Life on the Coral Reef

THE CORAL REEF ECOSYSTEM

Coral reefs provide the basis for the most productive shallow water ecosystem in the world. An **ecosystem** is a group of living things, such as coral, algae and fishes, along with their non-living environment, such as rocks, water, and sand. Each influences the other, and both are necessary for the successful maintenance of life. If one is thrown out of balance by either natural or human-made causes, then the survival of the other is seriously threatened.

DID YOU KNOW? All of the Earth's ecosystems are interrelated, forming a shell of life that covers the entire planet – the biosphere. For instance, if too many trees are cut down in the rainforest, soil from the forest is washed by rain into rivers that run to the ocean. The muddy silt drifts out to sea, covering the nearby coral reefs. Some corals can remove the silt, but many cannot. If the silt is not washed off within a short period of time by the current, the polyps suffocate and die. Not only the rainforest is destroyed, but also the neighboring coral reef.

Reef Zones

Coral reefs are not uniform, but are shaped by the forces of the sea and the structure of the sea floor into a series of different parts or **reef zones**. Understanding these zones is useful in understanding the ecology of coral reefs. Keep in mind that these zones can blend gradually into one another, and that sometimes a zone will be missing entirely. Coral reef ecosys-

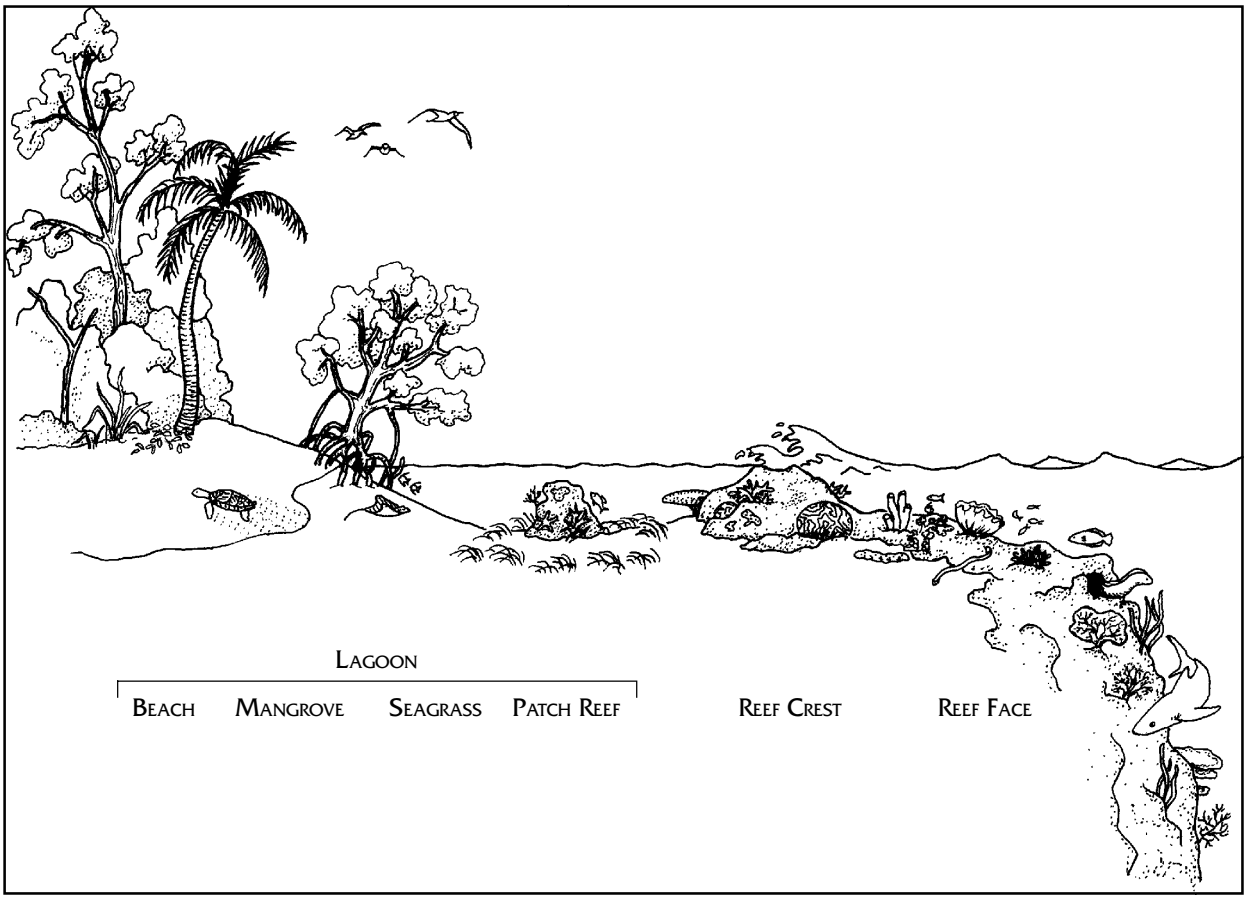


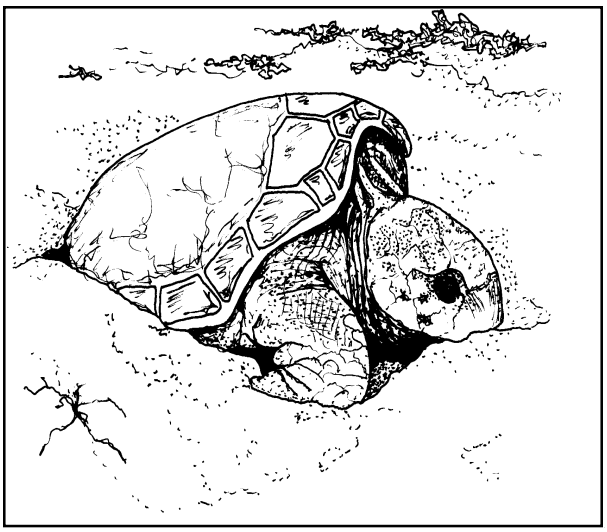
Figure 2-1. Reef zones: (a) lagoon, (b) reef crest, and (c) reef face. (Illustration: Wendy Weir)

tems are also interrelated with nearby terrestrial ecosystems, that may consist of tropical rainforests, coastal lagoons, or small islands.

