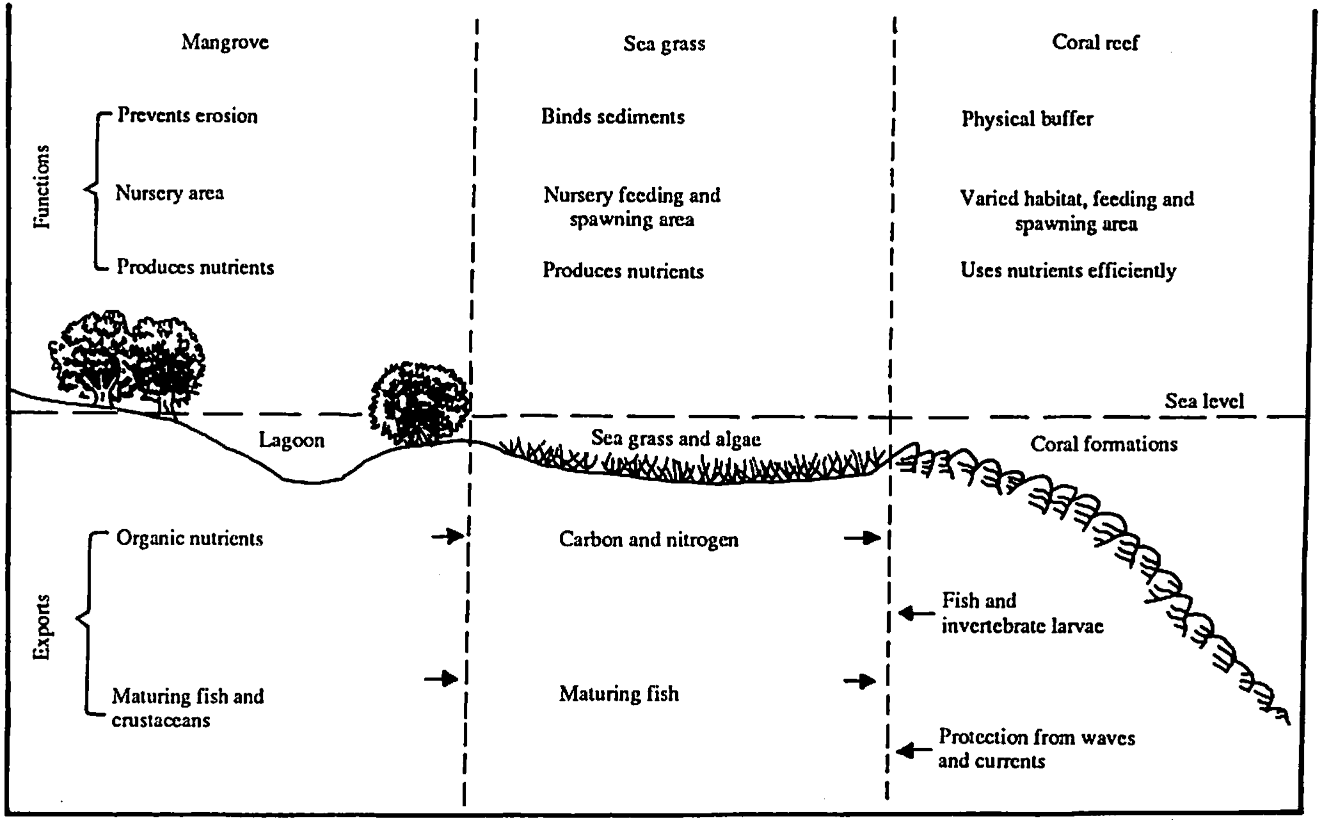

Fig. 6. Mutual benefits among mangrove, sea grass and coral reef ecosystems[42].

reflecting the 18,000 km coastline of the many small islands. For example, the Sulu Archipelago and Sulu Sea islands, and some eastern, Pacific-facing coasts support many coral reefs, some of them atolls. Most islands in the South China Sea have fringing reefs, but much of the southern Chinese and Vietnamese coastal area has a noticeable lack of reef growth (see center spread map).

Value of Coral Reefs

Role in the Coastal Environment

Fringing and barrier reefs are natural breakwaters which protect low-lying coastal areas from erosion and other destructive action by the sea. Coral reefs also contribute to terrestrial accretion by providing sand for beaches and low islands[10]. These reef functions naturally protect thousands of coastal villages, low-lying coastal plains and coastal engineering structures built behind the outer edges of reefs along tropical coasts[21]. If these reef-buffers were removed, the equivalent artificial structures for protection would cost billions of dollars. Calcification is responsible for reef structure formations and sediments. This major biogeochemical process on coral reefs contributes about 50% of the total calcium carbonate deposited in the world's oceans annually[32].

Reef Resources Used by People

Coral reef resources have been exploited by humans since prehistory, as indicated by remains of marine shells and other marine species found in Palawan caves. The Spaniards used corals for building houses in the Philippines in the 16th century, and observation suggests that corals have been used in Southeast Asia for construction since that time.

Reef-related fisheries annually yield an estimated 9-12% of the world's total fishery of 70 billion kg[32, 24] and are probably undervalued because of their subsistence nature. The contribution of reef fish to the total fisheries of the Philippines ranges from 8% to 20%[5, 25, 1] and up to 20% in West Sabah, Malaysia[20]. The contribution of a reef fishery to some small island fisheries in the Philippines has been shown to be more than 70% with fish harvests from these reefs of up to 30 t/km^2/year[1, 43, 31].

Space is more limiting than food on a coral reef. The night and day sharing of space on a reef allows a healthy reef to shelter two separate communities of fish, greatly increasing the diversity of species and number of individuals the reef can accommodate. The standing crop of fish populations on reefs may reach 5 to 15 times the size of the crops of productive North Atlantic fishing grounds[35]. Also the yield of fish from reefs and their surroundings may reach 5,000 kg per fisherman per year[30].

Coastal people supplement fish intake by the consumption of sea turtles and invertebrates such as octopuses, bivalves (*Tridacna* and other clams), gastropods, shrimps, spiny lobsters, sea urchins and sea cucumbers. Hundreds of thousands of sea turtle eggs are harvested in the Sulu Islands, Philippines, the eastern peninsular Malaysia and Indonesia every year.

Miscellaneous food products from the reef include edible algae, jellyfish and sea anemones. Consumption of these items depends on particular traditional and cultural preferences (Table 1).

Coral reefs have traditionally served as sources of building materials. Lime is extracted from many Indonesian reefs for use in cement[33], and tiles are made from massive corals in the Philippines. Sand extracted from reefs serves as a fill material and is widely used in cement mixes.

One type of interaction particularly well developed on coral reefs is antibiosis, the production by one organism of substances that are harmful or repulsive to others. Some of these substances are used as pharmaceutical and industrial products and include substances with anticancer, antimicrobial and anticoagulant properties. Sources range from sea hares to sea fans, anemones and nudibranch animals. Algae also provides a source of agar and carrageenan.

In the late 1960s, international trade in ornamental corals, shells, sea turtles and coral reef fish began to flourish. These items now support large industries and end up mainly as decorative pieces in various parts of the world[38]. Fish with a value of US$24-40 million a year are imported to the United States for aquarium use. The Philippines exported 7,000 t of corals and 4,000 t of ornamental shells in 1974, but these have since declined[22]. Even though bans exist on coral and sea turtle collecting, these items continue to leave this country in large quantities. Hydrophiid sea snakes have been exploited primarily for skins and secondarily for meat since the 1930s in the Philippines[27].

Other Economic Benefits from Reefs

The aesthetic appeal, biological richness, clear waters and relative accessibility of coral reefs make them popular recreation areas for local and foreign tourists. In this sense, coral reefs are a valuable resource for the tourism industry. Skin and scuba diving, underwater photography and amateur shell collecting are common activities on reefs. Diving tourism has increased tenfold in Fiji during the past 10 years. In the Maldive Islands, where the main attraction for tourists are coral reefs, there were 2 hotels in 1972 and 37 in 1981.

Table 1. Coral reef resource products and uses[40].

A. Major reef export products of economic importance.		
Resource	**Role in reef**	**Product-use**
Stony coral[a]	Primary reef frame builder	Building material, fish tank decoration
Precious coral[b]	Enhances habitat	Jewelry, decoration
Fish[b]	Link in metabolism	Food, aquarium fish
Mollusks[b]	Calcification, food chain	Shell collection
Tridacna clams[b]	Calcification	Decoration, novelty
Top shells, *Trochus*	Calcification, food chain	Mother-of-pearl
Oysters[b]	Calcification, food chain	Pearls
Lobsters[b]	Scavenger	Gourmet food
Sea cucumbers	Detritus feeder, sand	"Trepang," food
Sponges[b]	Borer	Toiletry
Sea turtles[b]	Food chain	Shell, oil, meat, eggs
Sea snakes[b]	Food chain	Skin, crafts
Misc. invertebrates	Varied	Antibiotics, drugs
Coral sand	Substrate, beaches	Concrete, building
Ecosystem	Conservation, genetic diversity	Tourism, aesthetic appeal, natural laboratory

B. Subsistence food products commonly used.	
Organism group	**Kind**
Fish[c]	Large variety
Bivalves	Clams, mussels, oysters
Gastropods	Most large ones
Cephalopods	Squid, cuttlefish and octopus
Crustaceans	Crab and shrimp
Echinoderms	Sea cucumbers and sea urchins
Coelenterates	Jellyfish and anemones
Sea turtles	All except Hawksbill, eggs
Algae	Many edible varieties

[a]McManus[22] notes that 1,830,089 m^3 were exported from the port of Zamboanga, Philippines in 1976.

Coral reefs are known as good laboratories for ecological science. Research on the coral reef ecosystem has increased dramatically over the past 15 years. The 1985 International Coral Reef Congress in Tahiti attracted more than 400 papers despite the expensive venue, compared to 290 at the 1981 symposium in Manila. National and local scientific research on coral reef ecology and fauna is increasing as field monitoring becomes necessary to answer new management questions. Coral reefs also provide a laboratory for the study of basic biological processes by high school and college students in many countries.

A final but important resource, aesthetic appeal, is not as easily quantified as the other resources associated with the reef ecosystem. Tourism to reef areas may be an indicator of this value but in a pure sense there is no simple measure. Nevertheless, this feature of a reef may be important to many people who recognize the beauty of a coral reef and who are beginning to contribute to protection efforts.

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[b]Seriously depleted on many reefs throughout Southeast Asia and the Western Pacific region.

[c]The most significant contribution of reefs to subsistence food consumption in all Southeast Asian countries.

COLOR PLATES

Plate 1. A reef slope with dense fish populations. Often the most diverse assemblage of fish is on the reef crest and slope. Siquijor Island, Philippines.

Plate 2. A reef crest with a variety of hard (hermatypic or reef-forming) corals. Brown Rocks, Philippines.

Plate 3. This reef flat and crest has a very high diversity and cover of hard and soft corals only typical of naturally productive and pristine areas. Tubbataha Reefs, Sulu Sea.

Plate 4. Schools of surgeonfish on the shallow reef flat are not commonly seen where fishing is intense. Apo Reef, Philippines.

