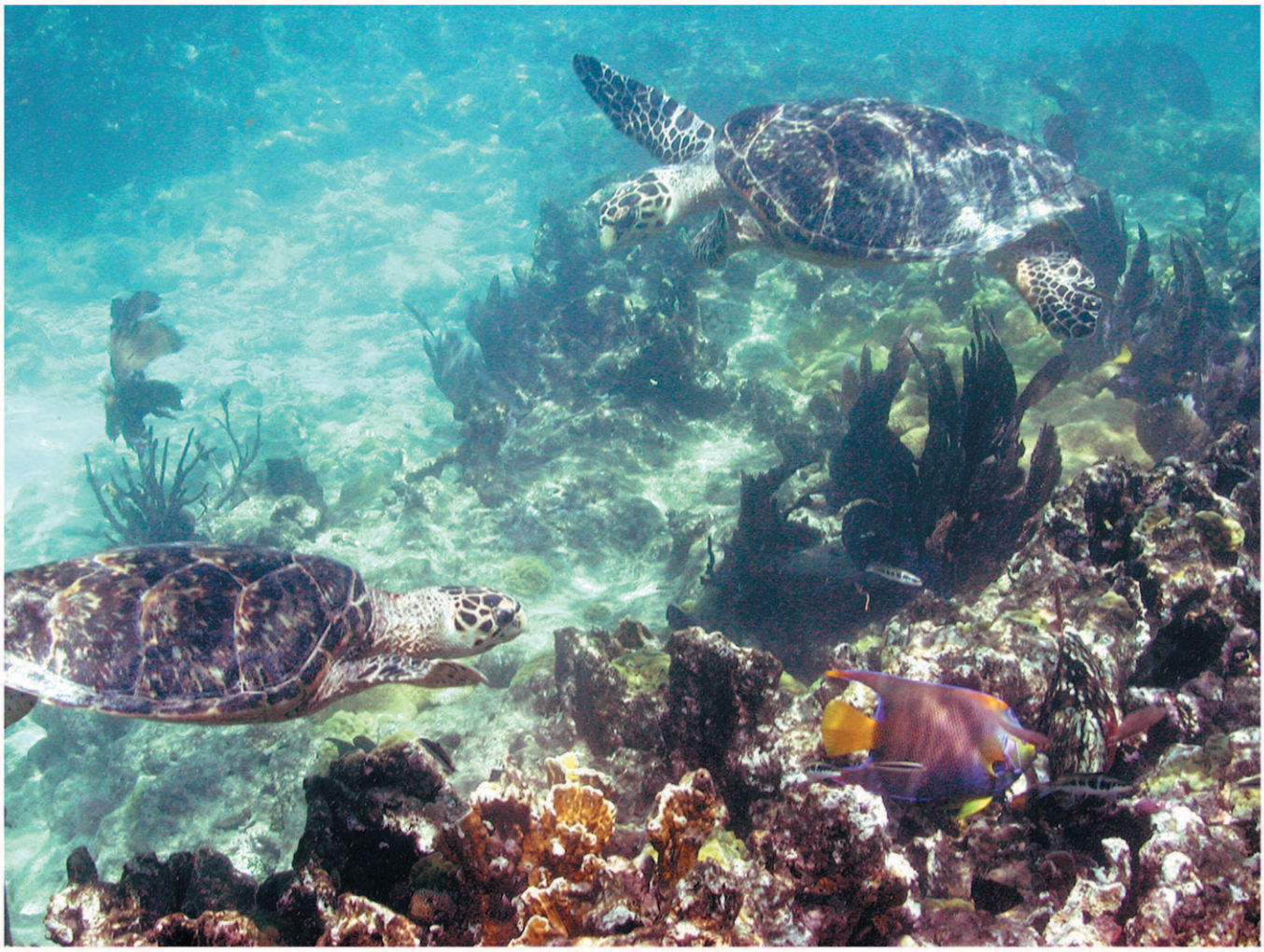
Coral Reef Teacher's Guide

REEF RELIEF®

a nonprofit membership organization dedicated to Preserve and Protect Living Coral Reef Ecosystems through local, regional and global efforts



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THE CORAL REEF TEACHER'S GUIDE

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Table of Contents

Benefits, Threats, and Solutions

LESSON PLANS

Acknowledgements

We would like to give special thanks to the following people whose dedication and efforts were integral to the development of the Coral Reef Teacher's Guide.

Wendy Weir - for the original concept and creation of the **Teacher's Guide** which was first published in 1996 by Coral Forest, a coral reef conservation organization that combined its educational efforts and activities with REEF RELIEF in 1998.

Joanne Hardesty - Sea View Elementary School, Salton City, CA

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Bill Alevizon, PhD - Author, *The Pisces Guide to Caribbean Reef Ecology*

Sue J. Estey, PhD - Environmental Defense Fund

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Special thanks to DeeVon Quirolo and Joel Biddle for revisions made in 2004.

Introduction

Coral reefs have been called the "rainforests of the sea". They are the most biologically diverse marine ecosystem on Earth and one of the most fragile of Earth's environments. And they are being destroyed at an alarming rate.

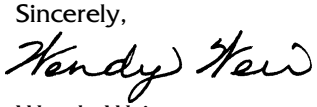
Coral reefs are found in 109 countries, but it is estimated that they have been damaged or destroyed by human activity in at least 93 countries. With each reef lost, countless forms of unique tropical marine life moves closer to extinction and indigenous communities are forced to move from their ancestral lands.

Some of the threats to coral reefs include pollution from sewage, fertilizers and pesticides, oil spills and hydrocarbon pollution, destructive fishing techniques and overfishing, mining, siltation from coastal development and logging, habitat loss from land development, and recreational overuse and abuse. These human-made threats cause irreparable damage when allowed to continue unchecked.

REEF RELIEF is a non-profit membership organization dedicated to protecting living coral reef ecosystems through local, regional and global efforts. In 1998, Coral Forest and REEF RELIEF combined efforts to protect coral reefs. This **Coral Reef Teacher's Guide** was first produced by Coral Forest and is now available through REEF RELIEF. One of the most important ways that we can protect coral reefs is by increasing awareness, support, and scientific knowledge of these complex underwater environments. The development and distribution of the **Coral Reef Teacher's Guide**, an interdisciplinary curriculum for grades K-5, 6-8 and 9-12, is an important part of this effort. The information available in this guide enables teachers and students to learn about the beauty and diversity of life on the coral reef, its incredible value to people and related ecosystems, the threats that it is facing, and the possible solutions to these threats. We hope that with this knowledge you will find a deep respect, understanding, and appreciation for coral reefs, and will work to protect their health and the lives of native coastal people dependent upon them for survival.

Human-kind is not separate from Nature. We live on this Earth. We are a part of this Earth. We must be responsible for our actions. Let us put our energy into protecting the coral reefs, the oceans, and the Earth, thereby ensuring a quality of life for all.

Sincerely,



Wendy Weir

Board Member, REEF RELIEF

How to Use the Teacher's Guide

The **Coral Reef Teacher's Guide** presents interdisciplinary, hands-on curriculum for grades K-5, 6-8, and 9-12. It has been created in an interesting and informative manner to encourage students to think about the complexity of coral reefs and their surrounding environment, the threats that they are facing, and the possible solutions to these threats. The guide also presents students with different ways to take action to save the reefs, thereby instilling in them the understanding and confidence that they can improve the world in which they live.

ORGANIZATION OF THE MATERIALS

The **Teacher's Guide** is divided into three sections:

- Background Information
- Lesson Plans: K-5, 6-8, and 9-12
- Resources

All information contained in these sections may be reproduced for classroom use.

Background Information - The Background Information provides teachers of all grades with extensive information about coral reefs. It addresses three major areas:

- What and Where are the Coral Reefs?
- Life on the Coral Reef
- Benefits, Threats, and Solutions.

Each area is designed to give teachers in-depth knowledge about coral reefs so that they can effectively instruct their students and use the lesson plans.

Lesson Plans: K-5, 6-8, and 9-12 - These lesson plans have been created by master teachers for teachers, and they have been extensively field tested in the classroom. They are designed to offer challenging, fun, and creative activities which will encourage students to think about and gain a knowledge of the diversity of life on the coral reef and its interrelationship with other ecosystems and human-kind. The lessons are interdisciplinary, effectively integrating multiple subjects such as math, science, language arts, art, geography, and social science. They are also spirally integrated with each grade level building upon the previous one.