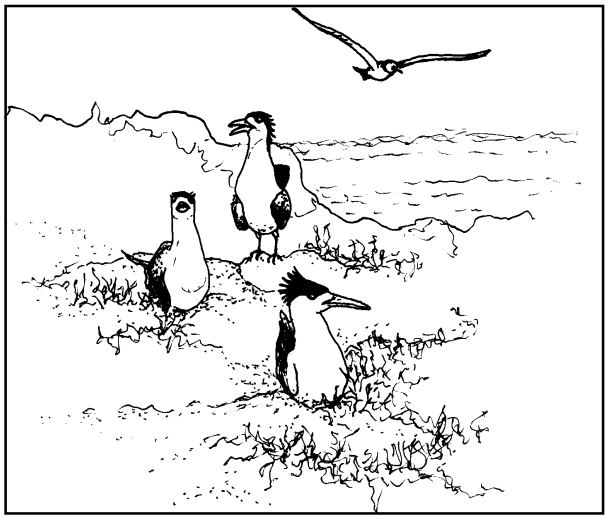
The main reef zones are: the **lagoon**, including the beach, mangroves, seagrass beds, and patch reefs; the **reef crest** or flat; and the **reef face** (Figure 2-1).

LAGOON

Between the beach and the reef crest lie the protected, shallow waters of the lagoon. This is a very rich, diverse zone and home to a variety of plant and animal life, including mangroves, seagrasses, sponges, conchs (pronounced *"kongk"*), sea urchins, fish, spiny lobsters, sea turtles, and small sharks.



(a)



(b)

Figure 2-2. (a) Loggerhead turtle laying eggs in the sand, and (b) crested terns nesting on the beach. (Illustrations: Wendy Weir)

Beach: On the land side of the lagoon a sandy beach is often found, formed by waves washing ground-up coral skeletons, animals and plants onto the shore. Some animals use the beach habitat for reproduction. Sea turtles climb up the beach at night to lay up to 100 eggs in the warm sand (Figure 2-2a), and some of the shore birds, such as crested terns, use the beach for their nesting ground (Figure 2-2b). Other birds rest on the beach during their migrations north and south, while some feed there.

Mangroves: Mangroves are often found in the transitional area between land and water. These trees are fairly unique because they thrive in seawater. Growing quickly, about 2 feet (60cm) in the first year, some mangroves have specialized seed pods, called **propagules**, that grow on the end of roots that drop down from the canopy of the tree. When the pods ripen, they fall into the mud and send out roots to start a new tree. Mangroves also have prop roots that stick out from the water, absorbing oxygen and preventing the underwater roots from suffocating (Figure 2-3a).

Mangroves are very important for several reasons:

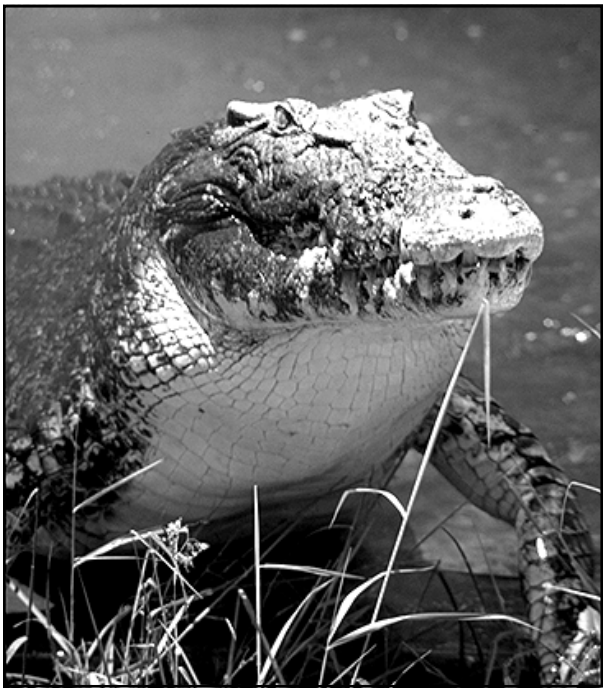
- They help in the process of claiming land from the sea and in protecting the coastline because their roots trap and consolidate sediments that would otherwise be washed back out by waves.
- Droppings from resident birds and falling plant material enrich the soil below, increasing its capacity to support other plant life.
- They serve as an important habitat for many different species of animals. Their complex tangle of roots and branches provides an excellent place for animals to feed, rest, mate, and give birth. For instance, large fruit-eating bats roost in the mangrove branches until nightfall when they fly out to feed. Lobsters and fiddler crabs feed on nutrients from the retreating tide, recycling minerals and organic matter into the mangrove forest. Other crabs eat the mangrove leaves. Juvenile fish seek the protection of the roots until they grow large enough to safely occupy the reef. Stingrays, small sharks, and crocodiles (Figure 2-3b) hide among the roots where they rest and search for food. Oysters and

mussels grow on the mangrove roots and are used for food by native coastal people.

Unfortunately, it is only recently that the need to protect mangrove habitats has been recognized. The mangrove forest may be one of the Earth's most endangered habitats with an estimated 50% of all mangrove swamps already cleared or altered worldwide. They are cut down for use as coal, and to make room for mariculture ponds and development, such as resorts and waterfront homes.

DID YOU KNOW? Madagascar once had large mangrove forests along its coast which served as a nursery for many species of reef fish. Now these forests have almost been entirely destroyed by logging for charcoal.

(a)



(b)

Figure 2-3. (a) Mangroves along shore, and (b) saltwater crocodile. (Photos: Wendy Weir)

Seagrass: Seagrasses are a group of marine plants that grow on the sandy floor of the lagoon, most often amid the patch reefs. They serve both as a protective nursery for numerous species of reef fish and as a rich source of food for adult fish who hide on the coral reef during the day and venture into the seagrass beds at night to feed. Only a few animals, such as the sea turtle, trunkfish, and sea cow (called a **dugong** in the Indian and Pacific Oceans and a **manatee** in the Atlantic and Caribbean), can be seen cruising between the seagrass and the coral reef during the day (Figure 2-4).

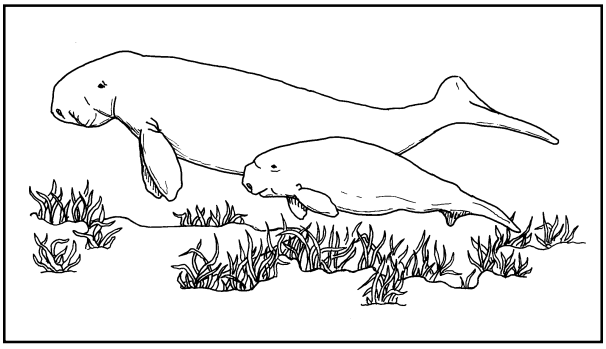
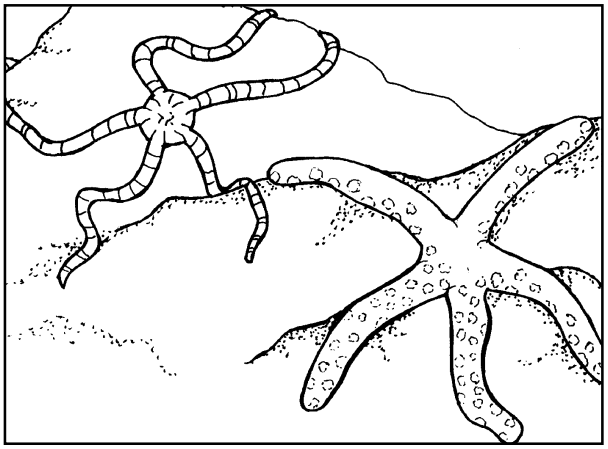