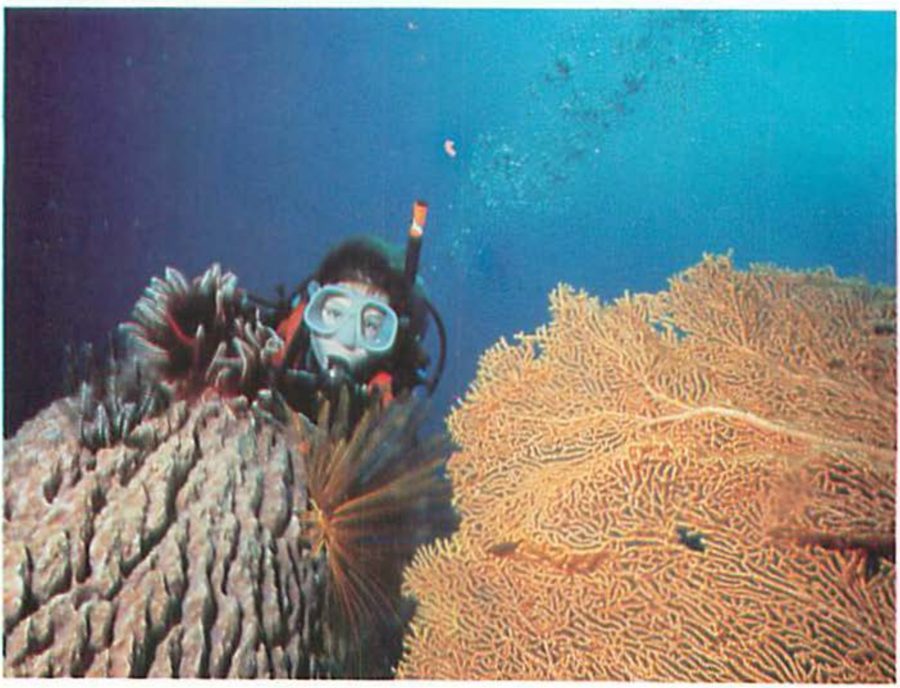


Plate 5. Many scuba divers enjoy the beauty of the coral reef. This diver is posing behind a large basket sponge and a gorgonian fan coral on the right. Apo Reef, Philippines. Photo by Myron Wang.

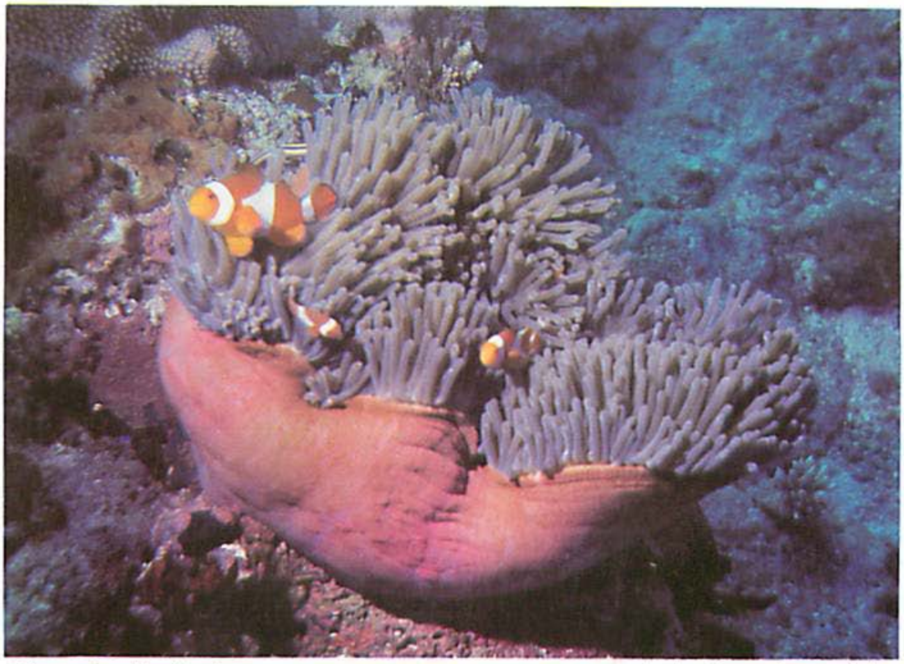


Plate 6. *Radianthus,* a common sea anemone, protects the clown fish, *Amphiprion ocellaris,* a classic symbiotic relationship, one of many found in the coral reef ecosystem. Apo Reef, Philippines.

Plate 7. The Pacific blue coral *(Heliopora)* is conspicuous on many reef flats in Southeast Asia. Its skeleton is used in jewelry making because of the permanent blue color. Pamilacan Island, Philippines.

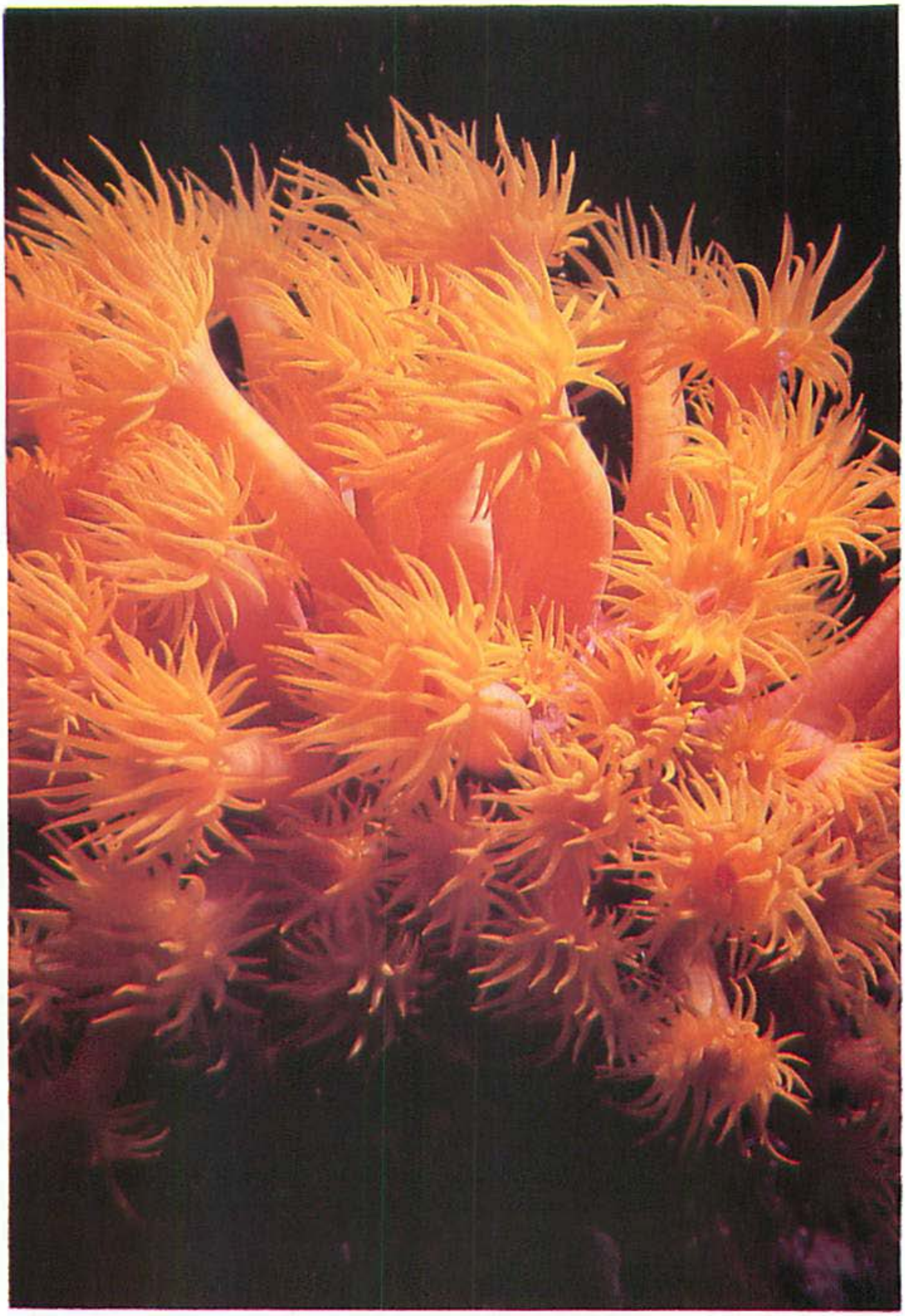


Plate 8. The polyps of the small, nonreef-building coral, *Tubastrea,* open at night or in well-shaded areas under coral outcrops. Most coral polyps open and feed at night. Apo Reef, Philippines.

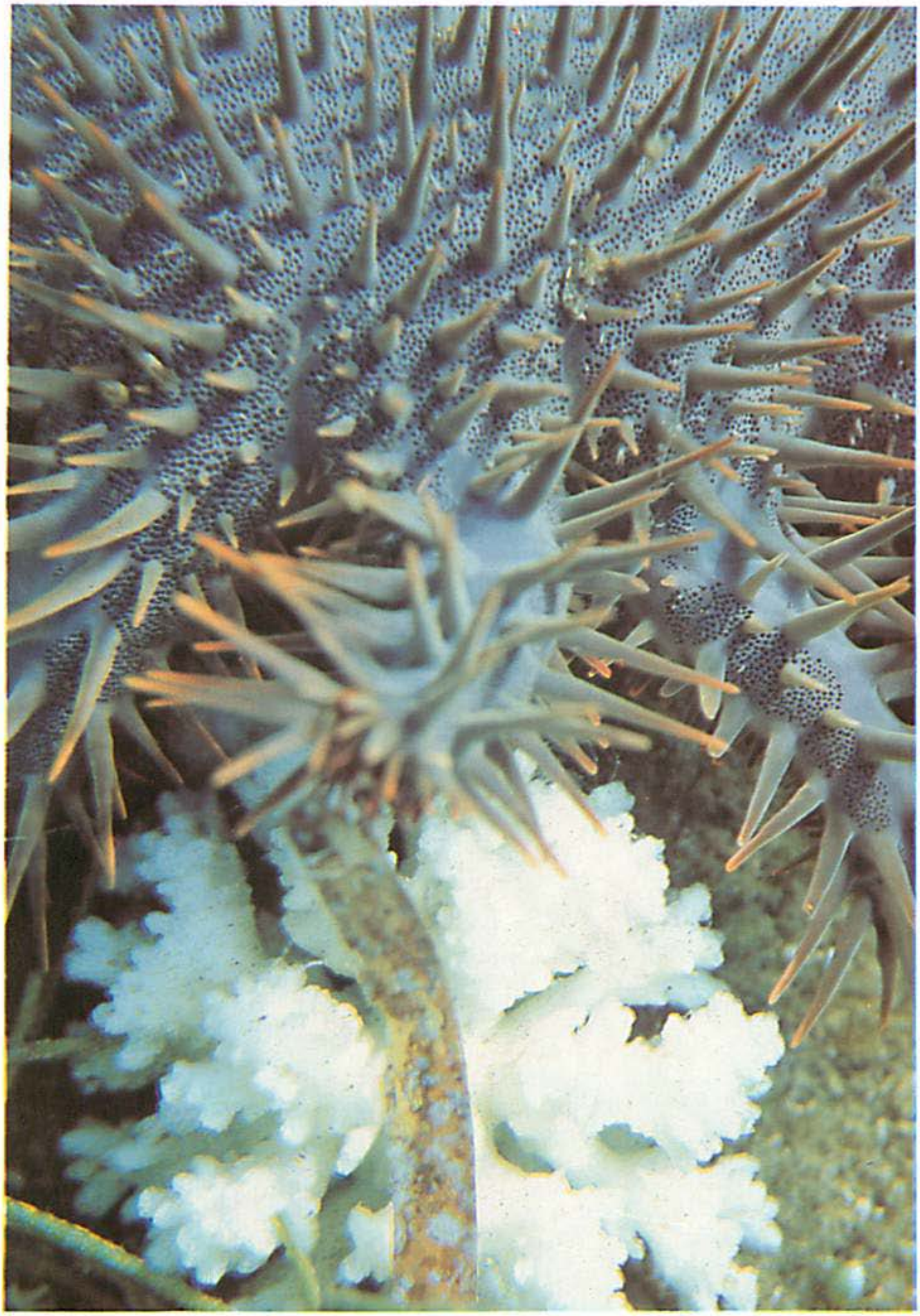
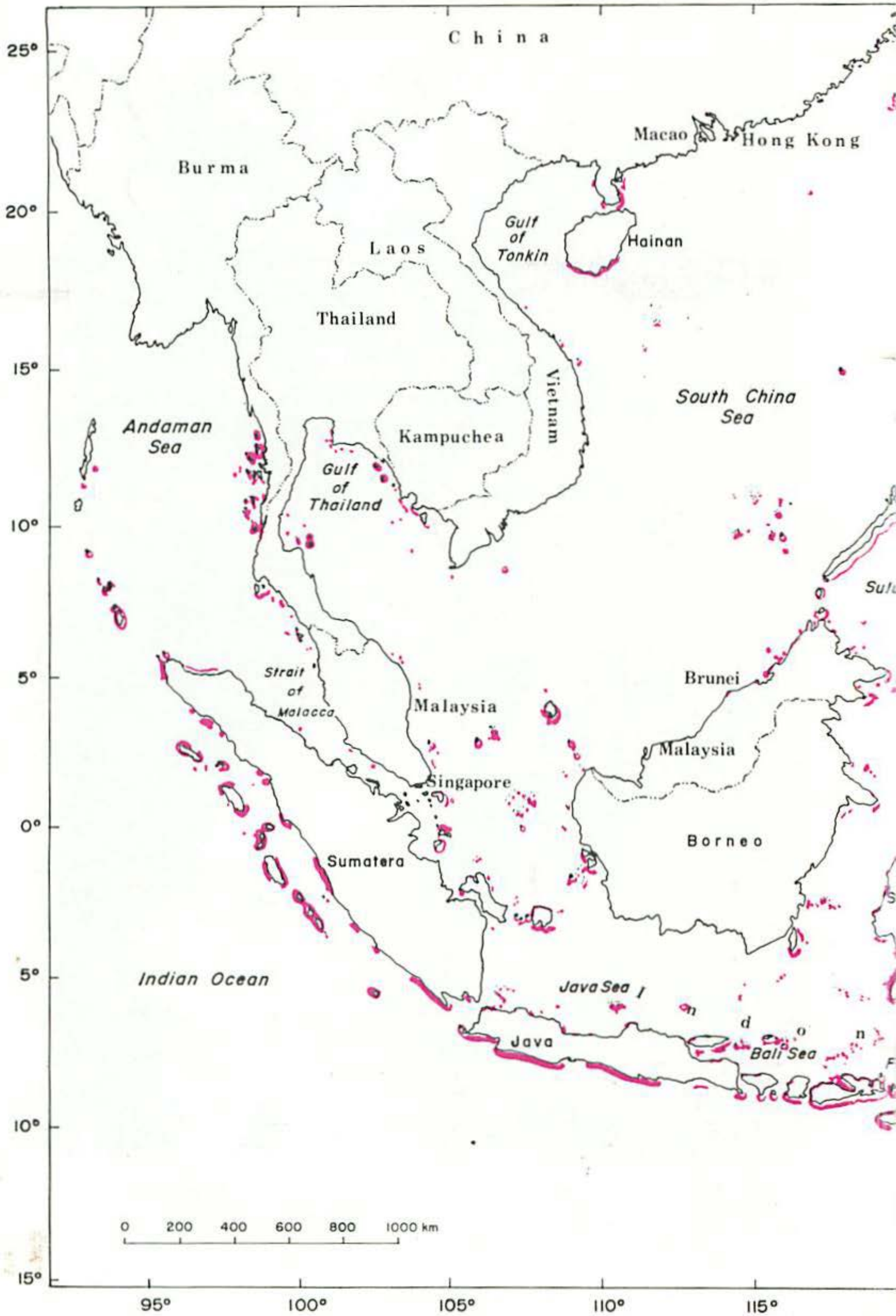


