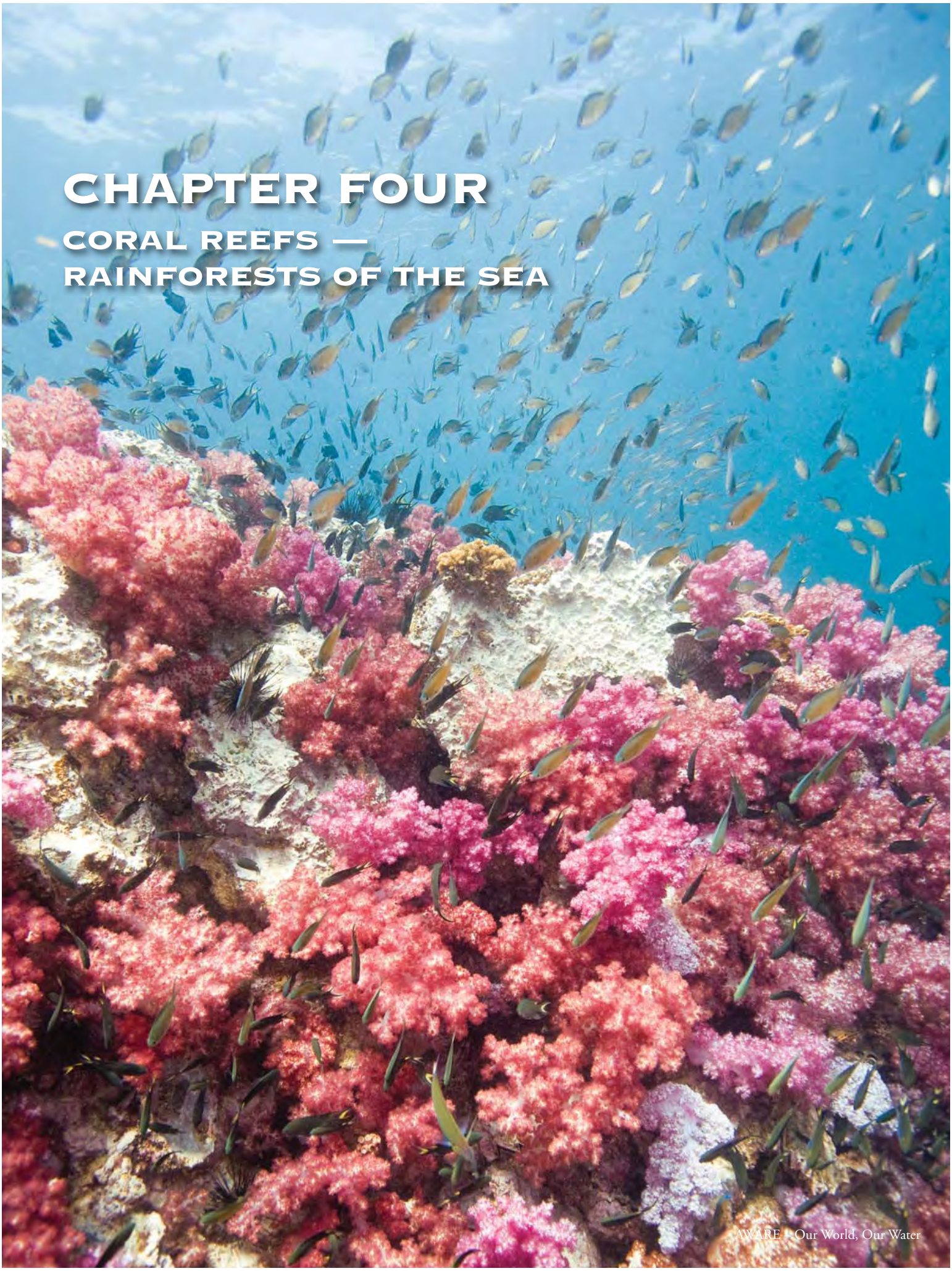


CHAPTER FOUR

CORAL REEFS — RAINFORESTS OF THE SEA

CORAL REEFS — RAINFORESTS OF THE SEA

- **Coral Reefs — Diversity and Beauty**
- **Reef Fish**
- **Limits to Abundance**
- **Threats — Natural and Human-induced**

STUDY QUESTIONS

Underline/highlight the answers to these questions as you read:

1. Why are coral reefs so important to the marine environment?
2. Why is the term *biotic reef* more accurate than *coral reef*?
3. Approximately how many different species of fish exist on coral reefs?
4. What percentage of the world's coral reefs are threatened, and how is this threat likely to continue in the future?
5. What are the natural and human-induced factors currently contributing to the destruction of coral reefs?
6. What is the estimated effect of recreational diving on coral reef destruction?