Figure 2-4. Dugong and calf grazing on seagrass. (Illustration: Wendy Weir)

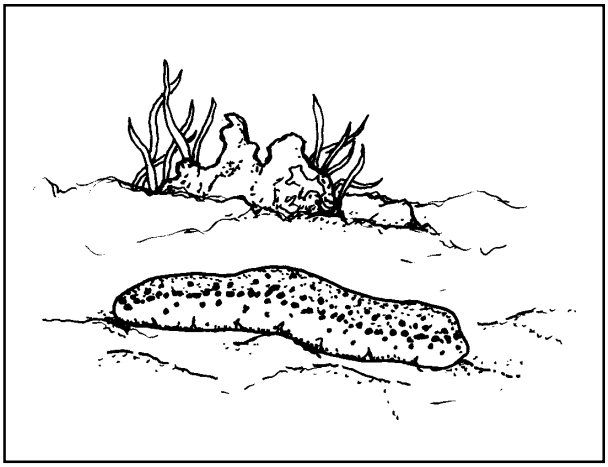
Patch Reef: Some lagoons also contain fairly flat, circular or oval islands of coral, called patch reefs, which are surrounded by sand and seagrass. They vary greatly in size, from that of a small car to larger than a football field. The diversity of marine life also varies greatly depending upon the size of the reef. Usually, the larger the patch reef, the greater the diversity.

Some of the marine life that exists on or around the patch reef are fish, sea stars, sea turtles, sea cucumbers, and mollusks, such as clams and conchs (Figure 2-5). Sea cucumbers, which resemble giant slugs, move slowly across the sea floor, extracting food from the sediment in the sand and processing large quantities of it through their long tubular bodies.

DID YOU KNOW? The green turtle is a vegetarian and feeds only on seagrass. Unfortunately, like other sea turtles around the world, it is endangered. Each year, large numbers of sea turtles are caught and



(a)



(b)

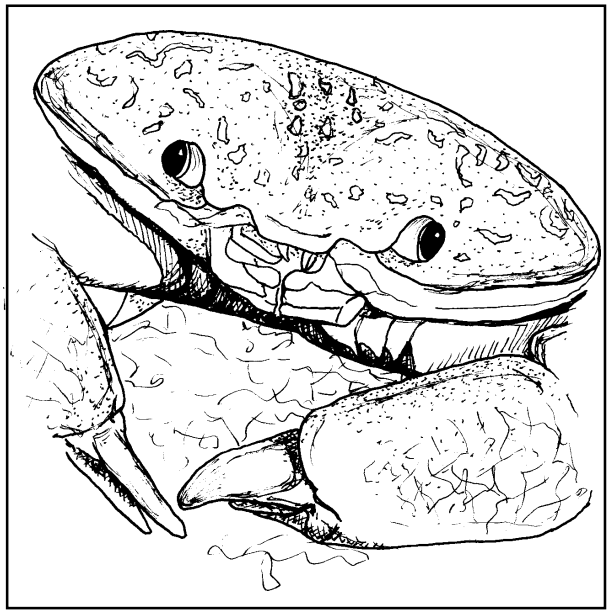
Figure 2-5. (a) Sea stars, and (b) sea cucumber. (Illustrations: Wendy Weir)

drowned in fishing nets, their eggs and flesh hunted for food, and their shells and skin used for ornament.

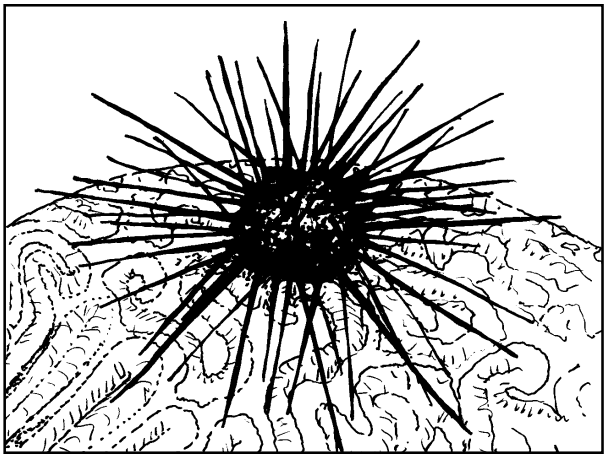
REEF CREST

The **reef crest** is the highest (shallowest) part of the entire reef, and the most easily visible from above the surface of the sea. It can be identified from the shore or air as a brownish band highlighted by a line of white breaking waves along its outer edge. Low tides and waves often expose portions of the reef crest, and storms crash against it, breaking off coral branches and plates. For this reason, fewer species of coral are present here compared to further down on the reef face. Still, the reef crest is home to many plants and animals, including parrotfish, barnacles, and coralline algae. As the tide changes, rimmed tide pools a few inches above sea level are sometimes formed on the reef crest. These pools are constantly replenished with seawater and are home to crabs, small fish, sea urchins, worms, sea stars, and marine snails, among other creatures. These animals are also found on other parts of the reef.

DID YOU KNOW? Crabs and sea urchins (Figure 2-6) are like janitors. They work to keep the reef clean. The crabs eat dead fish debris and the sea urchins eat the vegetation, such as algae, that grows on dead coral, keeping the surface clean so new coral can settle and grow.



(a)



(b)

Figure 2-6. (a) Crab, and (b) sea urchin. (Illustrations: Wendy Weir)

REEF FACE

The seaward facing slope of the reef is called the **reef face** and may be divided into two parts, upper and lower.

The **upper zone** is more brightly lit by the sun and is home to a tremendous diversity of reef life, such as hard and soft corals, sponges (Figure 2-7), clownfish and sea anemones, lobster (Figure 2-8), butterflyfish, angelfish (Figure 2-9), trunkfish, damselfish (Figure 2-10), sea stars, clams, lionfish, parrotfish, mollusks, sea turtles and much more. **Zooplankton** (microscopic drifting animals) and **phytoplankton** (microscopic drifting plants) (Figure 2-11) are swept into the reef face by upwelling currents from deeper parts of the ocean, supplying the reef life with easy access to food. This zone consists of gentle slopes which extend from about 10 to 15 feet (3 to 5m) to around 60 to 70 feet (18 to 22m) in depth.