Resources - At the end of the **Teacher's Guide** is a resource section containing a glossary, bibliography, references for students, list of coral reef-related organizations, educational merchandise, and action programs. This material

supports and enhances the teacher's ability to present information about coral reefs in an efficient and thorough manner. The videos, slides, and CD-ROMs are especially effective because they provide outstanding visual images of coral reefs for those who have never seen or visited them.

ORGANIZATION OF THE LESSON PLANS

Although the lesson plans are divided into three sections, K-5, 6-8, and 9-12, they can be used interchangeably based upon the level of the students. Each lesson plan is coordinated with the material in the Background Information. At the top right-hand corner of the page is printed the section in the Background Information to which it relates. For instance, the "Edible Coral Polyp" relates to *What and Where are the Coral Reefs?,* the "Coral Reef Coloring Page" relates to *Life on the Coral Reef*, and "Unsettling Sediments" relates to *Benefits, Threats, and Solutions.*

At the beginning of the lesson plan is listed the Objective of the lesson, the Vocabulary used, the Interdisciplinary Index involved (i.e. science, art, language art), the Materials needed, the step-by-step Presentation of how to perform the activity, and the Follow-up/Extension to the activity. Some of the lesson plans also include a summary of the relevant background information needed for the lesson.

STAY IN TOUCH . . . . .

REEF RELIEF would like to remain in contact with the teachers and students who have used this **Teacher's Guide**. If you have any suggestions, comments, new information, or need assistance, please let us know.

We also enjoy receiving lesson plans that students have completed, such as coloring pages, poetry, essays, and action letters. At times, we include pictures or copies of students' work in our slide presentations and newsletters in order to give people a better understanding of how children are contributing to and making a difference in our society.

Thank you for teaching students about the beauty of life on the coral reefs, and for helping to make our Earth a better and healthier place to live. Those who learn to respect all life are the ones who work to preserve it.

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THE CORAL REEF TEACHER'S GUIDE

BACKGROUND INFORMATION

- **What and Where are the Coral Reefs?**
- **Life on the Coral Reef**
- **Benefits, Threats, and Solutions**

Lionfish. (Photo: Terry Brown)

What and Where are the Coral Reefs?

Coral reefs first formed more than 500 million years ago in warm tropical climates, and since that time they have successfully developed and supported a tremendous array of plant and animal life. Covering less than 0.2% of the ocean floor, it is estimated that coral reefs contain approximately 25% of the ocean's species. Approximately 5,000 species of reef fish have been identified, and more than 2,500 species of coral, of which almost 1,000 are reef-building hard corals. About 4,000 species of mollusks alone live on the Great Barrier Reef in Australia. This vast diversity of life has given coral reefs the name "rainforests of the sea." Rainforests, which are habitat for more than 30 million insects, have a greater number of species, however coral reefs have a larger number of **vertebrates** (animals with backbones) and more major animal groups (**phyla**). Studies have shown that the most important contributors to the mass of a living reef are calcareous red algae, green alga Halimeda, foraminifera, and hard corals.

WHAT IS CORAL?

Coral is an **invertebrate** (animal without a backbone) marine organism of the class Anthozoa (phylum Cnidaria). Members of this class are characterized by a body that only opens at one end, the mouth, and by skeletons, either internal or external, of a stonelike, horny, or leathery consistency. Some **cnidarians**, such as jellyfish, float through the water. Others, such as sea anemones and corals, attach themselves to the reef.

Basically, there are two groups of corals: **hermatypes**, or hard corals that build reefs; and **ahermatypes**, or corals (both soft and a few hard) that do not. The major difference between hard corals and soft corals is that hard corals contain **zooxanthellae** (microscopic algae) within their tissue and the soft corals do not.

The term coral is also used to describe the skeletal remains of these animals, particularly those of the hard corals which form a limestone base that becomes the foundation of the reef.

DID YOU KNOW? The **Great Barrier Reef** is the largest structure built by living organisms on Earth, and it is the only living structure visible from outer space. Located along the northeast coast of Australia, it measures 1,240 miles (2,000km) in length.

THE CORAL BODY

The body of a coral animal is called the **polyp**, a hollow sac-like structure that is smaller than a common pencil eraser. At its free end is a **mouth** surrounded by **tentacles,** and inside the body is a **stomach**. The sticky tentacles contain harpoon-like stinging structures, called **nematocysts**, that enable the polyp to gather food by paralyzing its passing prey. The tentacles then deposit the food in the mouth where it passes down into the stomach. Nutrients are absorbed from the food and any solid waste materials are passed back out through the mouth. Within the stomach are long, tubular **mesenterial filaments** that the polyp extends to defend itself from attack by other encroaching coral.

In addition, the polyps of the hard corals extract **calcium carbonate** from the sea water and use it to build a hard external **limestone skeleton** beneath and around their base which secures the fragile polyp to a surface and serves as its protection (Figure 1-1).

DID YOU KNOW? Polyps have a mouth but they don't have a head or any teeth for chewing**.**

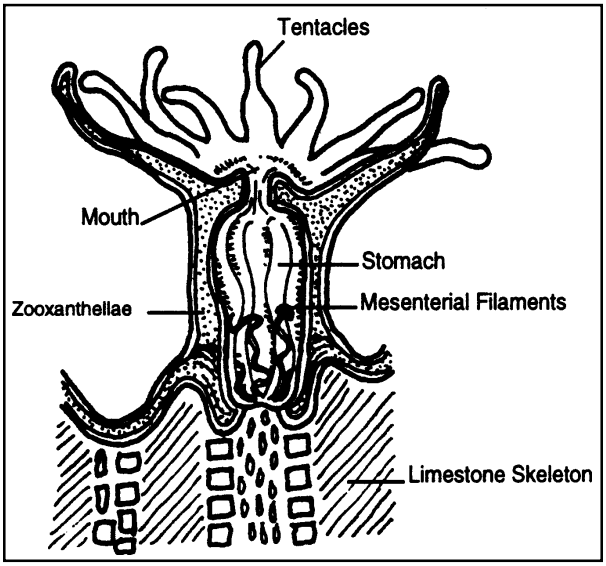


Figure 1-1. A cross-section of the coral polyp structure. (Illustration: Wendy Weir)

CORALS AND THEIR PLANT PARTNERS

Within the tissue of the polyp live many microscopic algae or plant cells called **zooxanthellae** (also called **endosymbionts**). These algal cells have a **symbiotic** (mutually beneficial) relationship with the coral.

The algae provide the polyp with food through the process of **photosynthesis** in which the plant cells use sunlight coming through the water to convert the carbon dioxide and water in the polyp tissue into oxygen and carbohydrates. The oxygen is used by the polyp for respiration and the carbohydrates are used for energy to build its limestone skeleton. In return, the polyp provides the zooxanthellae with nutrients, protection, a place to live, and carbon dioxide, a by-product of respiration which is vital for photosynthesis.

DID YOU KNOW? The color of the coral comes from the color of the zooxanthellae living in the polyp's tissue. This color can vary from white, yellow, brown, and olive to red, green, blue, and purple. The color of the coral's limestone skeleton without the zooxanthellae is white.

FOOD SOURCES

In addition to getting food internally from the zooxanthellae, some corals eat **plankton**. Plankton are creatures, both plant and animal, that move passively through the water at the mercy of wind and ocean currents. Most plankton are too small for you to see unaided.

The plant plankton are called **phytoplankton** and the animal plankton are called **zooplankton**. They acquire their nutrients and energy from a different, distant ecosystem. It is estimated that as much as 60% of the plankton on the reef are eaten by the coral polyps as they drift by.

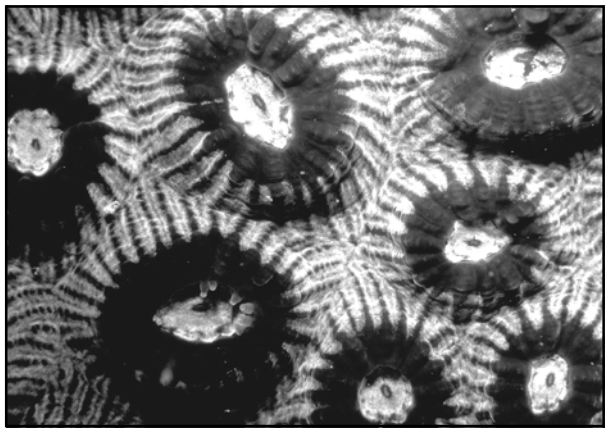
Most corals feed only at night, extending their tentacles when they are less likely to be preyed upon. During the day, the tentacles are withdrawn into the skeleton for protection (Figure 1-2).