Plate 9. The Crown-of-thorns starfish *(Acanthaster planci)* has between 9 and 23 arms with large poisonous spines. It feeds on coral polyps and is capable of denuding coral areas when it reaches plague proportions. Dumaguete, Philippines.



China
Burma
Laos
Thailand
Macao
Hong Kong
Gulf of Tonkin
Hainan
Vietnam
Kampuchea
Andaman Sea
Gulf of Thailand
South China Sea
Sulu
Strait of Malacca
Malaysia
Brunei
Malaysia
Singapore
Borneo
Sumatera
Indian Ocean
Java Sea
Indon
Bali Sea
Java
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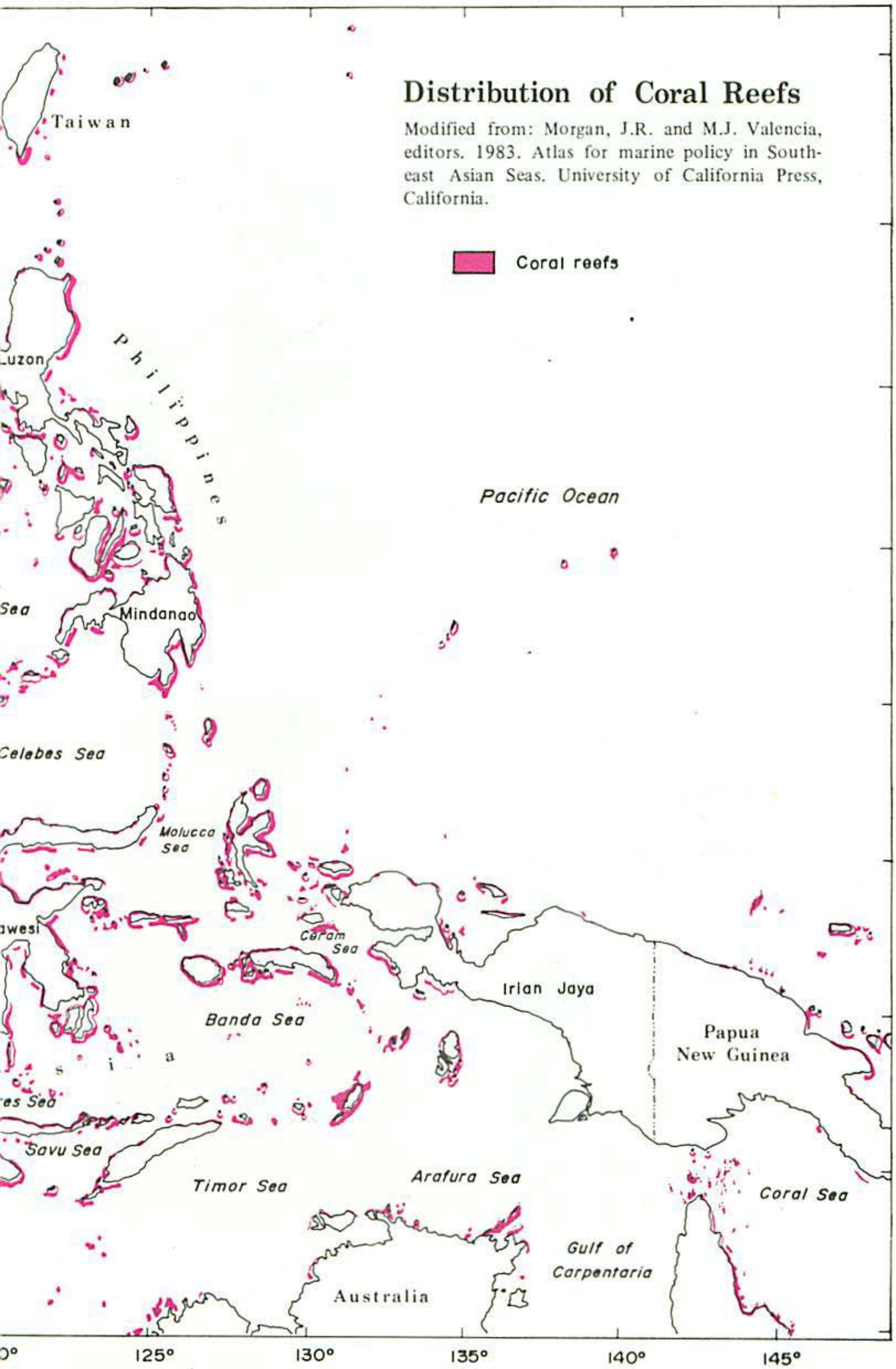
115°



Distribution of Coral Reefs
Modified from: Morgan, J.R. and M.J. Valencia, editors. 1983. Atlas for marine policy in Southeast Asian Seas. University of California Press, California.
Coral reefs
Taiwan
Luzon
Philippines
Pacific Ocean
Sea
Mindanao
Celebes Sea
Molucca Sea
awesi
Ceram Sea
Irian Jaya
Banda Sea
Papua
New Guinea
s i a
es Sea
Savu Sea
Timor Sea
Arafura Sea
Coral Sea
Gulf of Carpentaria
Australia
0°
125°
130°
135°
140°
145°

Plate 10. The Philippine butterflyfish *(Chaetodon adiergastos)* often hide under corals or in caves. This species, like all butterflyfish, is an indicator of the relative health and extent of corals on the reef. Tubbataha Reefs, Sulu Sea.

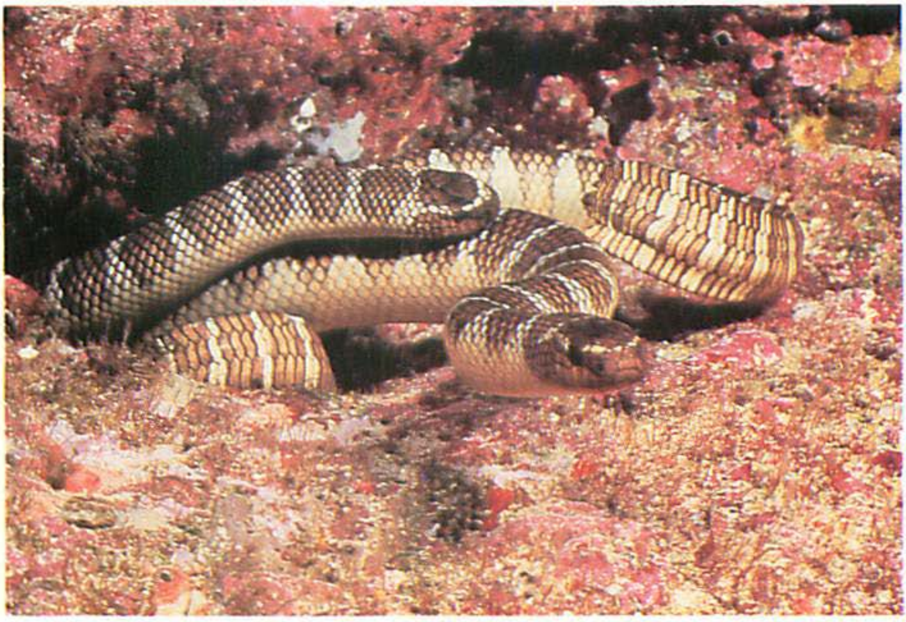


Plate 11. Banded sea snakes *(Hydrophis)* live on shallow reefs and occasionally climb on shoreline rocks. They also live on midwater reefs down to 30 m. All come periodically to the surface to breathe. Apo Reef, Philippines. Photo by Myron Wang.

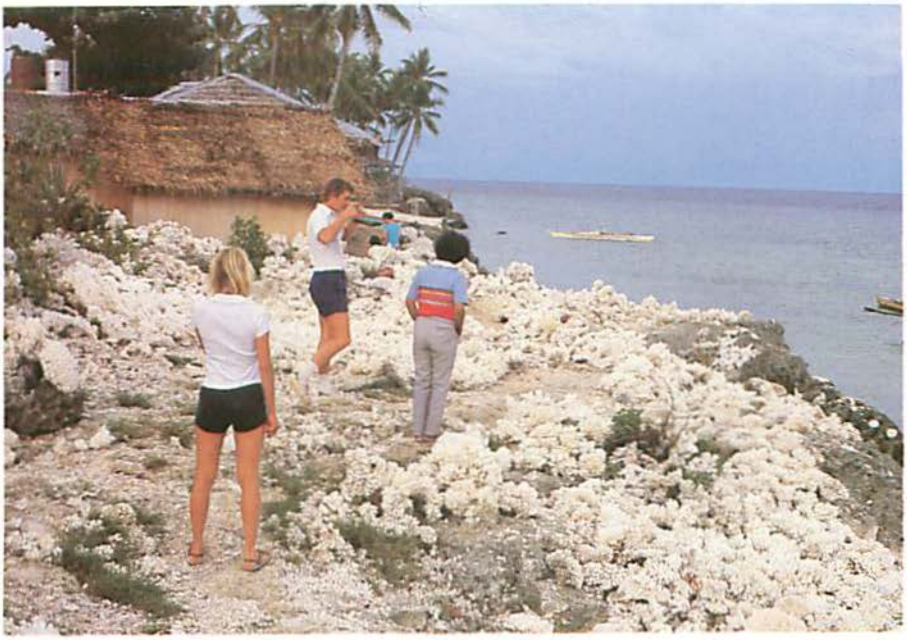


Plate 12. Corals are still collected in many areas in Southeast Asia and dried for export to be used in aquariums or for decoration. Mactan Island, Philippines.