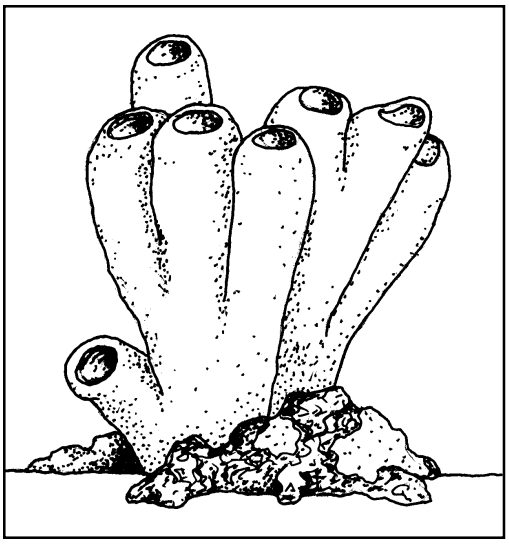


Figure 2-7. Sponge. (Illustration: Wendy Weir)

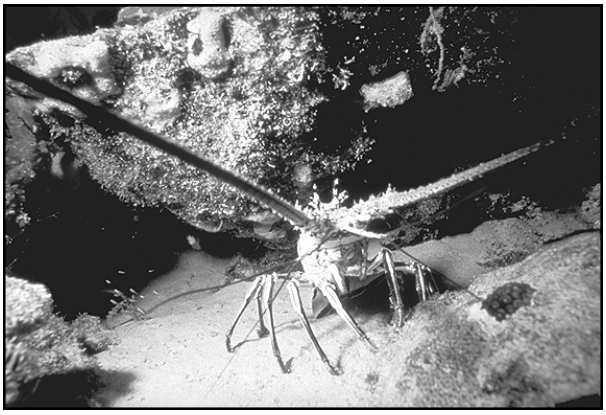


Figure 2-8. Spiny lobster. (Photo: Milton Beral)

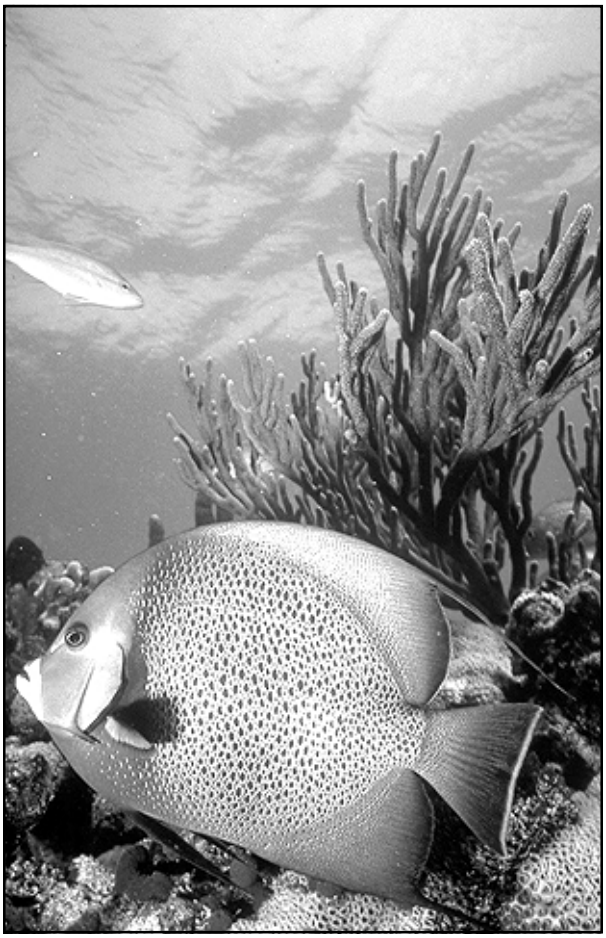


Figure 2-9. Gray angelfish. (Photo: Larry Benvenuti)

Figure 2-10. Damselfish amid soft coral. (Photo: Terry Brown)

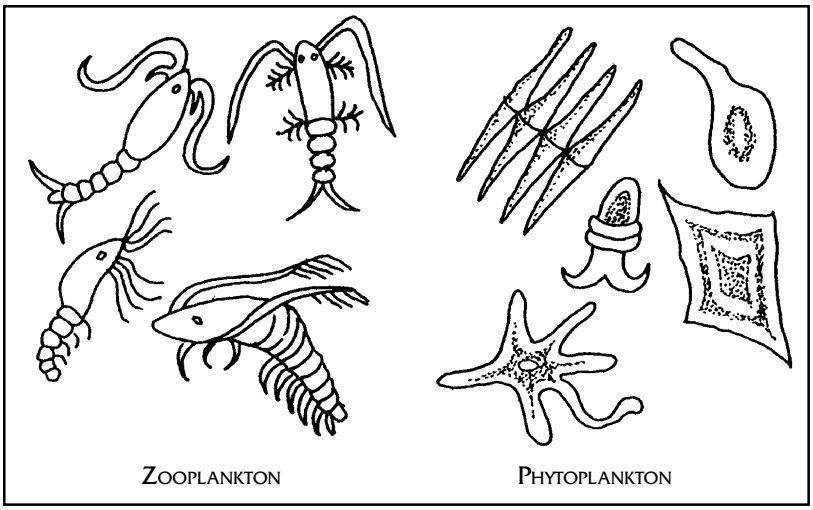


Figure 2-11. Plankton: zooplankton and phytoplankton. (Illustration: Wendy Weir)

The **lower zone** begins where the reef face starts to drop off. On some reefs, this area is characterized by spur-and-groove formations (high ridges of coral divided by sand channels or grooves) that run perpendicular to the shore. On other reefs, the face drops off sharply, plunging vertically hundreds of feet into the depths of the sea where it becomes too dark for reef-building coral to grow. Some of the marine life found living in this area are soft corals, moray eels (Figure 2-12), sharks, manta rays, and eagle rays (Figure 2-13).

DID YOU KNOW? Some coral species can take on different shapes in different areas. Near the top of the reef face, they can grow short and fat in order to withstand constant wave action and all but the heaviest of storms. Further down the face where the water is more calm, these same corals develop thinner branches or large plate-like forms in order to receive as much light as possible for their zooxanthellae.