DID YOU KNOW? Since corals are animals, those that eat only plants (phytoplankton) are called **herbivores**, and those that eat only animals (zooplankton and small fishes) are called **carnivores**.

REPRODUCTION AND GROWTH

Coral polyps reproduce both sexually (with a partner) and asexually (by themselves). **Sexual reproduction** occurs when the corals **spawn** (Figure 1-3a), releasing eggs and sperm into the water. The sperm then fertilizes the egg, creating a new individual called a **planula** or coral larva. Spawning usually occurs in mass in order to give the eggs and sperm a better chance of fertilizing themselves and surviving predators. Although most hard corals are **hermaphroditic**, containing both male and female sex cells, they sometimes fertilize the sex cells of other colonies thereby ensuring the coral's ability to maintain genetic diversity and adapt to new conditions.

(a)



(b)

Figure 1-2. (a) The coral polyp at night with extended tentacles (Photo: Jim Larson), and (b) during the day with hidden tentacles. (Photo: Terry Brown)

Once produced, the planula, which already contains zooxanthellae from the parent, floats up towards the light and drifts with the plankton from several hours up to several weeks. Those that survive then swim back down, settle on a solid, rocky surface, and develop into polyps. This is the only way in which the stationary hard corals can move to a new location. This is also how corals develop on concrete blocks, shipwrecks, and oil drilling platforms.

DID YOU KNOW? Once a year in Australia, for a few nights following the full moon in spring (October in the southern hemisphere), more than 130 species of corals along the **Great Barrier Reef** release millions and millions of eggs and sperm into the water at the same time. Reef organisms, like anemones, sea cucumbers, and the crown-of-thorns starfish, also spawn at this time.

Asexual reproduction occurs by **budding** (Figure 1-3b). The parent polyp clones itself by dividing to form a new polyp which remains attached to the parent polyp's tissue. A coral **colony** develops by the constant addition of new buds. As the new polyps grow, the old polyps beneath them die, adding their limestone skeletons to the foundation of the reef. In optimum conditions in nature, massive corals may grow up to .8 inches (2cm) a year and branching corals up to 4 inches (10cm) a year. Because of the corals' slow growth, the creation of a reef can take hundreds of years.

Coral colonies may also be attached to others of the same or different species, forming large and complex reef structures. Some of these colonies fight one another for more space and light by extending their long arms or mesenterial filaments that the polyp uses to attack and kill the other encroaching polyps. In the right conditions, new colonies can also grow from broken-off fragments of the original colony. In this way, reefs are able to regrow themselves after damage from storms, hurricanes, and cyclones.

DID YOU KNOW? In the 1970's, it was discovered that the age of a coral could be determined in the same way as a tree. By passing an X-ray through the coral, annual growth rings become visible and can be counted. Some of the corals along the Great Barrier Reef are estimated to be more than 800-1000 years old. This means that they first began growing around the time that the Battle of Hastings was fought in England (1066AD) and the first Crusade left France for Jerusalem (1096AD).

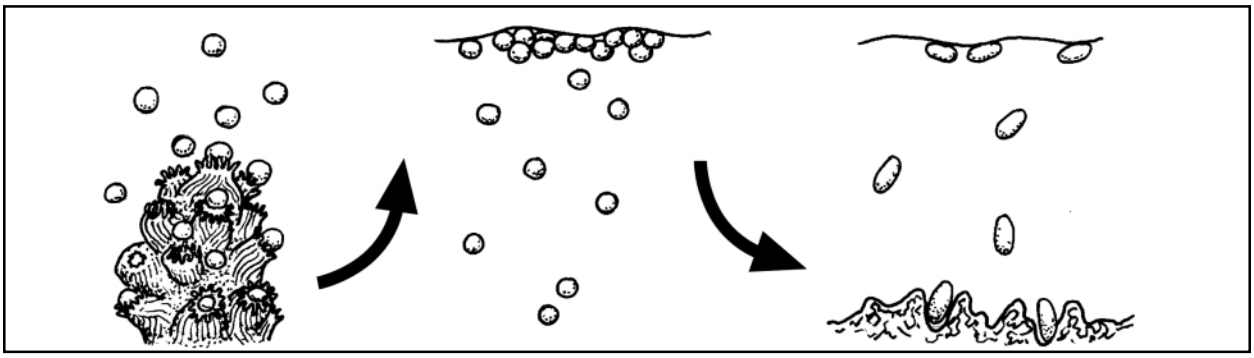


Figure 1-3 (a). Coral spawning: planula float to the surface, then swim down and settle on a solid surface to grow.

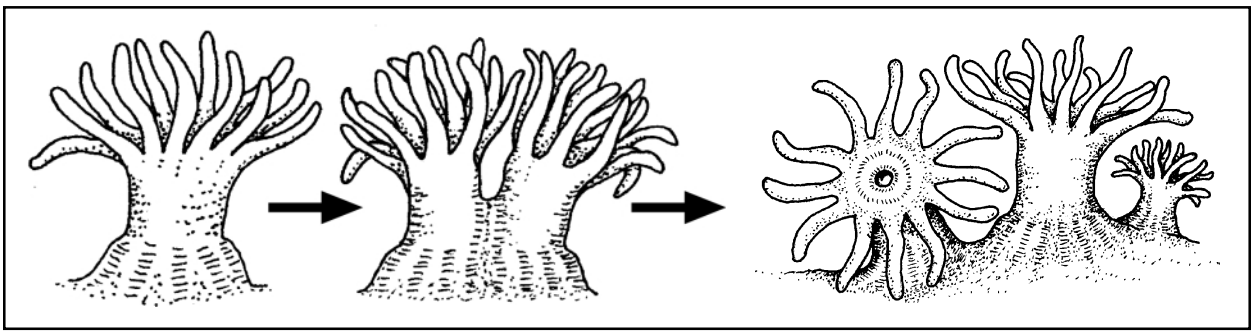


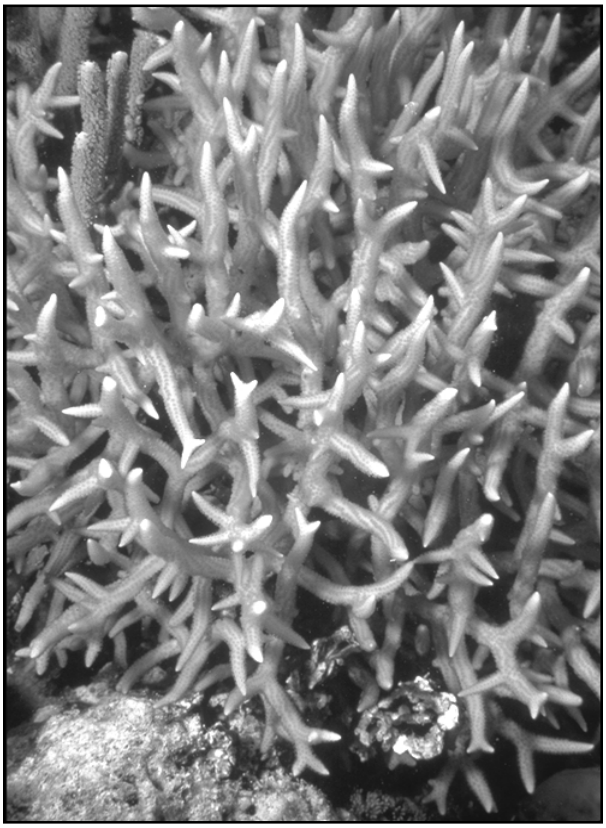
Figure 1-3 (b). Coral budding: polyps divide but remain interconnected by tissue to form a coral colony. (Illustrations: Wendy Weir)

TYPES OF CORALS

Hard Corals

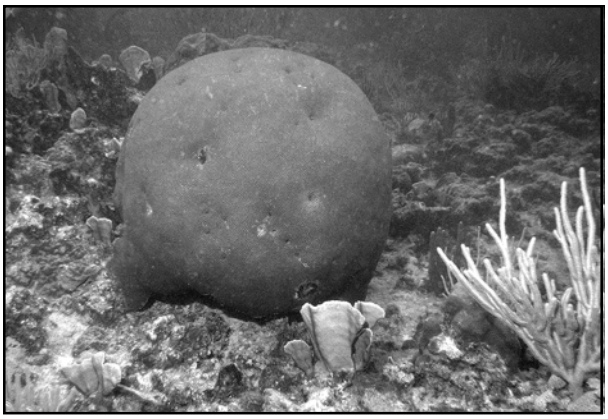
Reef-building corals, which secrete a hard external limestone skeleton, are commonly known as **hard (stony) corals**. They characteristically have tentacles in multiples of six and can be found either individually or in colonies. These hard coral colonies exhibit three basic growth forms: branching, massive, and plate (Figure 1-4).