Plate 13. Collector shells and shell craft for sale and export from reef gleaning in Thailand, Indonesia and the Philippines. Phuket shop, Thailand.

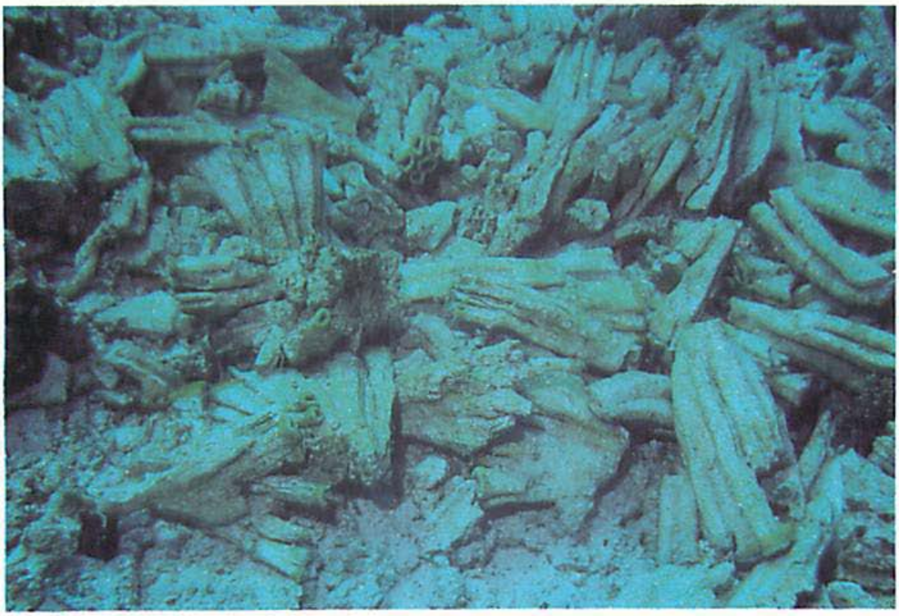


Plate 14. Corals that have been broken to rubble from dynamite or blast fishing become useless for providing food or habitat for fish and other coral reef inhabitants. Unfortunately, this sight is far too common on reefs in Southeast Asia. Balicasag Island, Philippines.

Plate 15. Reef gleaning is a traditional form of fishing in many areas for seaweeds, shells, crustaceans, small fish and other useful organisms. When this is done carelessly, shallow corals may be crushed. Pamilacan Island, Philippines.

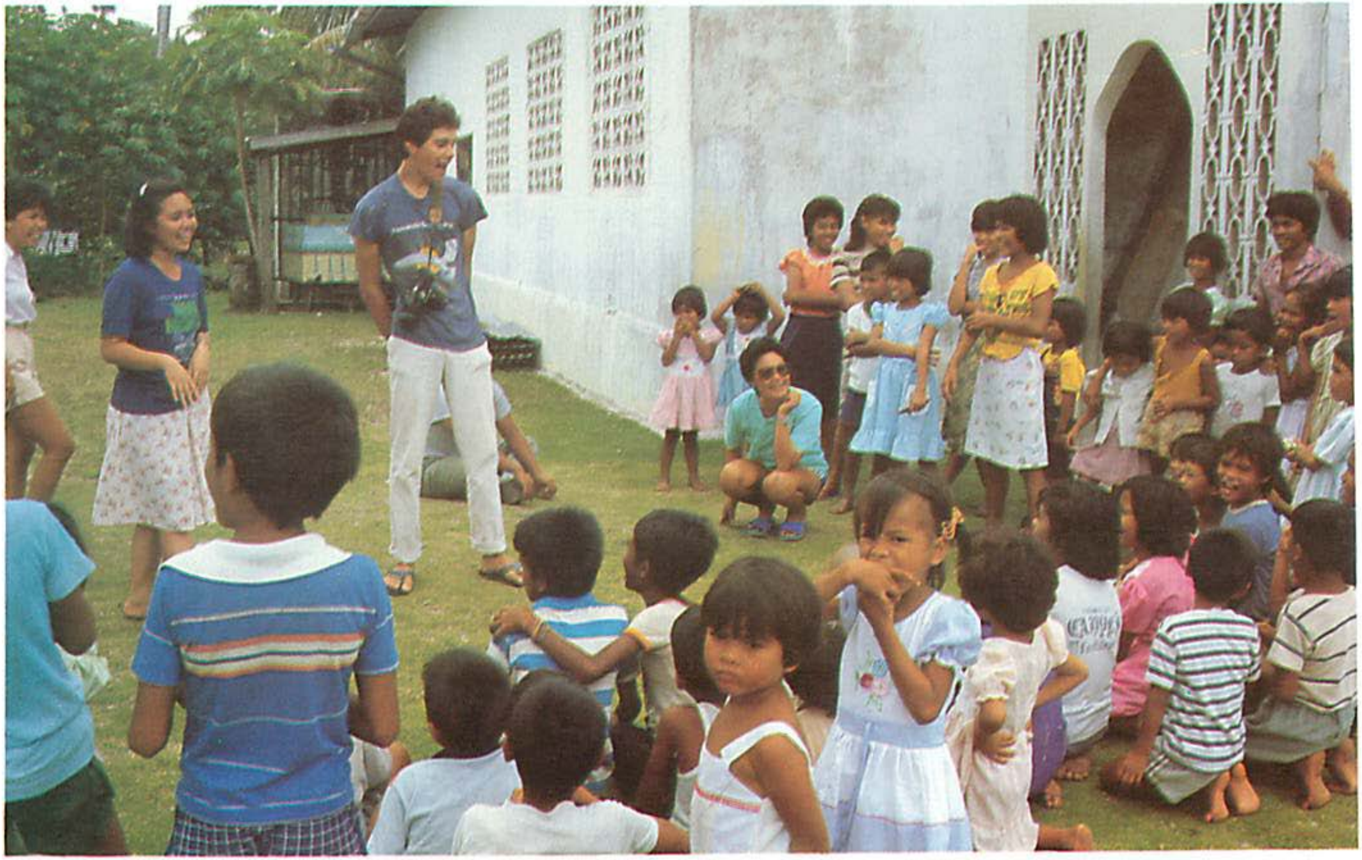


Plate 16. This group of fishermen children are participating in a nonformal class in marine conservation. Their families are dependent on coral reefs for food and livelihood. Pamilacan Island, Philippines.

Coral Reef Plants and Animals

Plants

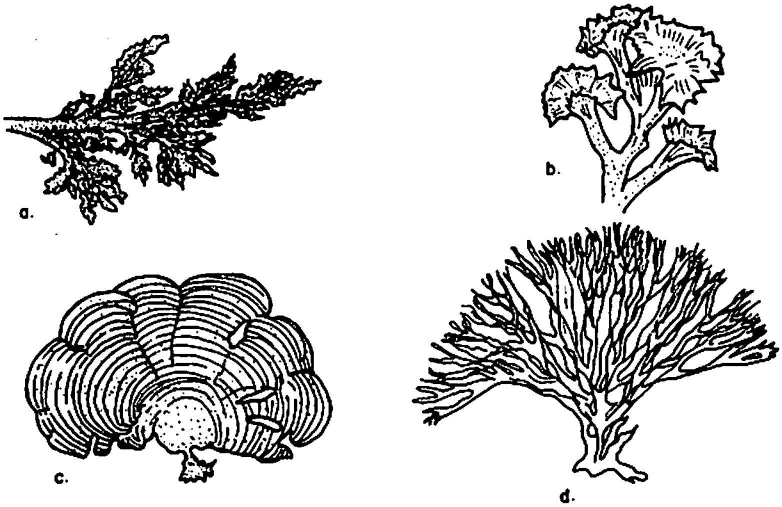
Algae comprise a large, diverse group of plants which are usually found in aquatic environments. Despite their relatively simple structure, algae are important ecologically. They are primary producers; that is, they are able to capture the sun's energy and use it to produce sugars and other complex compounds by storing energy. This entire process, known as photosynthesis, provides via algae the basis of energy for the food pyramid on a coral reef. This primary production is used by zooplankton (animal plankton) and other animal life higher on the food chain.

Microscopic algae are either planktonic or live symbiotically, that is, in mutually beneficial relationships with corals or other invertebrate animals. Much of the productivity of a coral reef ecosystem is dependent on symbiotic algae. The brown-colored zooxanthellae actually live within the tissues of coral polyps, *Tridacna* clams and certain other invertebrates, e.g., some sponges and mollusks as mentioned above, providing them with food.

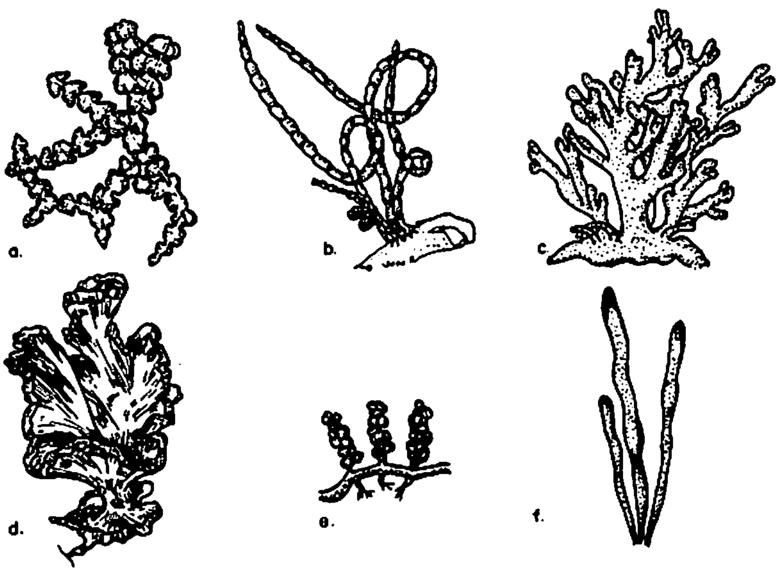
The larger algae or macroalgae include those we see on the reef-forming algal mats upon which some fish and invertebrates graze. Several common types are shown in Fig. 7.

Sea grasses are aquatic relative of land grasses that are completely adapted to the marine environment. They have a well-developed root system and function normally in their reproductive cycle while submerged in saltwater. Sea grass communities are often conspicuous in coral reef environments, particularly on reef flats and inshore areas.

Sea grass roots and rhizomes bind the sediment together, and with the additional protection given by the leaves, surface erosion is reduced. They play an active part in the sulfur, nitrogen and phosphorous cycles of the reef ecosystem and, as primary producers, they are grazed upon by sea turtles, sirenians and some fish. Nutrients produced by sea grasses are transported to coral areas by currents, fish and invertebrates and are important in reef productivity. The common sea grass *Enhalus* is shown in Fig. 8.



Brown algae: (a) *Sargassum*, (b) *Turbinaria*, (c) *Padina* and (d) *Dictyota*.



Green algae: (a) *Halimeda*, (b) *Chaetomorpha*, (c) *Codium*, (d) *Ulva*, (e) *Caulerpa* and (f) *Enteromorpha*.

Fig. 7. Common coral reef macroalgae.

Invertebrate Animals

Sponges (poriferans) are the most primitive of the multi-cellular animals. They are very conspicuous on a coral reef and come in all sizes, shapes and colors. Sponges provide substrate for barnacles and encrusting algae and often harbor annelid worms, brittle stars and crustaceans in their tube systems. Some sponges are harvested by man.