Figure 2-12. Moray eel. (Photo: Terry Brown)

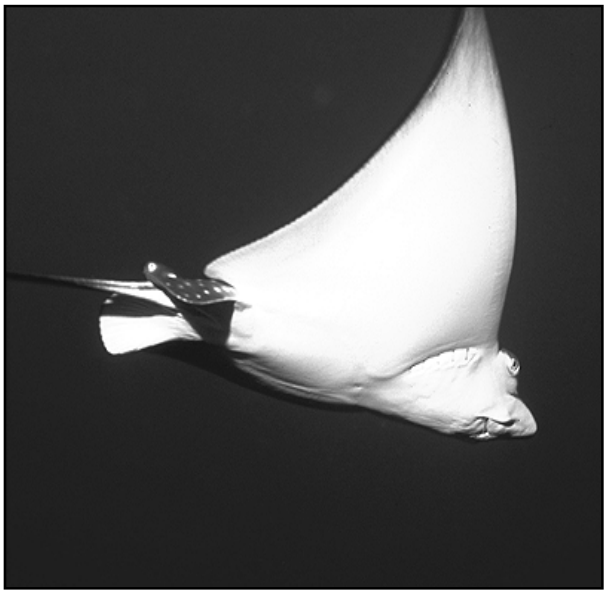


Figure 2-13. Spotted eagle ray. (Photos: Terry Brown)

VALUABLE RELATIONSHIP

The beach, mangroves, seagrass bed, patch reef and coral reef all work together to form a healthy ecosystem. The mangroves and seagrass beds protect the reef from being smothered by natural siltation by trapping soil runoff and silt from the land. They also serve as nurseries and a rich source of nutrients for reef life. In return, the reef helps to protect the beach, mangroves, and seagrass beds from erosion by waves; it provides sand for the beach and seagrass beds; and, it contributes some of the sediment for the mangroves. Harm or destruction to one or more of these elements in the ecosystem seriously affects the survival of the others.

The Food Chain

Nutrients and energy move through the coral reef ecosystem along numerous pathways. At the base of the food chain are the **primary producers**: the plants, including phytoplankton, algae, seagrasses, and mangroves, that are capable of photosynthesis. Algae occurs in all sizes, from the microscopic zooxanthellae that live inside coral to tiny drifting plants called phytoplankton to large seaweeds. The primary producers then pass energy and nutrients along the food chain to the **primary consumers**, animals that

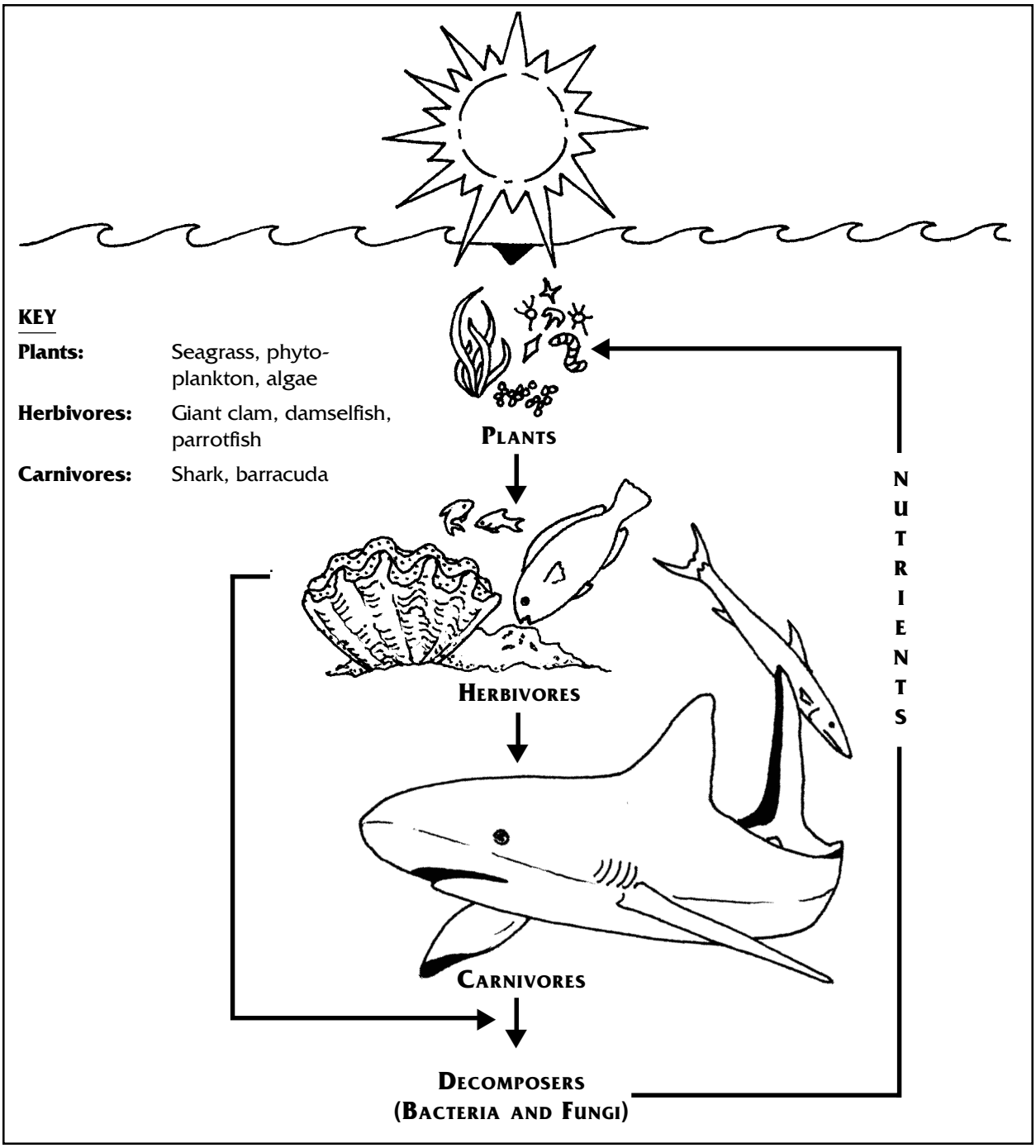


Figure 2-14. The food chain. (Illustration: Wendy Weir)

feed on plant material and are therefore called **herbivores**. In turn, these primary consumers are eaten by other animals, the **secondary consumers**, called **omnivores,** if they eat both plants and small animals, and **carnivores**, if they eat only animals. The food chain ends with the **decomposition** of the plants and animals by decomposers, mainly fungi and bacteria.

Energy and nutritional exchange within the reef ecosystem is an ongoing process, with some forms of reef life feeding mainly during the day (**diurnal**), some during the night (**nocturnal**), and some during the hours of dawn and dusk (**crepuscular**). Scientists now realize that the reef is able to produce and retain much of its own energy through this complex process of recycling food (Figure 2-14).