Common types of hard corals are brain coral, mushroom coral, pillar coral, staghorn coral, and plate (or table) coral. Water movement influences the shape of the corals. Where strong waves hit the reef front, corals have thick branching, massive (boulder), or flattened shapes. Where the water is calmer and deeper, the coral branches become more delicate and some take on the shape of large thin plates to absorb a maximum amount of light for their zooxanthellae. The mushroom coral is one of the few corals that does not grow in colonies.



(a)

DID YOU KNOW? Hard corals are the most widely distributed form of coral, occurring in all oceans from the shallow tidal zone to depths of 20,000 feet (6,000m).



(b)

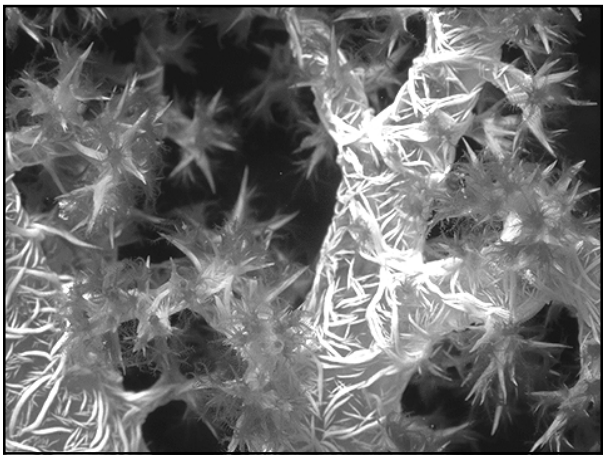
(c)

Figure 1-4. Hard coral growth forms: (a) branching (Photo: Jim Larson), (b) massive, and (c) plate. (Photos: Jim Thompson)

Soft Corals

Some types of corals secrete a flexible or soft skeleton. These are called **octocorals**, so named for their characteristic eight tentacles. Octocorals include the soft coral, sea fan, black coral, whip coral, and blue coral (Figure 1-5).

Octocorals also grow in colonies on the reef, but do not build reefs. They have branching, ribbon-like shapes and their soft internal skeleton allows them to bend, wave, sway, and spread out in the water. Some of the soft corals produce toxic compounds that make them unappetizing to predators. Soft corals thrive in strong currents where they have access to lots of plankton. They also grow well in areas where hard corals cannot grow, such as dark caves and overhangs.



(a)

(b)

Figure 1-5. (a) Soft coral, and (b) close-up of soft coral with nudibranch. (Photos: Terry Brown)

DID YOU KNOW? Coral jewelry is made from harvesting soft coral, such as black coral and whip coral. Killing coral to make jewelry and ornaments harms the reef.

LOCATION OF CORAL REEFS

Most corals thrive in shallow, clear, sunlit saltwater with a temperature between 79°F and 81°F (26°C and 27°C). If the temperature goes below 68°F (20°C) or above 84°F (29°C) for a prolonged period of time, most coral will die. The coral also needs plenty of sunlight to grow, so maximum coral growth will be found in clear water at depths of less than 30 feet (9m). However, the greatest diversity of coral can be found on reefs at a depth of 30 feet (9m) to 60 feet (18m). Below 165 feet (50m), the reef-building hard corals start to diminish, then gradually disappear.

DISTRIBUTION

Most coral reefs are located between 20°N (tropic of Cancer, 23°27') and 20°S (tropic of Capricorn, 23°27') of the equator (Figure 1-6). They are divided into three primary regions: the **Indo-Pacific**, the **Western Atlantic,** and the **Red Sea** (Figure 1-7). The Indo-Pacific region stretches from southeast Asia through Polynesia and Australia, eastward across the Indian Ocean to Africa. This is the largest and richest assemblage of reefs in terms of coral and fish species present. The Western Atlantic region stretches from Florida to Brazil, including Bermuda, the Bahamas, the Caribbean, Belize and the Gulf of Mexico. The Red Sea is the smallest of the three regions, located between Africa and Saudi Arabia. It is considered a separate region because of the high number of coral reef life found only in this area.

Based upon geographic distribution, 60% of the world's reefs are in the Indian Ocean and Red Sea, 25% are in the Pacific Ocean, and 15% in the Caribbean.

DID YOU KNOW? The reefs of the Western Atlantic region evolved later than those of the Indo-Pacific/ Red Sea region because of the youth of the Atlantic Ocean. These reefs do not have the great abundance and diversity of reef species that are found in the older Indo-Pacific/Red Sea area where the prehistoric Tethys Sea was located.

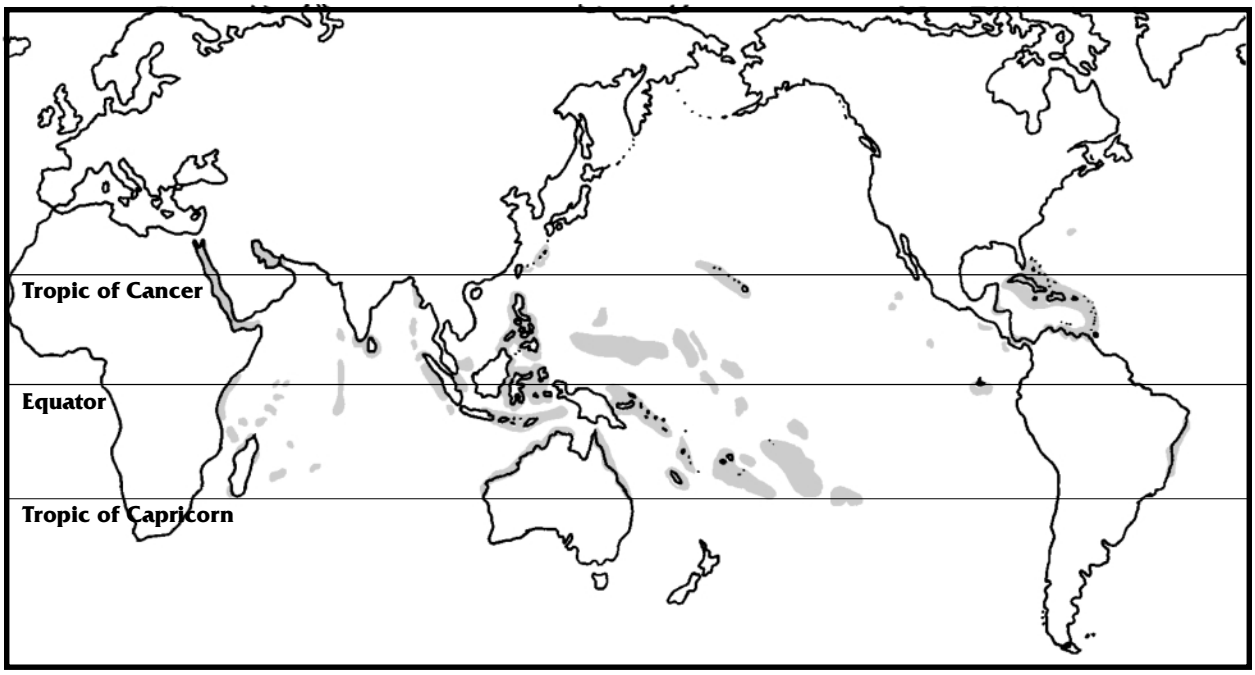


Figure 1-6. Coral reefs of the world. (Illustration: Wendy Weir)