Coral animals (cnidarians or coelenterates) form one of the major groups of the animal kingdom and are very important in coral reef ecology. The phylum is divided into three groups: hydroids, jellyfish and the Anthozoa comprised of soft corals, gorgonians, sea anemones, sea pens, black corals and the true stony corals.

The most conspicuous of the hydroids are the fire corals (*Millepora*) which look like stony corals. True to the group, they have strong stinging cells (nematocysts) and should not be touched. An important and integral part of the reef community, fire corals provide habitat for numerous fish and invertebrates including sponges, anemones, mollusks, crinoids and brittle stars. Other hydroids include sea ferns and the Portuguese Man-of-War (Fig. 9).

Fig. 8. Common sea grass *Enhalus*.

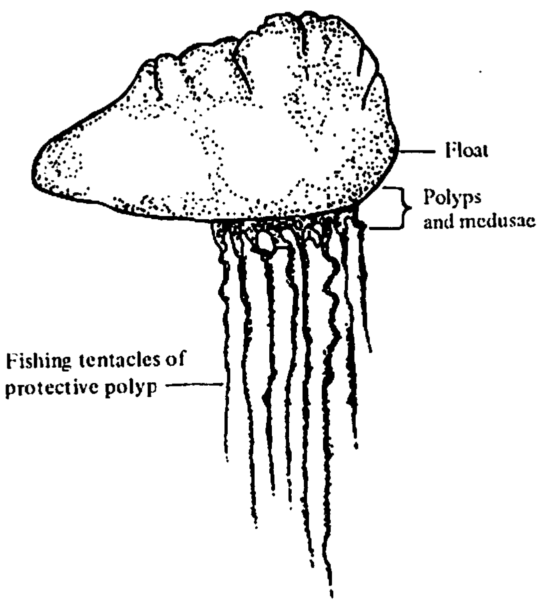


Fig. 9. Portuguese Man-of-War *(Physalia)*.

Soft corals are a numerous, extremely varied and colorful group. The polyps form massive, mushroom-shaped or lobed colonies, but do not form a hard calcium carbonate skeleton. Thus, most are soft to the touch, slightly slimy and have the appearance of fingers jutting upward. Soft corals provide food for some mollusks such as false cowries and nudibranchs.

Sea anemones are solitary polyps, much larger and heavier than the polyps of other coral animals; many reach one-half meter in diameter and are often brightly colored. They provide habitat for the well-known clown or anemone fish of the damsel family and for certain crabs and shrimps. In this symbiosis, the clown fish is unaffected by the sting of the anemone and lives protected among the tentacles. It attracts other fish which may be captured by the anemone and used as food by both partners.

The hard or stony corals (scleractinians) comprise the single most significant feature of any coral reef. The variety of shapes, formations, colors and textures is almost unlimited; 500 or more species are known to occur in Southeast Asia, most of which are reef-forming (hermatypic). The physical structure of corals provides substratum and living space for several thousands of other species of invertebrates, fish and marine algae. Thus, the corals form the cornerstone of a very complex ecosystem. The hard corals are always found in colonies attached at hard substrates, with the exception of several which are "solitary," and, at maturity, detached from the substrate. In all coral formations, only the surface portions exposed to sufficient light remain alive. The underlying coral structure is a dead calcium carbonate skeleton deposited by the living surface polyps. In some cases, this skeleton, formed by the coral colony, may be very large (up to several meters).

The skeletal configurations of corallites are determined in part by the growth pattern of the colony as a whole. Both polyp configuration and growth form are influenced by environmental factors such as currents, salinity, light intensity, temperature, physical space and, possibly, competition among various species.

Two of these factors merit further attention. Reef-forming corals are apparently quite sensitive to temperature, and are restricted to warm waters precisely because they grow only in temperatures of 18-27°C. Second, most hermatypic corals require adequate light intensity and are, therefore, usually restricted to shallow waters (50 m deep), depending on water clarity. The requirement for light is imposed by the presence of the symbiotic microscopic algae (zooxanthellae) which live in the outer tissues of coral polyps (Fig. 10) and require sunlight to carry out photosynthesis. Otherwise, coral polyps feed most actively at night on microscopic zooplankton and organic particles in the water.

Growth rates for stony corals vary with the form of the coral. Massive corals, for example, grow up to 2 cm in diameter and less than 1 cm in height per year. In comparison, the common genus of branching coral, *Acropora*, may grow between 5 and 10 cm or more per year. In any case, growth rates are slow and vary considerably with site-specific environmental conditions.

A very large variety of *worms* live in the coral reef. Most are small and inconspicuous, inhabiting crevices in the rock and coral. A few, flatworms, ribbon worms and segmented worms, have large, visible members commonly associated with reefs. Worms contribute to the natural bioerosion of carbonate rock into rubble and sand by burrowing into the rock.

Crustaceans are well-known group of arthropods which contains such forms as barnacles, crabs, shrimp, lobsters and crayfish. Many crustaceans have special relationships with other animals on the reef. Barnacles attach to many substrates including, for example, sea turtles and crabs. Many shrimp have commensal arrangements such as the burrowing shrimp which live with goby fish or small crabs; the cleaner shrimp with some fish; or the small painted shrimp associated with anemones. Hermit crabs carry shells which often support small anemones, sponges or barnacles. Most larger crustaceans have food value for people and are of economic importance.

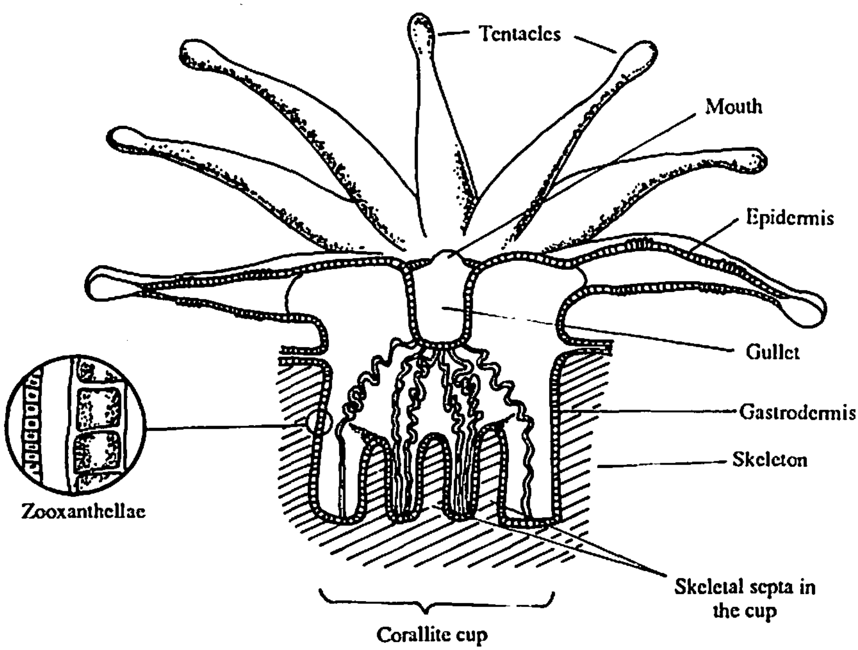


Fig. 10. Anatomy of a coral polyp[26].

The word "mollusk" means soft, and mollusks are characteristically soft-bodied. The only hard part of these animals is the protective shell, and even this is absent in some groups such as sea slugs. Mollusks are divided into the gastropods or snails, mostly known for their decorative shells; the bivalves including clams, oysters and mussels, mostly known for their food value to people; and cephalopods or squid, cuttlefish, octopus and the *Nautilus*. It is often thought that cephalopods are not associated with mollusks because, except for the *Nautilus*, they have no external shell. Mollusks contribute a sizeable amount of calcium carbonate to the reef ecosystem which is an important contribution to sand formation. The diversity of mollusk animals plays an important role in the complex food web of the reef. They are also the basis of the large ornamental shell trade and support major fisheries for bivalves and cephalopods.

Phylum *echinoderms* (Fig. 11) is one of the most familiar groups of marine invertebrates; it includes starfish, sea urchins, sand dollars, serpent stars, sea lilies, brittle stars, sea cucumbers and feather stars. Most are shallow bottom dwellers commonly found on coral reefs and in sea grass beds.

Starfish are omnivorous, eating anything from sponges, barnacles, snails, bivalves, other echinoderms, polychaetes and small crabs to coral, algae and edible sediment in the water. A few species have preferred food items. One species, with implications for reef health, is the Crown-of-thorns starfish, *Acanthaster planci*, which is notorious for its habit of destroying hard corals by feeding on them. Dense infestations of the Crown-of-thorns inevitably lead to the loss of a significant portion of the living coral cover on the reef. There are few known predators of the Crown-of-thorns; the best known is a large gastropod, the Giant triton. The Sponge crab, some groupers and shrimp also feed on the juvenile starfish, as does the Frog shell. Unfortunately, people remove these mollusk predators of the Crown-of-thorns from the reef.

Sea urchins, often present in large numbers, graze on algae in sandy and rocky areas and are preyed upon by starfish, fish and people. Their fluctuating populations affect both algal and predator communities on the reef. Some species of urchins are popular food items and support small export industries.

Sea cucumbers reside in most parts of the coral reef and feed on algae and bottom detritus. They have few natural enemies, and people probably take the heaviest toll. Dried and sold in tropical markets (as *trepang*), they are popular with the Chinese.

Coral Reef Fish

Forty percent of the known fish species of the world, or about 8,000, live on continental shelves of warm seas less than 200 m deep. Tropical waters near

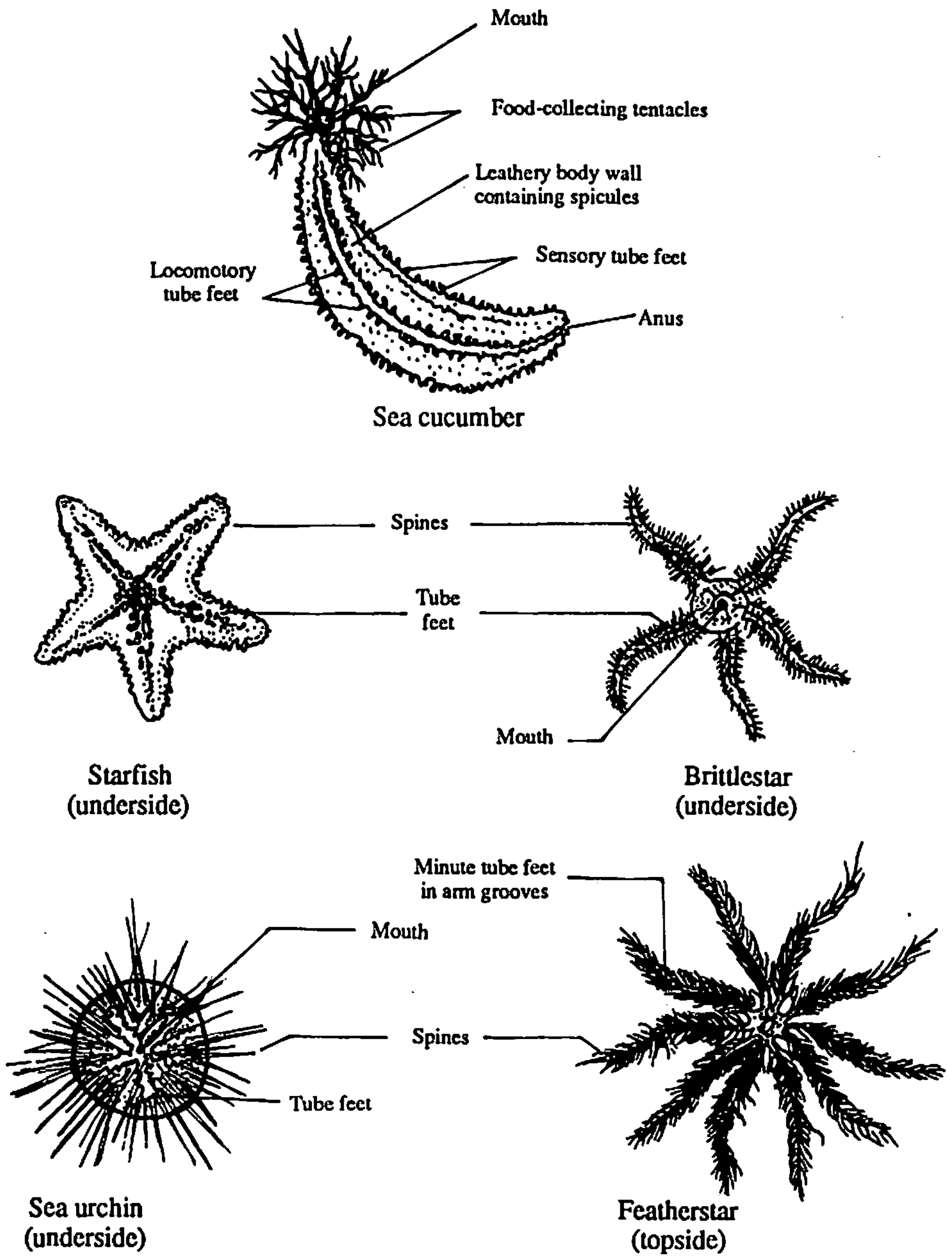


Fig. 11. Common echinoderms.

or on coral reefs, as compared with temperate areas, harbor more numerous species but generally fewer individuals per species.