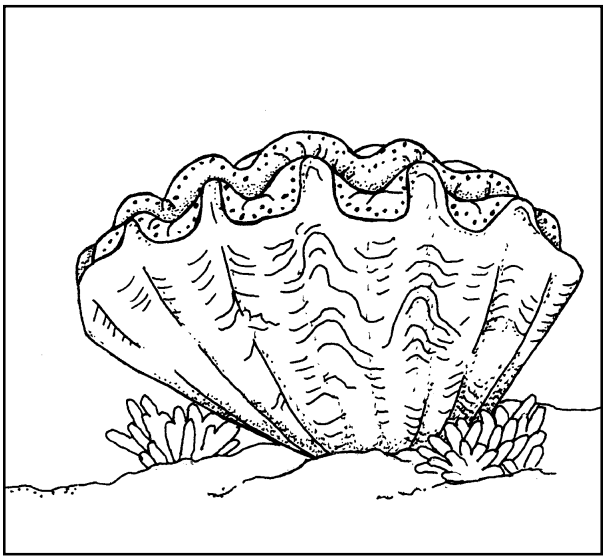
HERBIVORES

Herbivores graze on plant material. Most herbivores live in shallow, well-lit water because that is where the plants grow best. They range in size from very small, like some zooplankton that feed on phytoplankton, to very large, like the giant clam that can reach more than 40 inches (1m) in length and weigh more than 1,000 pounds (453kg).

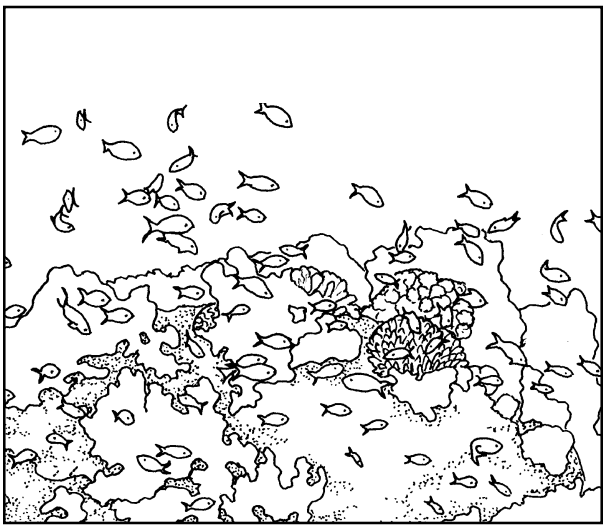
Like coral, the **giant clam** (Figure 2-15a) has a symbiotic relationship with its microscopic plant partners, the zooxanthellae. The clam grows its own food source, the zooxanthellae, in its fleshy mantle. The zooxanthellae give the mantle its blue, green, and brown color. Some of the carbohydrates from the zooxanthellae are absorbed by the mantle's tissue while other zooxanthellae are harvested by its blood cells and digested. Humans have devastated populations of these clams in many parts of the Pacific, harvesting them for food and decoration. Fortunately, projects are underway to farm these giant clams and return them to the coral reefs.

Among the reef fish that eat plants, there are three basic families: damselfish, parrotfish, and surgeonfish. The **damselfish** (Figure 2-15b) is considered a reef "farmer" because it actively guards and grows small patches of algae on an area of coral to serve as its food source. The brightly-colored **parrotfish** has fused teeth that resemble a parrot's beak which it uses to bite and scrape algae off the hard coral. After ingesting bits of coral, it crushes them in its digestive system, and excretes them as sand. The **surgeonfish** earned this name because of a sharp, knife-like spine located on each side of its body near the base of its tail. When threatened by a predator, it raises its tail making it difficult and painful for the predator to swallow. They are one of the most common herbivores found on reefs around the world.

Other reef herbivores are conch, green snails, sea urchin, herring, some sea turtles, and sea cows.



(a)



(b)

Figure 2-15. (a) Giant clam, and (b) damselfish on reef. (Illustrations: Wendy Weir)

OMNIVORES AND CARNIVORES

A number of animals on the coral reef are omnivores, feeding on both plants and animals. Among the most common of these are the graceful and beautifully-colored **angelfish**. Along with herbivores, omnivores are the most visible marine life on the reef during the day.

The carnivores on the reef feed only on animals, using many different strategies to capture their prey. The amount of food eaten by carnivores varies greatly, from certain sharks who eat 10% of their total body weight in food per week to the small lizardfish who eats almost 80% of its total body weight in small fish each week.

The best known carnivore is the **shark** (Figure 2-16), although a few species of shark do not eat meat. Sharks have been present in the ocean for 300 million years and can be found at all depths. Many reef sharks, such as the nurse shark, are most active at night, resting amid the coral during the day. Various experiments have shown that sharks rarely bother divers who remain passive; sharks only become aggressive when provoked. Sharks are now being overfished for their meat, their fins (to make shark's fin soup), and their cartilage (for use as an anti-cancer agent). Because they are at the top of the reef food chain, their loss could greatly impact the reef community.

Other carnivores are the barracuda, jacks, and grouper.

DID YOU KNOW? There are **cleaning stations** along the reef. At special locations, small **cleaner fish** and shrimps can be found that will clean debris and parasites off of larger fish. The fish being cleaned will allow them to move about in their gills and mouths, and will not eat them. In some places, fish actually line up for this service. Cleaner fish are very important in keeping fish, and therefore the reef, healthy and strong.

DECOMPOSITION

The final stage of the food chain is decomposition. When plants and animals die, their elements are chemically broken down by tiny, simple life forms: **fungi** and **bacteria**. In this way, nutrients necessary for new plant growth are released back into the reef environment.