CORAL REEFS — DIVERSITY AND BEAUTY

"In the scope of the endangered ecosystem, the coral reef environment is a precious resource we, as divers, hold close to our hearts. And, we are fortunate that we, as individuals, have the power to protect it.

– Drew Richardson, Project AWARE Foundation Chairman

There's no more special place on earth to those who dive or snorkel than a coral reef. Temperate areas offer thrilling sights and great places to dive (see Chapter 3), but most divers also look forward to visiting spectacular tropical coral gardens to watch their colorful inhabitants. This makes coral reef health of particular concern to underwater explorers.

Beyond their innate beauty and popularity as dive and snorkel sites, coral reefs are habitat and nursery grounds for 25 percent of all known marine species – many of which humans rely on for food. This is an impressive statistic considering how little of the sea bottom is coral reef. While the total range is difficult to determine, the most accepted figure is that coral reefs cover only about 284,300

square kilometres/110,000 square miles. That's about one-tenth of one percent of the total sea bottom, or an area about the size of the state of Nevada, USA, or Ecuador.

Coral reefs are important because they are storehouses of biodiversity. The term *coral reef* does not do justice to the complexity of these ecosystems. They could more accurately be called *biotic reefs*. Some biologists refer to reefs as *rainforests of the oceans* because they support an incredible array of organisms. Pharmacologists have found an abundance of biomedical compounds on reefs, from antibiotics to anti-cancer agents, and suspect there are thousands more yet to be discovered.

From a purely physical perspective, coral reefs are vital structures. They protect islands and coastal communities from storms, wave damage and erosion. Corals and mangroves absorb up to 90 percent of the wave energy.

Many tropical nations base their tourism industries on the appeal of the surrounding coral reefs. In some areas, reef diving or snorkeling tours are significant income sources and are foundational to the countries' economies.

The Coral

Corals grow best in the shallow, clear water of tropical and subtropical oceans where the annual temperature range is between 18-30° C/64-86° F. Reefs are actually massive coral colonies. Corals are tiny marine invertebrates (from the phylum Cnidaria) that secrete skeletons of calcium carbonate (limestone) to form small cups called corallites. The reef grows as individual coral polyps, which anchor within these limestone cups, collectively form the large reef structure.

Most corals are impressive builders. The largest structure on earth manufactured by living organisms is Australia's Great Barrier Reef, which is visible even from outer space.

Corals that build massive reefs (*hermatypic* or mound building corals) have a special symbiotic relationship with algae that reside deep within the polyp's tissues. The algae (*zooxanthellae*) enable the coral polyps to function as both plant and animal. The algae

Photo courtesy of Tom Haight

produce food via photosynthesis, while the polyp catches plankton from the water column. The algae releases oxygen and sugars that are consumed by the polyp and the polyp releases carbon dioxide and nitrogenous waste that sustains the algae. Because algae depend on light, reef-building corals do not grow well deeper than 25 metres/82 feet.

When a coral colony dies, either through natural or human-induced factors, it forms a substrate on which new corals grow. Coralline algae (algae that itself secretes limestone) cements the sand and coral fragments together to fill in the spaces between the larger fragments of dead coral skeletons. This cementing process and growth provides stability and makes reefs less susceptible to damage from waves and storms.

The Reef

Coral may form a reef's foundation, but reef ecosystems flourish due to an amazing menagerie of other organisms. For example, bacteria and algae coat the sandy bottom and portions of the reef not covered by living coral. This provides food for mollusks, crustaceans, sea cucumbers, sea urchins and herbivorous fish. These organisms, in turn, provide vital housekeeping functions that keep the ecosystem healthy and also serve as food sources for organisms higher up on the food chain.