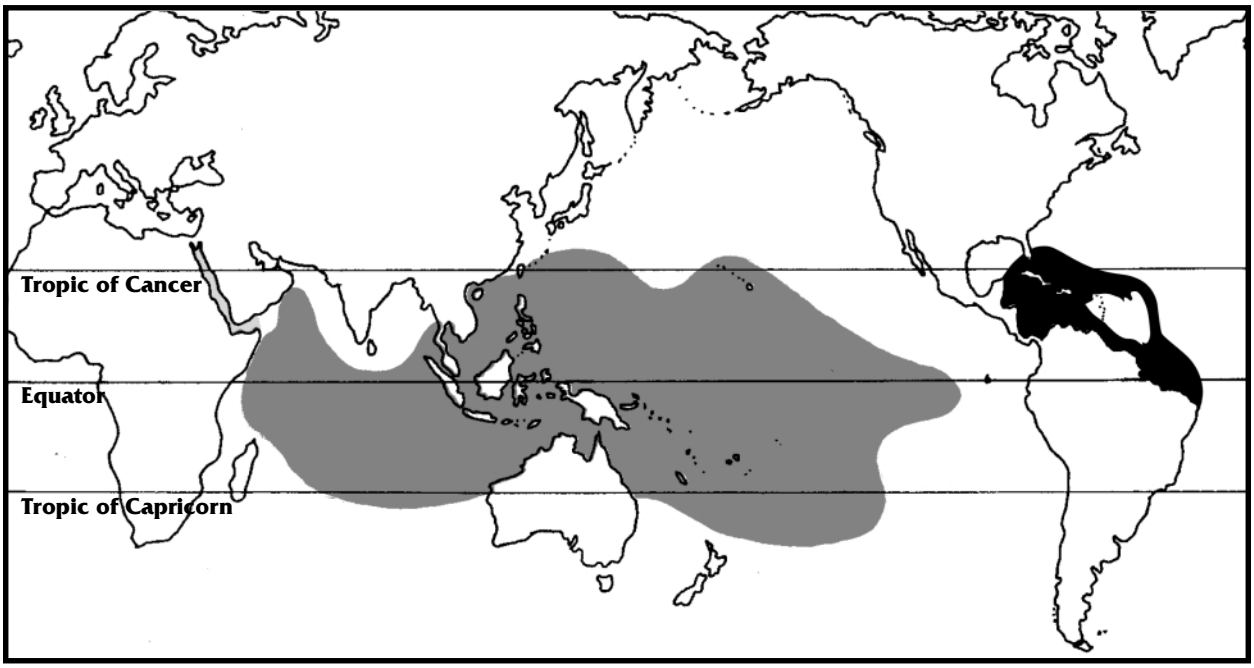


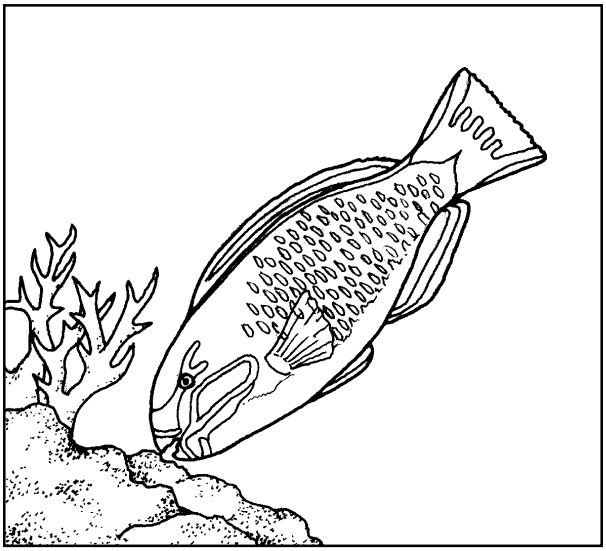
Figure 1-7. Coral reef regions of the world: Indo-Pacific (dark gray), Western Atlantic (black), and Red Sea (light gray). (Illustration: Wendy Weir)

CORAL REEF FORMATION

Today's coral reefs have accumulated during the last 10,000 years since the last glacial periods of the Pleistocene epoch. As glacial ice melted and sea levels and temperatures rose, present-day reefs began to form.

Hard corals provide the main structural framework. Other organisms, such as coralline algae and protozoans, bind and cement everything together with sheetlike growth that stabilizes the reef. Sand and sediments are created by boring organisms, such as sponges and bivalves (i.e. clams, oysters); green calcified algae (Halmedia) which has calcium carbonate plates that drop off; and, grazers, such as parrotfish and sea urchins, which attack the coral for food, extracting nutrition from the polyps, breaking down their limestone bases, and excreting the waste as sand (Figure 1-8).

DID YOU KNOW? The calcium carbonate from the sand, shells, and coral maintains the pH balance in the ocean which in turn maintains life as we know it.



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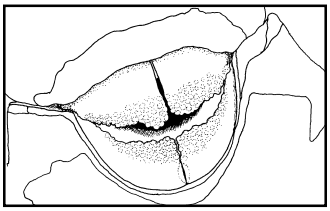


Figure 1-8. A source of sand: (a) parrotfish grazing tail-up on hard coral, and (b) close-up of the parrotfish's "beak." (Illustrations: Wendy Weir)

TYPES OF REEFS

There are three major types of coral reefs: fringing reef, barrier reef, and atoll. In tropical areas, **fringing reefs** grow directly from the shorelines of continents and islands. **Barrier reefs** are found further out, separated from the shore by a stretch of protected water, the lagoon. **Atolls** are offshore ring-like coral formations that surround a shallow, central lagoon.

Darwin's Theory of Atoll Formation: In 1842, Charles Darwin provided the theory of atoll formation which offers the most widely accepted explanation of coral reef formation today.

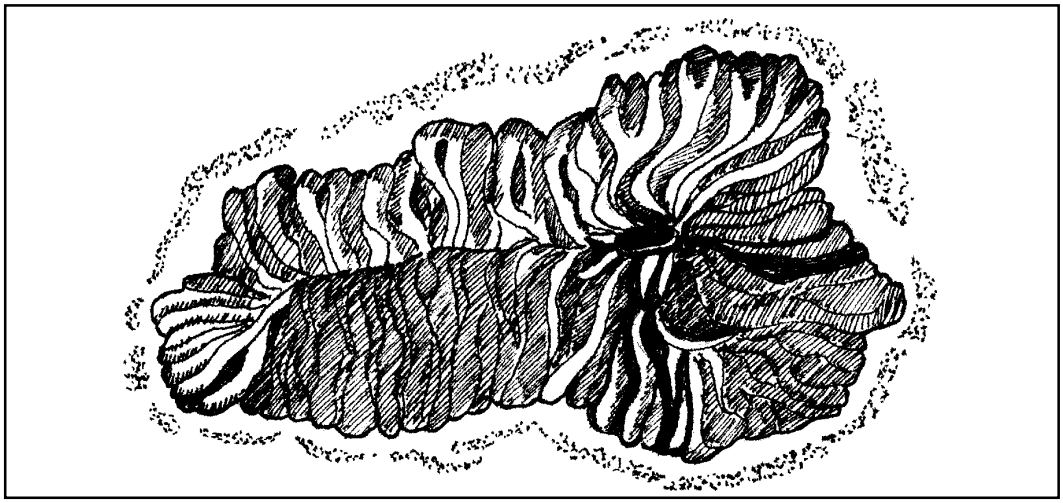
The theory is best understood in terms of reef formation on a tropical island. A tropical volcanic island furnishes the shallow underwater base on which the coral grows. Eventually, the island becomes surrounded by a fringing reef which is separated in places from the island by only a shallow, narrow strip of water (Figure 1-9a).

If the island sinks gradually into the water, then a channel develops between the land and the coral forming a barrier reef (Figure 1-9b). A similar process can occur with larger land masses due to the shifting of crustal plates. The Great Barrier Reef is the best example of this.

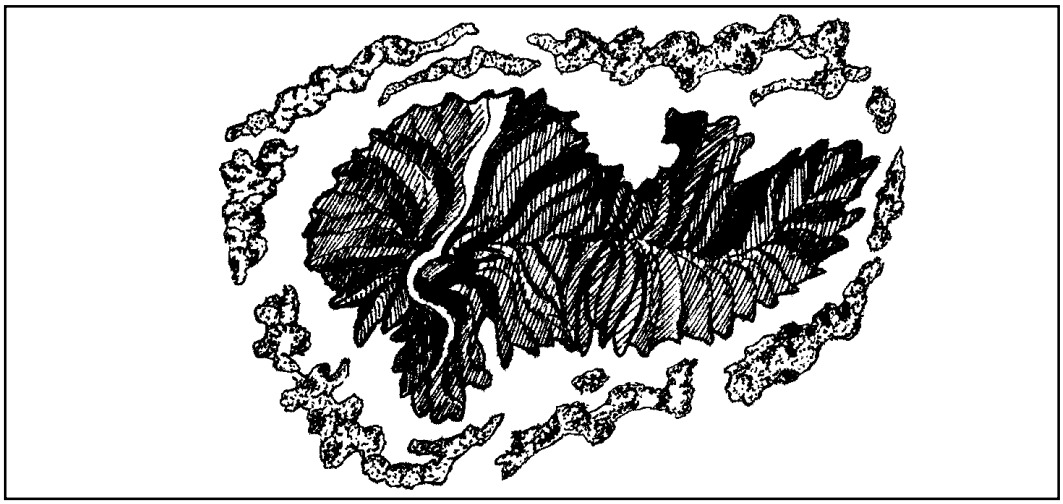
If the island continues to sink slowly enough beneath the surface of the water, coral growth is able to keep pace and the reef survives as an atoll (Figure 1-9c). Rather than being a closed ring, the atoll usually consists of numerous tiny islands separated by channels. These channels allow for water exchange between the open sea and the lagoon.