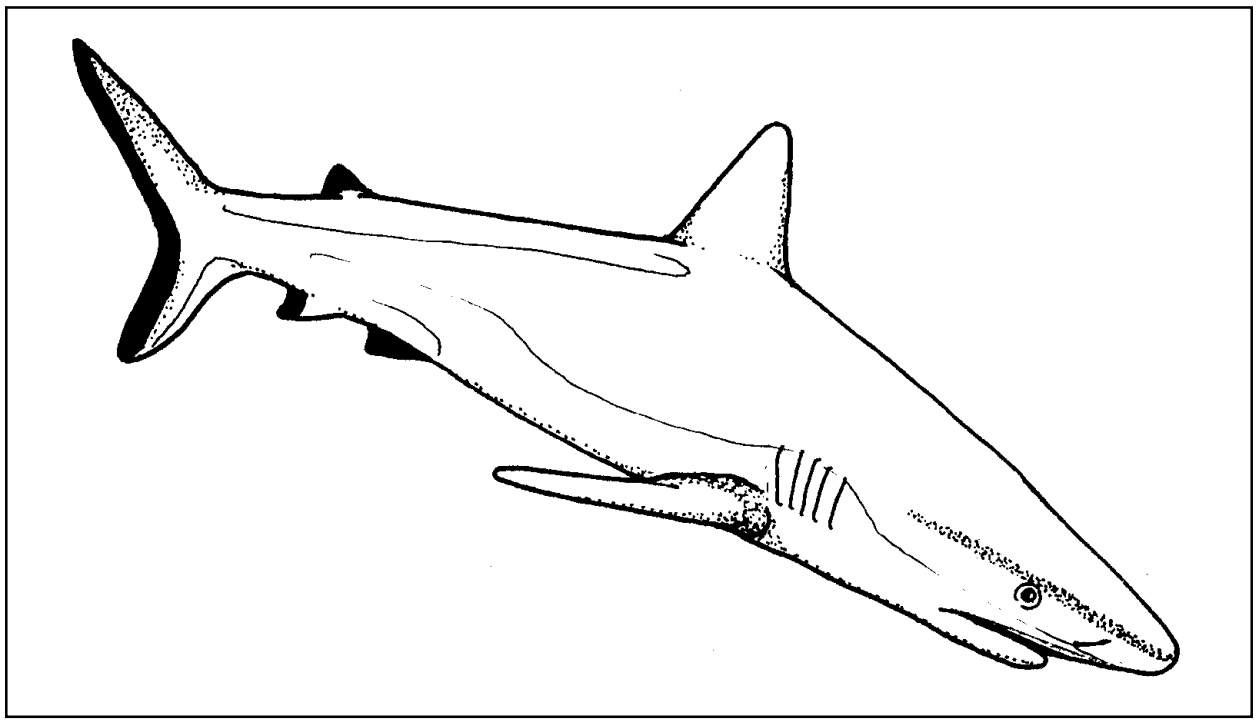


Figure 2-16. Gray reef shark. (Illustration: Wendy Weir)

Decomposition also plays a role in shaping the overall reef environment. For instance, when coral dies, its limestone skeleton is overgrown by seaweeds and algae, and is invaded by animals, such as **worms** that bore tubes into its surface. Other animals follow, using these tubes for their homes. Some species of sponges also bore into the dead coral by releasing chemicals to break down the limestone skeleton into tiny pieces. These pieces then drift down towards the bottom, forming part of the sediment on the reef floor.

DID YOU KNOW? It has been reported that worms and sponges are able to make a dead staghorn coral branch completely disappear within one year by boring into its surface.

Predation and Protection

METHODS OF PREDATION

Many reef animals feed on plankton. Plankton consists of both animals (zooplankton) and plants (phytoplankton), and some reef animals feed on both while others just feed on animals. For instance, **coral polyps** and **Christmas tree worms** extend their tentacles to catch plankton as it floats by. Like its relative the coral polyp, the **sea anemone**, a carnivore, attaches itself to a piece of limestone rock and extends its poisonous tentacles to catch the zooplankton and tiny fish that float by in the ocean current.

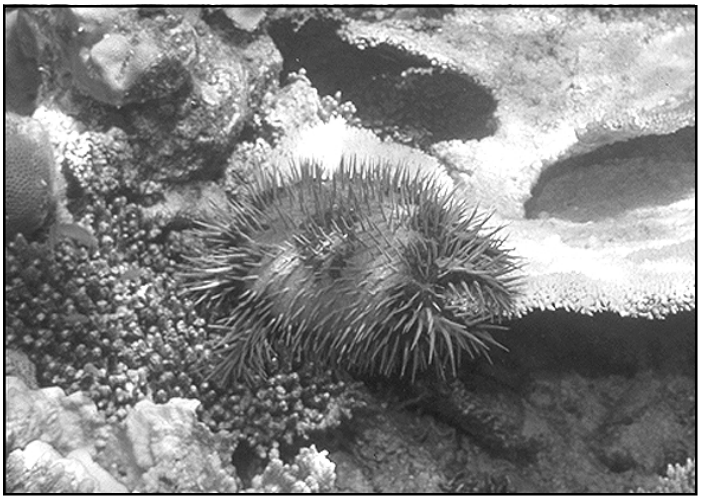
The **lionfish** (Figure 2-17a) uses camouflage to hide itself among the coral and then ambushes unsuspecting prey as it passes. Some sharks and barracuda use speed to chase down their prey. The **trumpetfish** uses stealth, hiding behind another fish or within a waving gorgonian coral in order to sneak up on its prey.

The **clown triggerfish** (Figure 2-17b) and **trunkfish** catch small crustaceans and fish that hide in the sand by blowing streams of water out of their mouth to move the sand, or by removing the sand with their fins or snout.

(a)

(b)

Figure 2-17. (a) Lionfish, and (b) clown triggerfish. (Photos: Terry Brown)



(a)

(b)

Figure 2-18. (a) Crown-of-thorns sea star (Photo: Jim Thompson), and (b) giant triton. (Photo: Terry Brown)

The **moray eel** glides along the reef, searching for crabs and small fish that hide in coral crevices. Its strong, narrow head and flexible body give it the ability to enter difficult spaces to attack its prey. Some moray eels are even able to wiggle out of the water and up on the beach to catch crabs.

Sea stars live on and around the coral reef, eating coral polyps and buried mollusks, such as clams and scallops, by enveloping their stomach around the food item. All sea stars are characterized by radial symmetry wherein the body parts are repeated around a center, like the spokes of a wheel.

One type of sea star, the **crown-of-thorns** (Figure 2-18a), is very threatening to coral reefs because it eats coral polyps, killing the coral. Entire reef ecosystems along the Great Barrier Reef of Australia and parts of the Philippines have been temporarily devastated due to population explosions of the crown-of-thorns. There is quite a controversy regarding whether the crown-of-thorns population explosion is a natural, cyclical occurrence or the result of reef disturbances by humans. Some scientists believe population explosions are caused by nutrient overload from sewage which supplies a rich source of food for baby crown-of-thorns. The only natural predator on the crown-of-thorns is the giant triton (Figure 2-18b), a large marine mollusk which has been overcollected for its beautiful shell. Some scientists believe that this is another reason the crown-of-thorns has been able to multiply unchecked in certain areas.

DID YOU KNOW? If part of a sea star is broken off, the sea star will regenerate (grow back) the missing part. The part that is missing will also grow into a new sea star.