Other organisms, such as sponges, worms and mollusks, play an important role by eroding a reef's massive limestone fortresses. This type of erosion is a positive force because it creates additional living space within the reef. Scientists estimate that 40 to 70 percent of a coral reef is actually open space. Broken segments of coral provide new habitats and are eventually cemented back into the reef by coralline algae. The actions of grazers such as parrotfish and sea urchins produce large quantities of sediment, which also results in new living spaces for smaller fish and invertebrates.

Photo courtesy of Robert Baker

Same Slow Growth Rate?

Contrary to popular belief, all corals do not grow at the same rate. In fact, there are considerable differences among species. For example, branching corals like staghorn coral can grow horizontally about 10 centimetres/four inches per year, while massive forms like boulder coral grow at one-tenth this rate. Vertical growth differs as well and can be as slow as less than a few millimetres/fractions of an inch per year.

Limits to Abundance

In biology, the term *gross primary production* (GPP) describes the total amount of living matter in a given area produced by plants. It's a way of quantifying the base of the food chain. In nutrient-rich coastal areas, the GPP is high and in the open ocean the GPP is very low. Logically, coral reefs should rank in between, but lower on the scale. However, they often have a GPP that is 250 times more than the surrounding ocean. This makes reefs one of the highest production areas of any natural ecosystem.

This seeming violation of the laws of thermodynamics — high productivity in nutrient poor water — is quite complex and not completely understood. But, in general, this occurs because corals and coral communities are extremely efficient at recycling nutrients (nitrate and phosphate). The nutrients that make their way there tend to stay there.

From their high GPP, it seems reasonable to assume that coral reefs produce far more food than is needed by inhabitants, however reef production is nearly balanced by what it consumes – there is little surplus. This balance has important implications for coral reef fisheries. Unlike productive ocean ecosystems, the amount of organic matter (fish and invertebrates) that can be taken without causing damage to the coral community is limited. A coral reef that has adequately supported a limited sustenance fishery for centuries would likely collapse within a matter of years once commercial fishing was introduced.

REEF FISH

There are more than 21,000 species of fish worldwide, with more than 4000 species found on coral reefs. Many reef fish display vibrant colors arranged in intriguing patterns, while others have a single hue or features that allow them to blend in with their surroundings. Reef fish are generally small in comparison to fish that inhabit the open ocean, yet their sizes and shapes vary widely.

Their behavior, food sources, reproduction strategies, life cycles and survival techniques also differ considerably. For example, damselfish dart about in almost constant motion, while scorpionfish lie quietly, camouflaged from unsuspecting prey. Parrotfish sleep under ledges sometimes protected by a mucous cocoon, while cardinalfish come out from hiding at night. Also, most butterflyfish mate for life, while male hawkfish tend to gather harems.

Identifying Fish

Because there are so many different reef fish species, it is impossible to learn all of them or even most of them. However, the most commonly encountered fish tend to belong to the same few families (30 to 50), which makes general identification a little easier.

Project AWARE Foundation, PADI and Reef Environmental Education Foundation (REEF) jointly developed the PADI Specialty Diver course AWARE - Fish Identification that emphasizes fish

watching by identifying common characteristics among fish families rather than individual species. Through training materials obtained from REEF or other available sources, students learn the key characteristics of fish families and identify them by placing them in groups. The 12 commonly used groups that include more than 30 different fish families are:

1. Butterflyfish, angelfish and surgeonfish

This group usually have thin bodies and are oval or disk shaped. They are also generally bright and have interesting patterns. Most

Butterflyfish are round with small bodies and concave foreheads. They also have elongated mouths to pick tiny invertebrates from crevices. Angelfish have long dorsal fins and rounded foreheads. Surgeonfish are also called tangs and are usually a solid color and have spines protruding from each side of the base of the tail.

2. Jacks, barracuda, porgy and chubs

This group is usually silver in color with forked tails. They are also some of the larger fish on the reef. Jacks, also called trevally, are

open water silver and blue fish. These large fish are strong swimming predators. Barracudas are distinct fish with long cylindrical silver bodies and large mouths with sharp teeth. Porgies, which are also called sea bream, are usually oval shaped with steep sloping heads. Chubs, or rudderfish, have elongated oval shaped bodies and are usually silver and found higher in the water column.