Atolls are found in deep, clear water throughout remote areas of the Indo-Pacific region. Located in the Marshall Islands in the Pacific, **Kwajalein**, the world's largest atoll, is almost 80 miles long (129km).

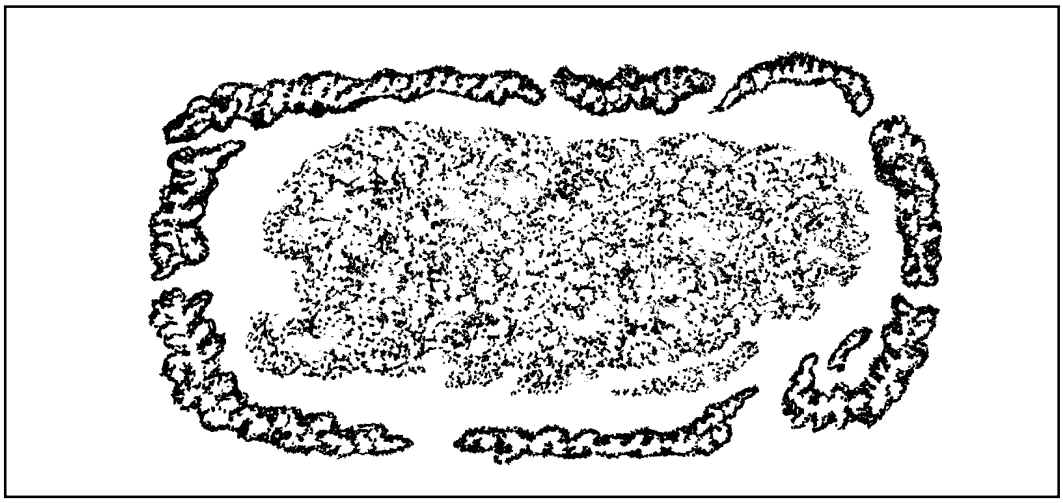
DID YOU KNOW? Darwin's theory of atoll formation was very controversial in his time. Most people did not believe that land could sink. They did not understand, as we do today, that the Earth is a dynamic mass, constantly moving and changing its form.



(a) Fringing reef



(b) Barrier reef



(c) Atoll

Figure 1-9. Types of coral reefs: (a) fringing reef, (b) barrier reef, and (c) atoll. The dotted areas represent coral. (Illustrations: George Mauro)

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-

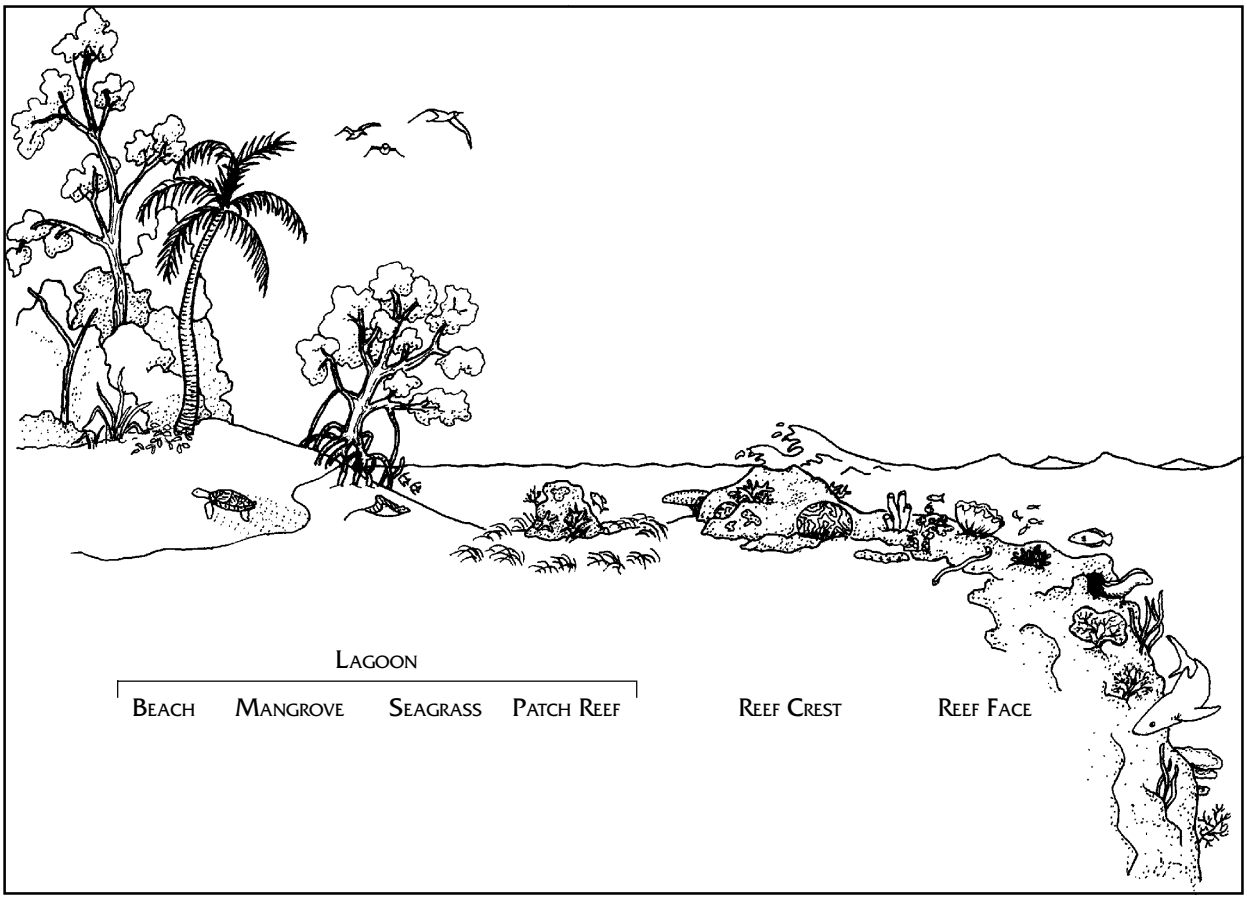


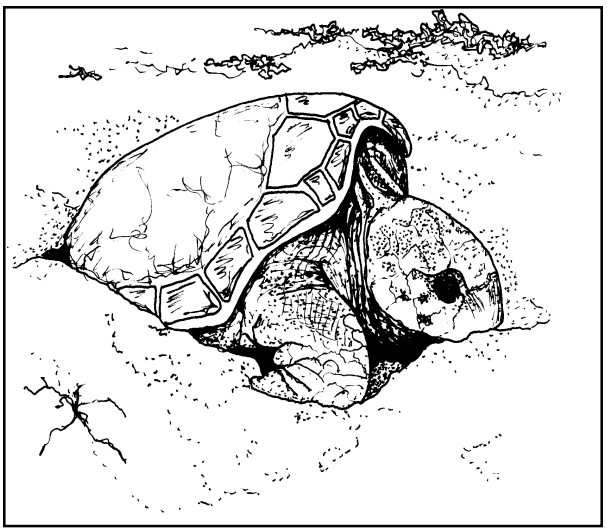
Figure 2-1. Reef zones: (a) lagoon, (b) reef crest, and (c) reef face. (Illustration: Wendy Weir)

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.