Fish may be classified according to their way of life. For example, pelagic fish live in open water, while benthic (demersal) fish live on or near the sea bottom. A close relationship exists between the evolutionary status of a fish, as exemplified by its shape, body structure and physiology, on the one hand, and its habitat, ecology and behavioral traits on the other. Many soft-rayed fish (e.g., herrings) are built to swim through open water, unencumbered by heavy spines or scales, feeding on foods that they can harvest by simply opening their mouths. The more highly evolved spiny-rayed fish, on the other hand, are able to take advantage of small caves in reefs.

Food webs on the reef are exceedingly complex and the intricate network of crevices and surface areas on the coral reef supports a tremendous diversity of marine invertebrates and algae which in turn provides food for various species of eel-like and spiny-finned fish. The snappers, grunts and other fish which take shelter in the reef by day but move elsewhere to feed at night are only partly dependent on the reef ecosystem. They enter reef food webs when they are preyed on by large resident fish feeders such as groupers, and defecate there, but do not actually feed on the reef themselves.

In reef flats and lagoons, communities of bottom-dwelling fish live around coral heads and in the sandy patches between them. Glomerate or massive corals generally devoid of deep crevices are frequented by polyp-grazers such as

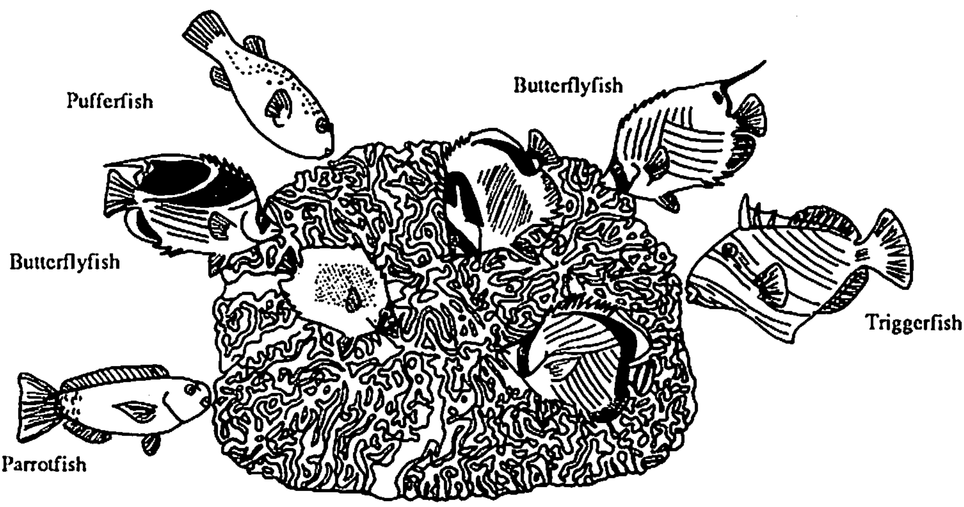


Fig. 12. Coral polyp "grazing" fish[26].

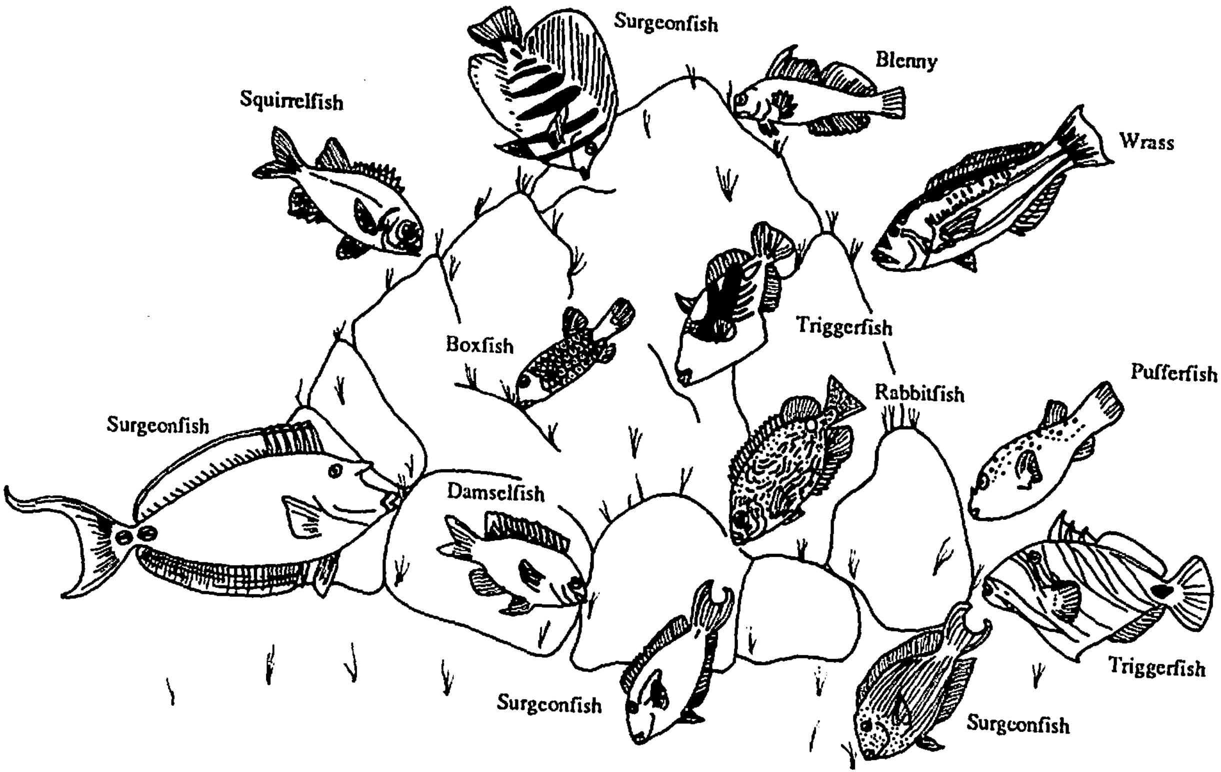


Fig. 13. Common herbivorous fish of the reef (26, modified).

parrotfish, triggerfish and butterflyfish (Fig. 12). Ramose or branching corals provide cover for numerous small fish such as gobies and damselfish which may swarm up to feed on zooplankton and dash back into the cover of the coral.

The reef algae support large populations of herbivorous fish (Fig. 13). Some characteristic reef "browsers" with cutting teeth to bite pieces off algal fronds include surgeonfish, damselfish, triggerfish, butterflyfish, rabbitfish and pufferfish. "Grazers" which remove some of the substrate or actually bite pieces off the coral formations include some blennies, gobies, surgeonfish, parrotfish, a few damselfish and triggerfish.

All fish on the coral reef fit into the food web in some manner so that there is an intricate balance of many predator prey relationships. Several groups are of particular importance to the coral reef ecosystem. Some butterflyfish, for example, feed almost exclusively on coral polyps. These fish are, thus, only present where corals abound and may be used as a simple indicator of coral health and cover by their diversity and number. Since parrotfish feed on coral

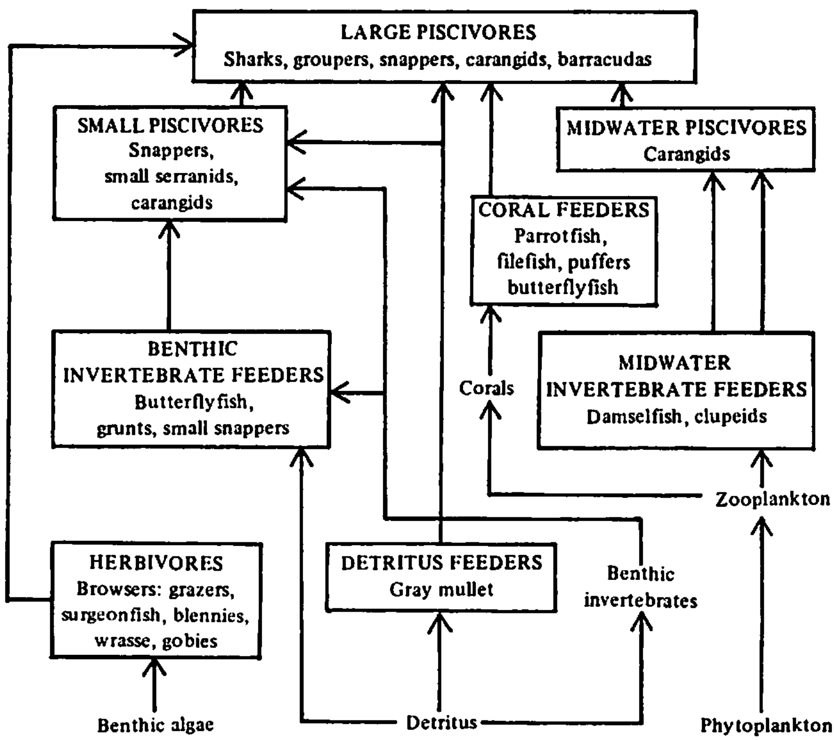


Fig. 14. Trophic relationships of coral reef fish[26, modified].

and calcium rock and expel white granules which have been ground by their pharyngeal mill, they contribute significantly to reef erosion and sand formation. One adult parrotfish may dump 500 kg of sand/year on the reef.

Many fish which feed directly on the reef display territorial behavior and rarely venture far from their source of food and protective cover. Territorial limits may be based on food supply, spawning patterns, frequency of predators, requirement for space and more, all of which add to the complexity of reef-fish relationships (Fig. 14).

Reptiles

The only two reptiles common to coral reefs are sea snakes and sea turtles. Both have been severely depleted by overharvesting. The sea snake is sought for its skin and meat. Sea turtle eggs have many natural predators (i.e., iguanas, monitor lizards, wild pigs and birds) but the most troublesome are people. Sea turtles are captured for their meat which is consumed locally and their shell which supplies export markets in the Philippines, Indonesia and Malaysia.

Threats to Coral Reefs

Natural Causes

Shallow-water reefs along storm or monsoon paths often suffer physical damage which takes years to repair. Such damage normally includes uprooted coral heads and scattered broken corals(46). Extreme low tides may expose corals directly to sunlight and to freshwater runoff, both of which are lethal over several hours of exposure(10). In 1982/1983, the surface temperature of the water in the Eastern Pacific rose to over 31°C, probably as a result of an abnormal "El Niño" year. The impact of the higher temperatures was exacerbated by abnormally low tides, which left shallow reefs exposed to sunlight, rainfall and fresh water flooding. These environmental disturbances caused many reefs to lose 70% to 90% of their living coral cover to depths of 15 to 18 m. Recovery will take many years.

Interactions between different coral species and between corals and other reef organisms are significant in reef dynamics(9). Predation on hermatypic corals tends to accelerate bioerosion. This may be more significant than the mechanical action of currents and waves in producing calcareous sediments on the reef.