3. Snappers and grunts

These fish have long tapered bodies with heads that slope down to their mouths. Snappers have upturned mouths with visible canine teeth. Grunts, so named because of the noise they make, they are colorful and often congregate in groups. They are also known as sweetlips.

4. Damselfish, chromis and hamlets

These small oval fish are often seen darting in and out of crevices. The are often colorful and display many different patterns and shadings. Damselfish are algae-eaters that defend their territory, even charging divers to protect their nest. Chromis are have bodies that are more elongated than damselfish and have deeply forked

tails. Hamlets are actually members of the seabass family but are shaped similar to damselfish with flatter sloping heads.

5. Groupers, seabass and basslets

Grouper is the common name for the larger seabass family members. Usually big-bodies with large mouths and lips, grouper are some of the larger fish seen on reefs and are often in the shadows by themselves. They also have a short, spiny dorsal fin that softens as it tapers down the tail. The other members of the seabass family are

smaller and have more elongated bodies than grouper. Basslets are tiny, colorful fish that usually inhabit deeper reefs or walls.

6. Parrotfish and wrasses - Usually colorful, this group includes parrotfish with their beak-like teeth plates and rainbow colors, while wrasse are generally smaller and have elongated bodies. Parrotfish use their bony beaks to scrape algae off of hard surfaces. Wrasses forage for small invertebrates in the sand.

7. Squirrelfish, bigeyes and cardinalfish

This group is primarily nocturnal, ranging over the reef freely at night but hiding in cracks and crevices during the day. You can spot them by looking for their reddish color and big eyes. Squirrelfish have a pronounced rear dorsal fin that resembles a squirrel's tail. Bigeyes have a continuous dorsal fin, large eyes and are less scaly. Cardinalfish are small reddish fish with short snouts and two separate dorsal fins.

8. Blennies, gobies and jawfish

These small fish with long bodes are often found on the bottom backed into small holes with only their head poking out. Blennies will perch themselves up on their pectoral fins and are distinguished by the appendages on their head, called cirri, that appear to be eyebrows or little horns. Gobies rest on their pectoral fins in a straight, flat and motion-less position and are referred to as a cleaner fish. Jawfish have long bodies and large jaws and are often found in holes constructed by moving stones.

9. Flounders, scorpionfish, lizardfish and frogfish

These bottom dwellers demonstrate excellent camouflage and unusual shapes. Flounders are a flatfish with both eyes on the side which

faces the surface. They also often burrow into the sand. Scorpionfish are camouflaged to match their surroundings and have stocky bodies and spiny venomous dorsal fins. Lizardfish have elongated bodies with large upturned mouths and rest on the bottom. Frogfish, also called anglerfish, have bulky bodies, webbed pectoral and ventral fins and large upturned mouths. They attract small fish by dangling a wiry appendage in front of their mouth to act as bait.

10. Filefish, triggerfish, puffers, trunkfish, cowfish, goatfish, trumpetfish and drums

This group is made up of all unusually shaped free-swimming fish. Filefish and triggerfish comprise a family of fish called leatherjackets because of their tough skin. They have thin bodies and distinctive prominent lips. Puffers have the ability to draw water into their bodies to inflate their size. Some of these have spines which are erect when the fish expands. Trunkfish and cowfish are called boxfish due to their triangular shape and bony scales. Goatfish are long and cylindrical and have distinctive barbells that hang down from their chin. Trumpet-fish have tubelike bodies and long mouths that flair open to suck in prey. Drums have extremely long foredorsal fin and striking black and while coloration.

11. Eels

These fish have long snakelike bodies and spend the day in crevices, holes or under ledges. They are found free swimming mostly at night.

12. Sharks and rays

These fish have an internal "skeleton" made of cartilage. Sharks use their tails for propulsion while rays have modified pectoral fins that they use to swim in a flying motion.

What is REEF and how can you get involved?