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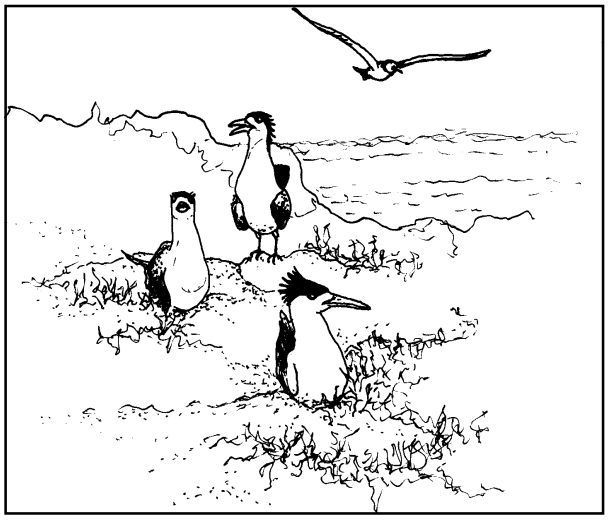


(b)

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:

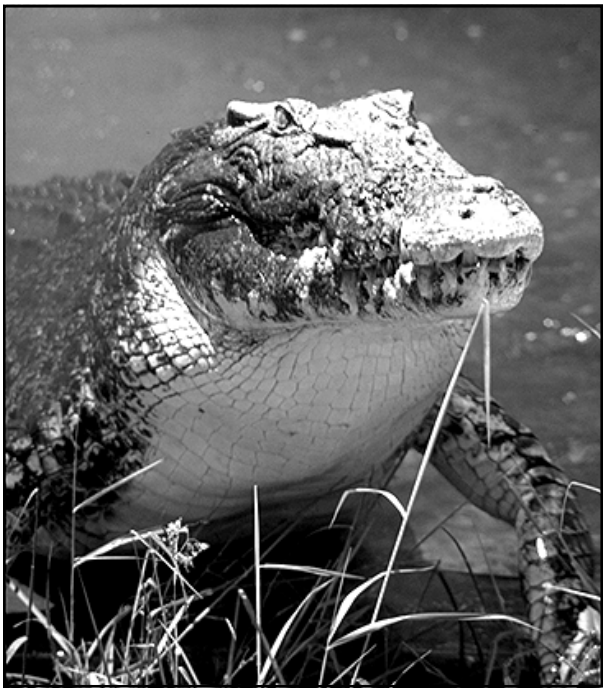
- They help in the process of claiming land from the sea and in protecting the coastline because their roots trap and consolidate sediments that would otherwise be washed back out by waves.
- Droppings from resident birds and falling plant material enrich the soil below, increasing its capacity to support 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).

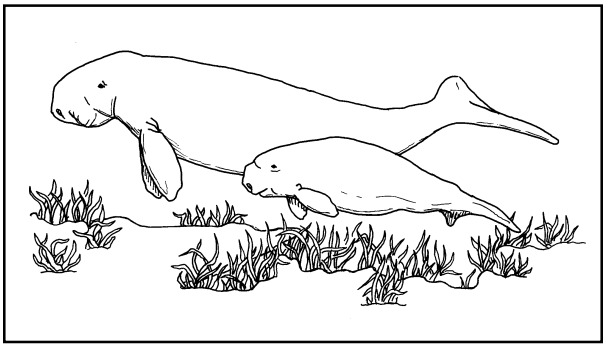
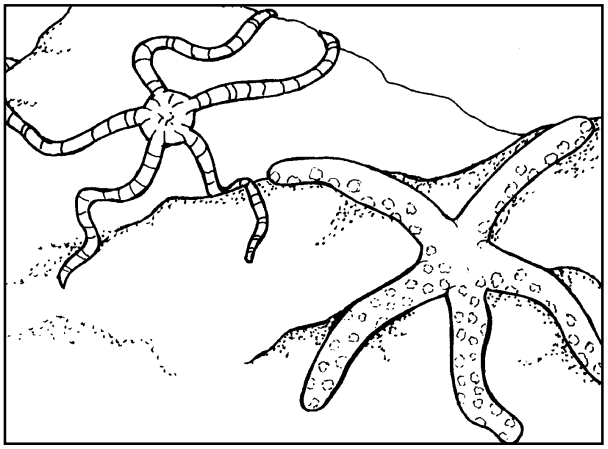


Figure 2-4. Dugong and calf grazing on seagrass. (Illustration: Wendy Weir)

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



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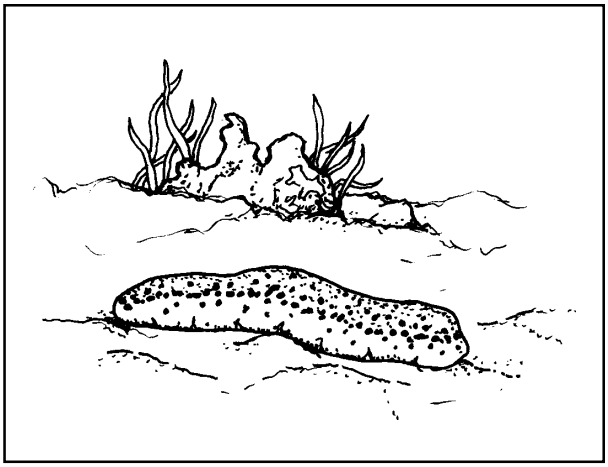


(b)

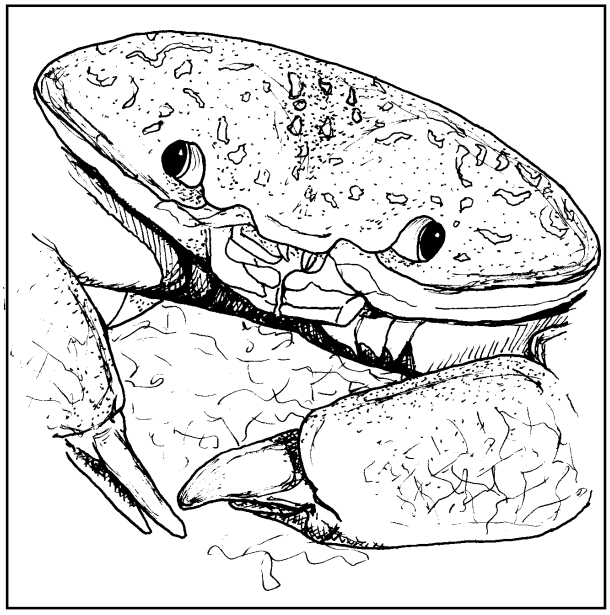
Figure 2-5. (a) Sea stars, and (b) sea cucumber. (Illustrations: Wendy Weir)

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.



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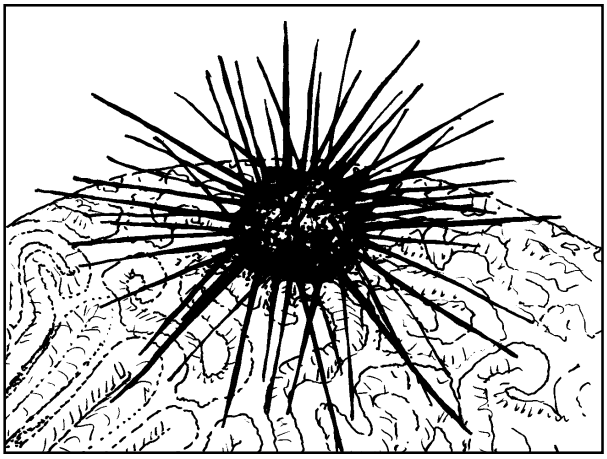


(b)

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.

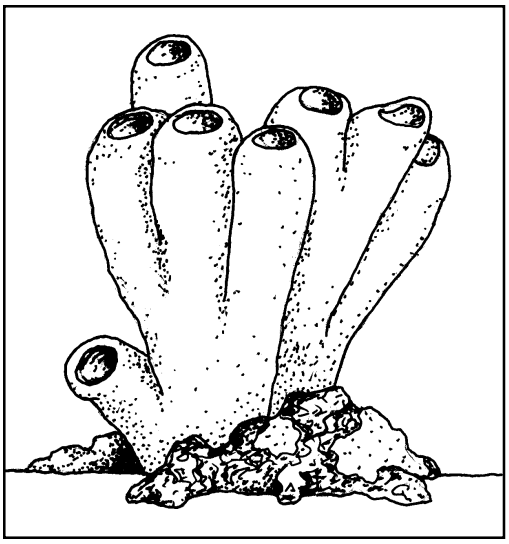


Figure 2-7. Sponge. (Illustration: Wendy Weir)

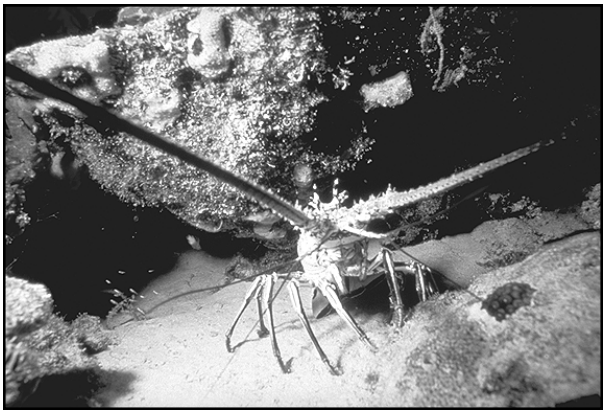


Figure 2-8. Spiny lobster. (Photo: Milton Beral)