Predation also modifies reef community structure. The Crown-of-thorns starfish eats stony corals, and devastates large areas of reef during a population outbreak. In 1978/1979, on reefs of islands off east coast Peninsular Malaysia, the coral cover was reduced by 70%-90% by an infestation of Crown-of-thorns(7). There are those who believe that the outbreaks are a natural and recurring phenomenon, and others who believe they are the result of human activities, for example, through over collection of their molluskan predators such as the Giant Triton. Researchers who have monitored reefs that suffered outbreaks in the 1960s and 1970s estimate the time to recover at somewhere between 10 to 40 years, unless further infestations occur. It also appears that the regenerated community may be less diverse than before the outbreak, dominated by fast-growing species, though this could well be a transient phenomenon(37).

Human Causes

Increasing population pressure has a direct effect on coastal resources. The rate of population growth in the Philippines, for example, is about 3.7% a year, and the population density of 159/km^2 is nearly double the Southeast Asian average. Since 87% of the population live within 50 km of the coast, there is considerable pressure on coral reef resources. A summary of human impacts on coral reefs in Southeast Asia is presented in Table 2.

The most important single cause of reef degradation is sedimentation resulting from human terrestrial activities[47]. These include unsound agricultural and forestry practices, mismanagement of watersheds, exploitation of mangroves, earth-moving for construction and the dumping of terrestrial and

Table 2. Human activities and their impacts on coral reefs.

Activities	Impacts
1. Extraction of coral limestone	Reef foundation degradation
2. Extraction of coral sand	Turbidity, water flow dynamics
3. Explosive fishing techniques	Habitat destruction
4. Terrestrial sediments from human activity	Turbidity, smothering
5. Physically damaging fishing methods	Habitat destruction
6. Reef trampling by humans or anchors	Habitat destruction
7. Overfishing of fish and invertebrates	Changes in ecosystem balance, lowers sustainable yield
8. Aquarium fish collection	Selectively depletes population
9. Urban-industrial pollution	Biological degradation
10. Oil spill	Biological degradation
11. Oil drilling	Turbidity, habitat destruction
12. Fish poisoning	Biological degradation
13. Spearfishing	Selective depopulation of fish
14. Construction	Habitat destruction, turbidity
15. Tourism	Collecting, minor habitat disturbance
16. Thermal or salinity changes	Detrimental to coral polyps and invertebrates

marine mine tailings and effluents. Increased turbidity reduces the penetration of sunlight, thus, inhibiting photosynthesis in primary producers such as the symbiotic algae of coral polyps. This in turn slows coral growth. Coral communities in deeper waters are at the margins of light penetration and may be the most vulnerable. Sedimentation also smothers living coral, and silt hinders the settling of coral larvae(15).

Perhaps the most lethal form of sedimentation is from heavy concentrations of mine tailings(18, 4). Currents affect the rate and extent of dispersal of the sediment. Whole reefs have been smothered in the southern Philippines and western Thailand by mining activities.

Soil erosion caused by deforestation and agriculture eventually deposits large quantities of silt on coral reefs. This is more widespread than pollution from mine tailings, but unfortunately data on quantities and the associated effects are not available.

Coral mining and harvesting for local use and international trade directly contribute to reef degradation(22, 20). Corals are commonly used for construction in Indonesia and many reefs near population centers are mined for limestone(33). Removal of corals creates sedimentation and changes water movement and shoreline erosion which may drastically affect the reef.

Destructive fishing methods common in the Philippines, Indonesia, Malaysia and Thailand include blasting, muro-ami, dragging nets over reefs, use of cyanide, use of small mesh nets and traps, traditional spearing and spearing using scuba. Even though these deleterious fishing methods may not necessarily lead to overfishing, they may damage the reef itself and thus reduce the potential fish yield.

Reef-front trawling and reef-front bottom trawling have caused damage to considerable tracts of coral habitat. Because the fine mesh nets capture many juvenile fish, these methods probably cause the depletion of many fish stocks(28).

Blasting is one of the most destructive fishing techniques in the region(2). Although illegal, it is common in many areas. Blasting shatters the coral reef for a radial distance of several meters, depending on blast depth and strength. Damaged areas thereafter support little fish life; are slow to recover (up to 30 years for 50% recovery); and encourage infestation by some algae and other prolific species such as Crown-of-thorns starfish(2).

Muro-ami and kayakas fishing techniques, common to the Philippines and reported in Indonesia and Sabah, are related to traditional Japanese methods of using swimmers to chase fish into a net(5) (Fig. 15). The swimmers bang the bottom substrate with poles and rocks to make noise, scaring the fish out of hiding and herding them into nets. The consequence is many broken corals in a disturbed bottom habitat.

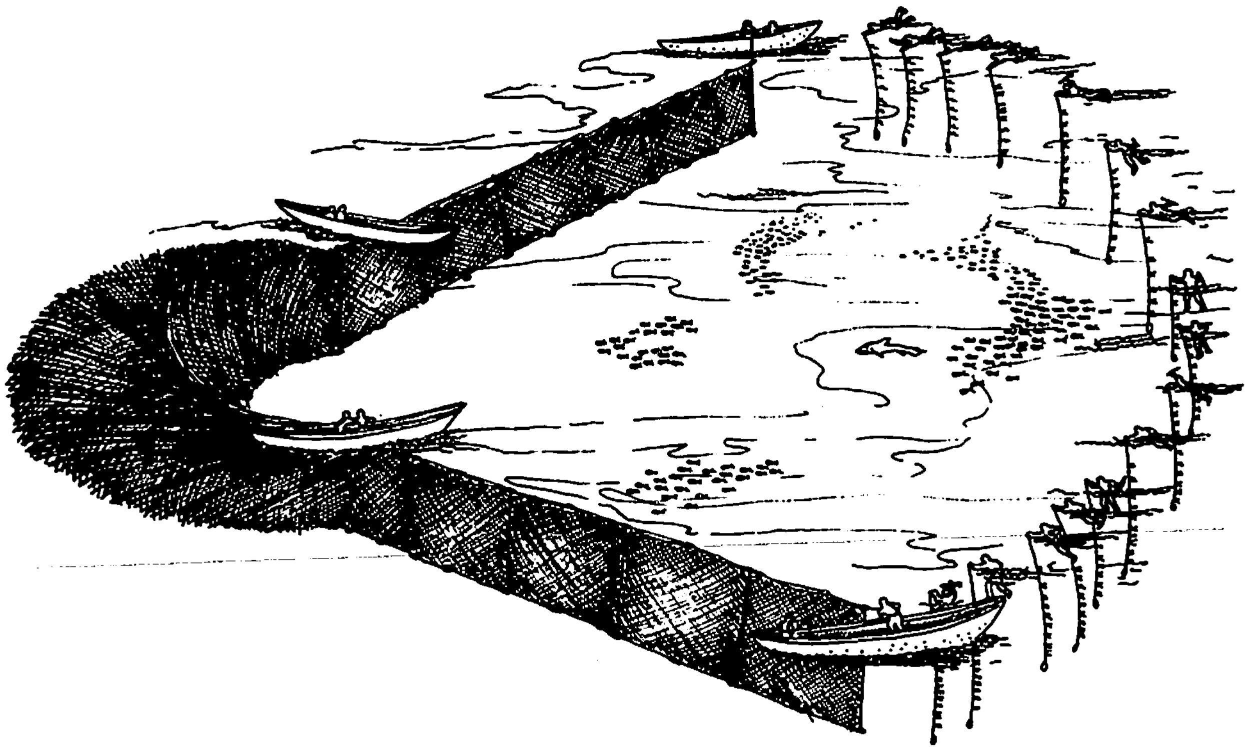


Fig. 15. Muro-ami fishing operations damage coral reef habitat.
Source : Bureau of Fisheries and Aquatic Resources, Philippines.

Fish traps are a legitimate fishing method when used judiciously. At times, however, the coral is broken and used for trap weights, and abandoned traps continue to catch fish until the traps disintegrate. Sometimes large traps are dropped on reef ledges and retrieved along the slope with a line, during which sizeable coral formations can be smashed.

Bait or aquarium trade fishing often involves breaking colonies of branching and foliose corals in order to shake fish out of them. Fish toxicants are also used, some of which (e.g., sodium cyanide) are detrimental to the health of coral and other invertebrates. The aquarium trade is frequently directed toward certain popular fish such as cleaner wrasses, which serve a particular ecological role in the reef community. Their capture can be disruptive to the fish community. This same principle applies in spearfishing for large, desirable species such as groupers, parrotfish and surgeonfish which are virtually absent in heavily speared reefs.

Inshore fishing in reef environments normally involves the use of small- to medium-sized boats whose anchors are designed to hook corals or other substrates. Frequent dropping and removal of such anchors damage heavily visited coral areas. Boats transporting tourists also drop anchors at popular snorkeling and diving areas and can cause significant damage[6].

Reef gleaners break corals by walking over the reef at low tide, and swimmers damage corals with their fins. Tourists sometimes remove live corals and reef animals from protected areas. The extent of such damage is unknown but is usually concentrated near resorts or popular diving areas.

Pollutants, other than sediment, which affect coral reefs include heavy metals, sewage, hydrocarbons and thermal discharge[15]. Since these pollutants occur near populated, industrial areas, reefs bordering major cities in Southeast Asia are mostly destroyed.

Hydrocarbon pollution occurs near oil refineries, drilling platforms and in harbors. Evidence shows that oil kills reef fish and has detrimental effects on the reproduction, growth rate, colonization, feeding and behavioral responses of corals[21, 8, 19]. Oil platforms shade corals, and contamination occurs through the dumping of drilling muds and drill cuttings into the sea. At a drill site off northwest Palawan Island, Philippines, drill cuttings caused a 79% reduction in the amount of living hard coral cover close to the drill site[13].

The impact of thermal pollution is limited to hot water discharges from heavy industrial and power generating plants and some offshore oil sites. Since tropical organisms live at temperatures close to their upper lethal limits, the threat to reefs can be significant[15].

Construction of commercial and recreational facilities on or adjacent to reef areas has immediate mechanical impact. Such construction may alter water flow around the reef; cause local shading; and become a point source of pollution and littering.

The obvious response to the above threats to coral reefs is to minimize their occurrence. Details on the methods for doing so are beyond the scope of this book, but a summary of the more important methods is given in the next section. Nevertheless, common sense suggests that whenever and wherever reefs are being destroyed by these human activities, the cost to the environment and natural resources is greater than preventing the destruction.

Coral Reef Conservation

Problems

More than half of the reefs in the Philippines and Indonesia are in advanced states of destruction, with only about 25% of live coral cover in good condition and only 5% in excellent condition[47]. Comparable studies would probably indicate a similar status for reef quality in Thailand and Malaysia.

Numerous threats from humans to coral reefs have been described above. For example, collecting and exporting of corals, blast fishing, muro-ami fishing, use of cyanide to catch aquarium and food fish still flourish today in several Southeast Asian countries, although these activities are illegal and punishable by heavy fines and imprisonment.

Human impacts on coral reefs can be broadly defined as physical damage, changes in the deposition/erosion environment, overexploitation and chemical pollution. Siltation and sedimentation are quickly becoming the largest threats. Often, damage from siltation and sedimentation is irreversible.

A "tragedy of the commons," in the sense of Hardin[11], is evident as reef fisheries are overexploited by individuals who focus only on short-term gain. Examples are fishermen who use destructive methods which destroy the habitat and/or simply overfish a reef area so that fish recruitment and reproduction is reduced in the long term.

How can these problems be prevented and what are the goals of conservation in this context?

Sustainable Use

It is assumed here that the goal of sustainable use of coral reef areas and resources is desirable. Yet the necessity of ensuring sustainable use varies with a society's dependence on the resource in question. For subsistence societies such as many coastal communities in Southeast Asia, sustainable use of all the living resources is essential.

In the sea, humans still have the status of food-gatherers, a form of exploitation that demands the most careful maintenance of the ecological basis of the ecosystem concerned. But as population increases, many resource users are economically forced to ignore the conflict between short- and long-term interests for maintaining the resource. This is exemplified by overfishing and reef destruction which lower natural production as discussed.