REEF (Reef Environmental Education Foundation) is a private, nonprofit organization established in 1990 by underwater photographers and marine life authors Paul Humann and Ned DeLoach. REEF's mission is to educate, enlist and enable divers and nondivers to become active participants in conserving marine habitats. One way REEF carries out its mission is by providing vital reef and inshore fish biodiversity data to marine scientists, resource managers, conservationists and other interested parties by enlisting and mobilizing volunteer recreational divers and snorkelers to conduct underwater surveys.

Through REEF's program, fish watching becomes more than merely an enjoyable activity — you can personally contribute to the understanding and conservation of the aquatic environment. The REEF Fish Survey Project is an ongoing cooperative effort between REEF and The Nature Conservancy (TNC). TNC is a private, nonprofit organization established in 1951 to preserve plants, animals and natural communities that represent the diversity of life on earth by protecting the lands and waters they need to survive.

Through the Project, volunteers gather large amounts of species and abundance data, which is transferred into the Project database. The database provides the scientific, resource management and conservation communities with access to long-term and geographically broad species inventories, as well as historical records of reef fish populations.

To participate in the REEF Fish Survey Project, you need basic fish identification skills and must be a member of REEF. PADI's AWARE Fish Identification Specialty course is a great way to develop these skills. Developed by Project AWARE in conjunction with REEF, the specialty course introduces divers to the most common families and species of fish found in the diver's local area and teaches fish surveying so you can participate in the REEF Fish Survey Project.

THREATS — NATURAL AND HUMAN-INDUCED

One-fifth of the world's coral reefs is functionally dead; another 35 percent is at a critical or threatened stage and all reefs are under long term threat of climate change.

A survey by the International Union for the Conservation of Nature (IUCN), found that human activities have significantly damaged or destroyed reefs in 93 of the 109 countries where they occur. The reefs at greatest risk are in South and Southeast Asia, east Africa and the Caribbean.

Will coral reefs survive for future generations? Unfortunately, we don't know. However, one thing is certain — the only possible way for coral reefs to survive is to protect them. Coral reef nations need to develop and promote environmental programs that strongly discourage destruction and nations around the world need to work together to combat climate change.

Reef Sensitivity

Coral reefs are threatened by both human and natural causes. They are susceptible because they live within a very narrow tolerance range in respect to light, temperature and nutrition. If the water is too warm or too cool, corals can die of thermal stress. If the water gets too turbid and blocks light, they may suffer from starvation due to reduced photosynthesis. Nutrient-laden water may cause corals to be out-competed and overgrown by nutrient-loving macroalgae. Quick sea level shifts may leave a reef too deep or too shallow to adjust and cause its slow death.

Because of coral's sensitivity to even the slightest change in environmental conditions, reefs are one of the first ecosystems affected by pollution or atmospheric alterations. Many scientists from different disciplines study these fragile communities for early warning signs of environmental degradation and global climate change. Acting as ecological indicators is another important coral reef function.

Natural Threats

Because coral reefs have been around for hundreds of millions of years, they can adapt to some change. Natural environmental conditions may damage reefs, but, provided nothing else adds to the stress, they can recover. In fact, the pressure placed on reefs by natural stresses may help them evolve a high level of biodiversity. Threats from nature include:

- Global weather anomalies such as El Niño
- Severe storms (hurricanes, typhoons, etc.)
- Fresh water inundation
- Species blooms
- Exposure to air during extremely low tides
- Diseases

A satellite view of Hurricane Katrina

Photos courtesy of NOAA

Aftermath of Hurricane Katrina: an oilslick on Bay St. Louis, Mississippi.

Human-induced Threats

Not surprisingly, the most severe threat to coral reefs is from human-induced changes to the environment. Many scientists and resource

managers believe most of these occur on land. These threats include increasing population pressure and technology-enhanced coastal development. Unlike pre-industrial societies that had minimal effects on coastal environments, today's heavy machinery, mechanical dredges and other industrial building innovations easily transform coastal zones into cities and resort communities with little regard for their effects on nearby reefs.

Deforestation, overgrazing and poor land-use practices lead to massive soil erosion and river siltation. Sediment dumped onto coral reefs blocks out light, while domestic, agricultural and industrial waste such as fertilizers, pesticides and sewage from development brings an overabundance of nutrients. The result is that corals die and once-healthy reefs take on a drab appearance.