(a)

(b)

Figure 2-19. (a) Blue dash butterflyfish, and (b) clownfish hiding in the tentacles of a sea anemone. (Photos: Terry Brown)

METHODS OF PROTECTION

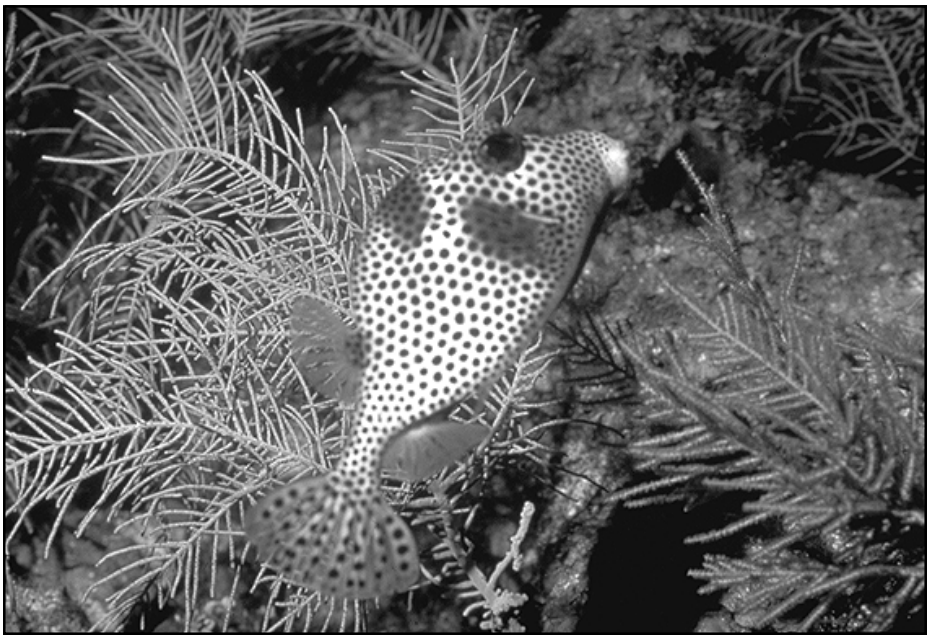
Coral reef animals use many different forms of protection. Some hide in the sand, others hide among the coral. Some swim into the lagoon and hide among the mangrove roots while others swim in schools along the reef face. Some eject poison while others inflate themselves to a much larger size. Some of the same methods that are used for predation are also used for protection.

Certain fish use their body color as **camouflage** to blend in with the surrounding environment, making it difficult for predators to see them. The bright yellow **blue dash butterflyfish** has a round black spot near its tail that looks like an eye. When a predator aims for what it thinks is the head (but is actually the tail), the butterflyfish is able to escape in the opposite direction. Its thin, pancake-like sides enable it to swim quickly between narrow coral formations and hide in places where its predator cannot fit (Figure 2-19a). Butterflyfish are active during the day, showing their bright, striking color patterns. At night, they seek shelter close to the reef's surface, often taking on a dull, dark color pattern to blend better with the reef.

The **sea anemone** has a unique, **synergistic relationship** with the **clownfish** which hides among the anemone's poisonous tentacles, safely protected from predators. It is believed that the mucus coating on the clownfish protects it from the stinging cells in the sea anemone's tentacles (Figure 2-19b). In return, the clownfish, being very territorial, drives off any fish that try to prey on the anemone. It also drops bits of food for the anemone to eat.

Some marine snails also use the poisonous cells of sea anemones for protection, but in a different way. When a **nudibranch** (pronounced *"noodebrank"*) feeds on the tentacles of the anemone, it does not trigger the stinging cells. Instead, the cells migrate to the nudibranch's exposed gills and serve the snail for protection. Nudibranchs come in a wide variety of shapes and colors (Figure 2-20a). Their bright colors warn predators of this poison.

(a)



(b)

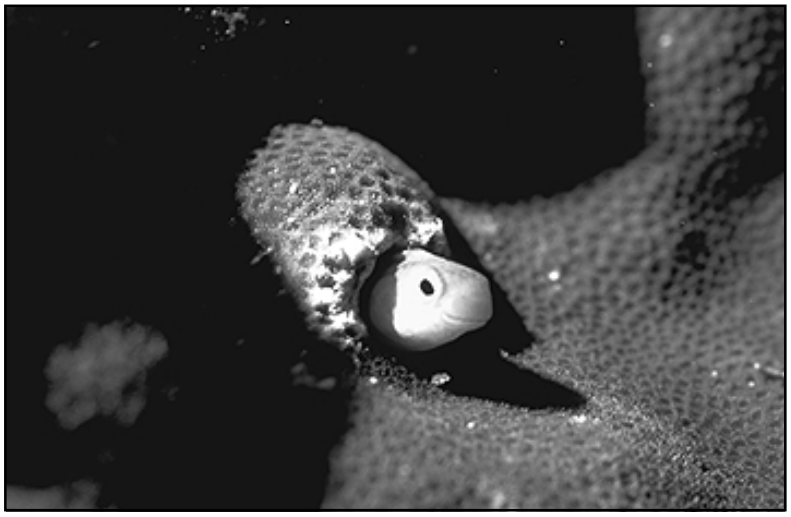
Figure 2-20. (a) Nudibranch, and (b) spotted trunkfish. (Photos: Terry Brown)

The **trunkfish** (Figure 2-20b), which is sometimes called a boxfish, has a hard, boney body or carapace similar to that of a trunk, which makes it hard for predators to eat. Some secrete poison from their skin when under stress. Trunkfish swim slowly, eating small animals, algae, and sponges.

The **stonefish** uses more than one method for protection: camouflage to blend in with its environment, and lethal poison in its dorsal spine to avoid being eaten. It is reported that the stonefish is the most deadly, venomous fish in the Indo-Pacific region. If touched, a small amount of its poison can seriously harm a diver.

The **octopus** and **squid,** and their relative the **cuttlefish**, are also excellent masters at disguise, able to change their body color rapidly to match their surroundings or to eject a thick cloud of black ink which acts as a "smoke-screen" to hide their escape. They have a highly developed nervous system with a relatively large brain and large eyes. These large eyes

(a)



(b)

Figure 2-21. (a) Speckled hermit crab (Photo: Larry Benvenuti), and (b) yellow gobie hiding in coral (Photo: Terry Brown)

give them a greater field of vision and ability to see at night, thus helping them to evade predators. They also use camouflage to sneak up on their prey.

Many **wrasses** can operate one eye independently of the other: one watches where it is going, and the other looks for predators. At dusk, many **parrotfish** hide themselves among the coral and excrete mucus from their mouth to form a soft, protective envelope around their body. The transparent mucus traps their scent so that predators cannot find them.

The **hermit crab** (Figure 2-21a) and the small **yellow gobie** (Figure 2-21b) protect themselves from larger predators by **hiding** inside holes. The hermit crab makes its home inside an empty shell and the gobie hides in a piece of hollow coral. At the slightest sign of a threat, they duck inside where it is safe. Gobies are among the smallest of reef fish, some measuring less than half an inch (1cm) in length.

When attacked, **porcupinefish** and **pufferfish** protect themselves by drawing water into their abdomen to **inflate** themselves to more than twice their normal size, thereby making it difficult for predators to swallow them. They also have large protruding eyes that can see in all directions, enabling them to spot predators quickly. Pufferfish produce a powerful poison, **tetrodotoxin**, which can cause serious illness and even death in humans who eat one that is prepared improperly. Despite this problem, pufferfish are considered a delicacy in Japan.