Most human-induced environmental changes are, at least initially, the result of development actions taken to provide positive benefit to some interested party. It is the goal of marine conservation to balance these positive development benefits with the negative environmental effects. The concept of "eco-development," that is, development and use that is ecologically considerate, takes account of ecological processes and those resources produced. This fits with sustainable use which ensures that coral reef resources would be used no faster than they are naturally generated. How can sustainable use be achieved?

Protection and Management

We now know a great deal about why reefs are deteriorating. We are also aware of the extent of the problem and its long-term implications in terms of loss of coral reef resources. Scientists have devised various management tools based on ecological theory, field studies and often common sense for managing coral areas. Yet, practical means for implementing these management tools are still lacking in many areas. Thus, few coral reef areas in the world and almost none in Southeast Asia are effectively protected. Legal protection and, in some cases, field management have not been effective.

Reef management is largely a matter of common sense. Parks and reserves constitute a common conservation method for marine areas which is beginning to be applied to the management of coral reef areas. Nevertheless, coral reefs are still poorly represented among the world's protected areas; only about 100 of the 1,162 national parks on the United Nations list include or adjoin reefs[37].

A marine reserve constitutes a defined space to which some form of management and limited entry is applied. Resources, habitat, ecosystems, species and the space required for their interactions are common criteria used for selecting boundaries. Management may range from functional, where resource use occurs, to preservational, where entry is prohibited. Marine parks and reserves, which hold good potential for reef management, are explored further in an accompanying book on this subject.

Other forms of reef management and conservation, sometimes within the definition of marine reserve include: (1) controls on fishing methods and rates of exploitation; (2) involvement and organization of local fishing communities to manage their own reef resources; (3) education of coastal populations; (4)

municipal, provincial and national legislation; and (5) various integrated approaches to coastal resource management by national agencies.

In Southeast Asia, even though the national laws for protection are good, effective management is site-specific. Examples of marine reserves include Bali Barat Marine Reserve in Indonesia, a national effort; and Apo and Balicasag Island Reserves in the Philippines, local, municipal efforts. Although education and involvement of local people are beginning in some areas in the Philippines and Thailand, these are still in their infancy in terms of need. Integrated management of coastal resources, including coral reefs, is beginning under the auspices of the Association of Southeast Asian Nations (ASEAN)-United States Agency for International Development (USAID) Program for Marine Sciences. This project hopes to begin implementation of management plans by 1990.

Tourism is beginning to support coral reef management efforts and sizeable, local economies which favor marine conservation and protected areas. Buck Island National Monument off St. Croix in the US Virgin Islands attracts some 50,000 visitors a year, 90% of whom visit the snorkel trail(37). The Virgin Islands National Park, which receives about a million visitors a year, generates more than US$23 million a year and has annual costs of only US$2.1 million. Local tour operators in the park share their income with the national park. Coral reefs near Phuket Island in Thailand attract many tourists. This industry will have to support reef conservation to maintain the aesthetic attraction of their coral reefs in the long term.

Conservation and management of coral reef areas require creative and innovative approaches. Strict legalistic means of protection has usually not been effective. Active participation of those people who use the resource is necessary for any effective management. Education and good examples can help convince coral reef users, both local and foreign, about the benefits of effective long-term management and sustainable use of coral reef resources.

References

1. Alcala, A.C. 1981. Fish yield of coral reefs of Sumilon Island, Central, Philippines. Natl. Res. Counc. Philipp. Res. Bull. 36(1):1-7.

2. Alcala, A.C. and E.D. Gomez. 1979. Recolonization and growth of hermatypic corals in dynamite-blasted coral reefs in the Central Visayas, Philippines. Proc. Int. Symp. Mar. Biogeogr. Evol. S. Hemisphere 2: 645-661.

3. Alcala, A.C. and E.D. Gomez. 1985. Fish yields of coral reefs in Central Philippines. Proceedings of the Fifth International Coral Reef Congress. Tahiti. Vol. 5.

4. Alino, P.M., M. Ross, V. Rosaroso and C. Oroso. 1981. A report on the subtidal marine environment around the Philippine Mining Services Corporation.

5. Carpenter, K.E. and A.C. Alcala. 1977. Philippine coral reef fisheries resources. Part II. Muro-ami and kayakas reef fisheries, benefit or bane? Philipp. J. Fish. 15(2): 217-135.

6. Davis, G.E. 1977. Anchor damage to a coral reef on the east coast of Florida. Biol. Conserv. 11: 29-34.

7. De Silva, M.W.R.N. 1982. The status and conservation of coral reefs in Peninsular Malaysia. Proceedings of the Fourth Annual Seminar, Malaysian Society of Marine Sciences.

8. Gettleson, D.A. 1980. Effects of oil and gas drilling operations on the marine environment. *In* R.A. Geyer (ed.) Marine environmental operation. Elsevier Scientific Publishing Co., New York.

9. Glynn, P.W. 1977. The coral reef community, p. 202-219. *In* Yearbook of science and the future, Encyclopedia britannica. University of Chicago Press, Chicago.

10.Goreau, T.F., N.I. Goreau and T.J. Goreau. 1979. Corals and coral reefs. Sci. Am. 241(2): 124-136.

11. Hardin, G. 1968. The tragedy of the commons. Science 162: 1243-1248.

12. Henrey, L. 1982. Coral reefs of Malaysia and Singapore. Longman Malaysia Sdn. Berhad, Singapore.

13. Hudson, J.H., E.A. Shinn and D.M. Robbin. 1982. Effects of offshore oil drilling on Philippine reef corals. Bull. Mar. Sci. 32(4):890-908.

14. IUCN (International Union for the Conservation of Nature), UNEP (United Nations Environmental Programme) and WWF (World Wildlife Fund). 1980. Sustainable utilization of species and ecosystems. World conservation strategy. IUCN, Gland, Switzerland.

15. Johannes, R.E. 1975. Pollution and degradation of coral reef communities, p.13-20. *In* E.J. Ferguson-Wood and R. Johannes (eds.) Tropical marine pollution. Elsevier Scientific Publishing Co., Amsterdam.

16. Kenchington, R.A. 1985. Coral reef ecosystems: a sustainable resource. Nat. Resour. 21(2).

17. Kenchington, R.A. and B.E.T. Hudson, editors. 1984. Coral reef management handbook. UNESCO Regional Office for Science and Technology for South-East Asia, Jakarta.

18. Lowrie, S.F.W., R.L. Llena and P. Suarez. 1982. The effect of tailings from a copper mine in southern Negros on the marine environment and fishing industry. Agham 8(3): 125-136.

19. Loya, Y. 1985. Effects of petroleum hydrocarbons on coral. IUCN Coral Reef Conservation Group, Commission on Ecology, Gland, Switzerland.

20. Mathias, J. and N. Langham. 1978. Coral reefs, p. 117-151. *In* T.-E. Chua and J.A. Mathias (eds.) Coastal resources of West Sabah, an investigation into the impact of oil spill. Penerbit Universiti Sains Malaysia, Penang.

21. Maragos, J.E., A. Soegiarto, E.D. Gomez and M.A. Dow. 1983. Development planning for tropical coastal ecosystems, chapter 5. *In* R.A. Carpenter (ed.) Natural systems for development: what planners need to know. Macmillan, New York.

22. McManus, J.W. 1980. Philippine coral exports: the coral drain. ICLARM Newsl. 3(1): 18-20.

23. Munro, J.L. 1983. Giant clams--food for the future? ICLARM Newsl. 6(1): 3-4.

24. Munro, J.L. and D. McB. Williams. 1985. Assessment and management of coral reef fisheries: biological, environmental and socio-economic aspects. Proceedings of the Fifth International Coral Reef Congress, June. Tahiti. Vol. 4

25. Murdy, E. and L. Ferraris. 1980. The contribution of coral reef fisheries to Philippine fisheries production. ICLARM Newsl. 6(1): 3-4.

26. Nybakken, J.W. 1982. Marine biology: an ecological approach. Harper and Row, Publishers, New York.

27. Punay, E.Y. 1975. Commercial sea snake fisheries in the Philippines, p. 489-502. *In* W.A. Dunson (ed.) The biology of sea snakes. University Park Press, Baltimore.

28. Ruddle, K. 1981. Pollution in the marine coastal environment of ASEAN countries, chapter 6. *In* C. MacAndrews and C. L. Sien (eds.) Southeast Asian Seas: frontiers for development. McGraw-Hill/Institute of Southeast Asian Studies, Singapore.

29. Russ, G. 1986. Effects of fishing pressure on an assemblage of coral reef fishes. Department of Zoology, University of Sydney, Australia.

30. Salm, R.V. 1984. Marine and coastal protected areas: a guide for planners and managers. International Union for the Conservation of Nature, Gland, Switzerland.

31. Savina, G.C. and A.T. White. 1986. Reef fish yields and nonreef catch of Pamilacan Island, Bohol, Philippines, p. 497-500. *In* J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds.) Proceedings of the First Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines.

32. Smith, S.V. 1978. Coral reef area and the contributions of reefs to processes and resources of the world's oceans. Nature 273(2): 225-228.
33. Soegiarto, A. 1983. The problems and efforts of protecting the coral reefs in Bali, Indonesia. Fifteenth Pacific Science Congress, 1-11 February 1983. Dunedin, New Zealand.
34. Soegiarto, A. and N. Polunin. 1982. The marine environment of Indonesia. Cambridge University, England.
35. Stevenson, D. and N. Marshall. 1974. Generalization on the fisheries potential of coral reefs and adjacent shallow-water environments. Proceedings of the Second International Coral Reef Symposium.
36. Sukarno, N. Naamin and M. Hutomo. 1986. The status of coral reef in Indonesia. *In* S. Soemodihardjo (ed.) Proceedings of MAB-COMAR Regional Workshop on Coral Reef Ecosystems: Their Management Practices and Research Training Needs, 4-7 March 1986. Bogor.
37. Wells, S.M. 1986. A future for coral reefs. New Sci. 30 (October):46-50.
38. Wells, S.M. 1981. International trade in ornamental corals and shells. Proceedings of the Fourth International Coral Reef Symposium, May 1981. Manila.
39. White, A.T. 1983. Valuable and vulnerable resources, p.26-39. *In* J.R. Morgan and M.J. Valencia (eds.) Atlas for marine policy in Southeast Asian Seas. University of California Press, Berkeley.
40. White, A.T. 1984. Marine parks and reserves: management for Philippine, Indonesian and Malaysian coastal reef environments. Department of Geography, University of Hawaii, Honolulu, Hawaii. Ph.D. dissertation.
41. White, A.T. 1985. Conservation of the marine environment, p. 310-340. *In* Marine policy in Southeast Asia. University of California Press, Berkeley.
42. White, A.T. 1987. Philippine coral reefs: a natural history guide. New Day Publishers, Manila.
43. White, A.T. and G.C. Savina. Reef fish yield and nonreef catch of Apo Island, Negros, Philippines. (In press).
44. White, A.T. and S.M. Wells. 1982. Coral reefs in the Philippines. Oryx 16:445-451.
45. Whittaker, R.H. 1975. Communities and ecosystems. 2nd ed. MacMillan, New York.
46. Woodley, J.D., E.A. Chornesky, P.A. Clifford, J.B.C. Jackson, L.S. Kaufman, N. Knowlton, J.C. Lang, M.P. Peason, J.W. Porter, M.C. Rooney, K.W. Rylaarsdam, V.J. Tunnicliffe, C.M. Whale, J.L. Wahle, J.L. Wulffe, A.S.G. Curtis, M.D. Dallmeyer, B.P. Jupp, M.A.R. Koehl, J. Neigel and E. M. Sides. 1981. Hurricane Allen's impact on Jamaican coral reefs. Science 214: 749-755.
47. Yap, H.T. and E.D. Gomez. 1985. Coral reef degradation and pollution in the East Asian Seas region. Environment and resources in the Pacific. UNEP Regional Seas Reports and Studies No. 69.

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