Coral Bleaching: A Bleak Future

Throughout the 1980s, large portions of normally colorful corals, sea whips and sponges on reefs worldwide turned white and died – a phenomenon called *coral bleaching*. Marine biologists noted bleaching in the Caribbean, Society Islands, Great Barrier Reef, Western Indian Ocean and Indonesia. The 1998 and 2005 global bleaching events sent an even stronger warning about the future of reefs.

Most scientists agree that human-induced climate change is the primary culprit. Unless we alter the climate change course, coral reefs as know them may be gone in the next 30 to 50 years.

Coral bleaching.

Resource abuse offshore, such as overfishing and coral mining, can also have devastating effects on reefs. Indicators of overfishing, such as decreases in average and maximum sizes as well as changes in the variety of fish caught, often go unrecognized because of poor fisheries management. Dwindling catches cause fishers to turn to more destructive practices like dynamiting and cyanide poisoning. Overfishing may remove the reef cleaners and algae grazers, which allows algae to out-compete the corals.

In Southeast Asia, destructive industries — such as coral harvesting for building materials and souvenirs have devastated large reef tracts and brought species like the giant *Tridacna* clam to the brink of extinction. Even the aquarium trade has had an effect on populations of fish, invertebrates and "live rock", or reef, removed from the environment.

A final, steadily growing threat to coral reefs is the effect of tourism. Although tourism can be an environmentally friendly way to generate income from coral reefs, this happens only when resort development and operations are carefully controlled. Certainly, some damage occurs to reefs from activities such as sport fishing, anchoring and accidental contact by snorkelers and divers. However, in most cases, these activities cause relatively minor damage in comparison to other threats. And most certainly, divers and snorkelers or marine tourists are uniquely positioned to further minimize their minor damage by interacting responsibly with the marine environment. Anchor damage is one activity that can be curtailed completely through the use of mooring buoys. A mooring buoy is a permanent anchor line to which a boat can attach over a dive or fishing site, precluding any potential anchor damage to reefs. Project AWARE supports the installation and use of mooring buoys and has compiled an extensive mooring buoy planning guide outlining the components that need to be considered when taking on such a project.

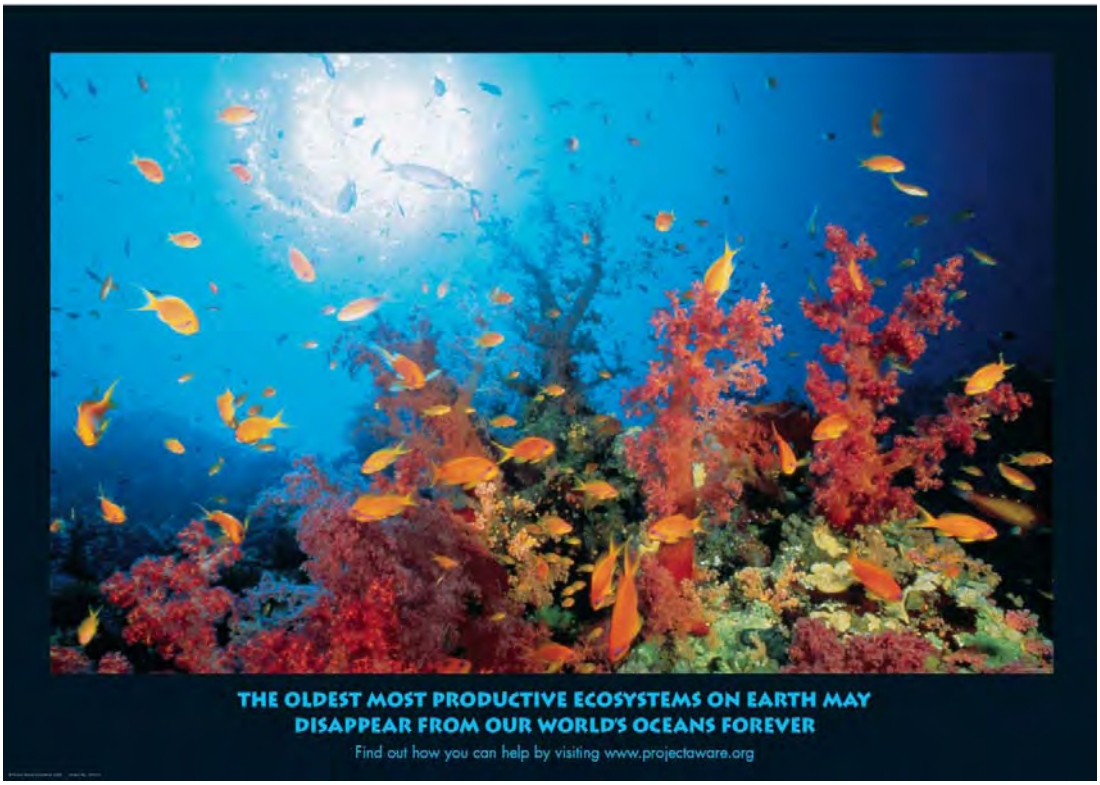
The bigger culprit is untreated sewage and other wastes from tourist facilities that pollute reef areas. Also, immediate damage occurs when builders situate resorts in coastal habitats like beaches, mangrove forests and seagrass beds.

Perhaps the most poorly understood human-induced threat involves changes to the atmosphere. Though still controversial, a growing number of scientists believe ozone depletion and increases in greenhouse gases could have serious consequences for coral reef health. Ozone depletion permits the passage of greater quantities of potentially damaging ultraviolet radiation. Data indicates this increase is highly destructive to corals and other zooxanthellae-hosting organisms.

Global climate changes wreak havoc in several ways, including raising sea surface temperature, altering the pattern, distribution and frequency of tropical storms, changing rainfall patterns and causing variations in ocean currents.

Summary of Human-induced Reef Stresses

- Coastal area overpopulation
- Coastal area development for ports, homes and resorts
- Siltation from inland erosion, especially in areas near large rivers and estuaries
- Pollution and eutrophication from chemicals, fertilizers, pesticides and sewage
- Overfishing resulting in disruption of ecological balance
- Destructive fishing methods, such as the use of dynamite and cyanide
- Extracting coral and coral sand for construction materials and souvenirs
- Removing fish and invertebrates, including live rock, for the aquarium trade
- Excessive collection of corals, shells, fish and other reef organisms
- Anchor and collision damage
- Atmospheric alteration



Project AWARE's Coral Reef Conservation Initiative

With the proliferation of natural and human-induced threats to coral reef habitats, Project AWARE has addressed these problems head-on with a coral reef conservation initiative. Built on the successful model of the Protect the Sharks initiative, Protect the Living Reef is designed to raise public awareness through informational brochures, display posters, stickers, campaign materials, and active participation in conferences and legislative efforts. The initiative also includes media focus through articles in dive publications, press conferences and public service announcements.

In addition to the public awareness campaign, reef cleanups and reef monitoring, Project AWARE's coral reef conservation initiative includes an educational program that features a PADI Specialty course: AWARE Coral Reef Conservation.

Quiz

1. Coral reefs are important to the marine environment because they:
   a. are nursery grounds for 25 percent of all known marine species.
   b. are storehouses for biodiversity.
   c. act as barriers to protect island lagoons and coastal areas.
   d. All of the above are correct.

2. True or False. Some biologists refer to coral reefs as *rainforests of the ocean* because they support a biologically diverse array of organisms.

3. Of the approximately 21,000 species of fish worldwide, more than _____ species are found on coral reefs.
   a. 16,000
   b. 8000
   c. 4000
   d. 2000

4. True or False. Today, as much as 50 percent of the world's coral reefs may be degraded beyond recovery.

5. Which of the following are human-induced threats to coral reefs? (choose all that apply)
   a. Fresh water inundation.
   b. Using cyanide and dynamite to catch fish.
   c. Siltation that results from coastal construction.
   d. Anchor damage.

6. True or False. Accidental contact by snorkelers and divers causes relatively minor damage to coral reefs.

How did you do? 1. d; 2. True 3. c; 4. False – estimates are closer to 10 percent 5. b, c and d 6. True