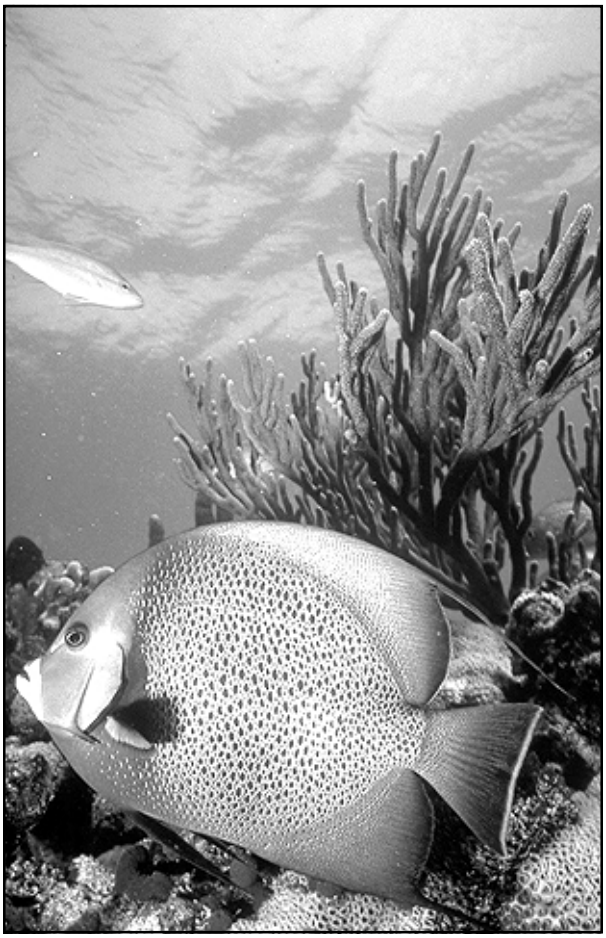


Figure 2-9. Gray angelfish. (Photo: Larry Benvenuti)

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

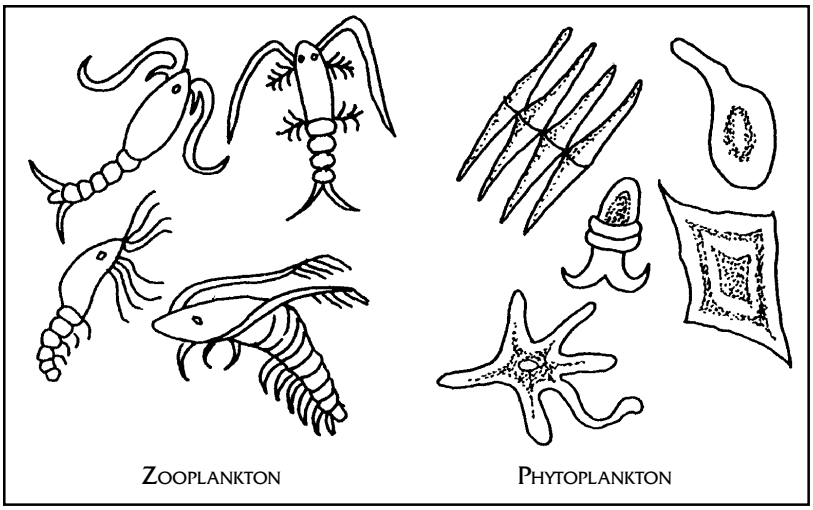


Figure 2-11. Plankton: zooplankton and phytoplankton. (Illustration: Wendy Weir)

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)

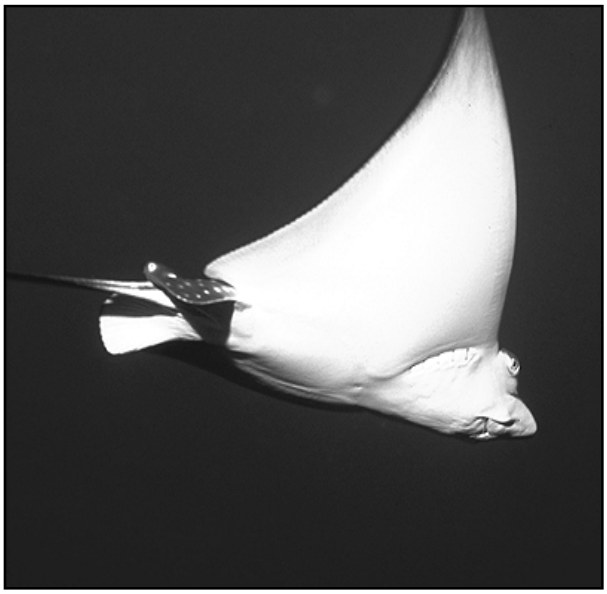


Figure 2-13. Spotted eagle ray. (Photos: Terry Brown)

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

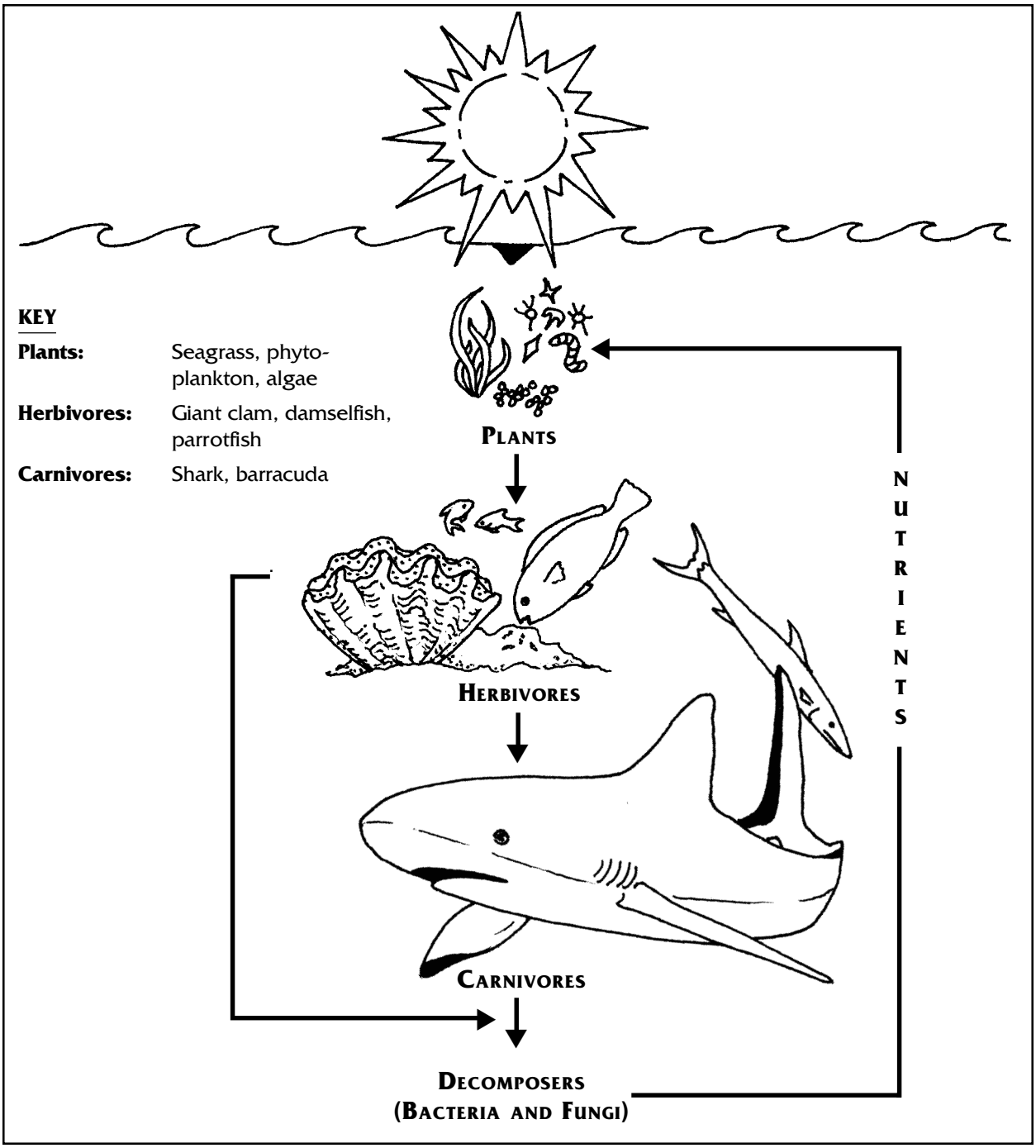


Figure 2-14. The food chain. (Illustration: Wendy Weir)

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).

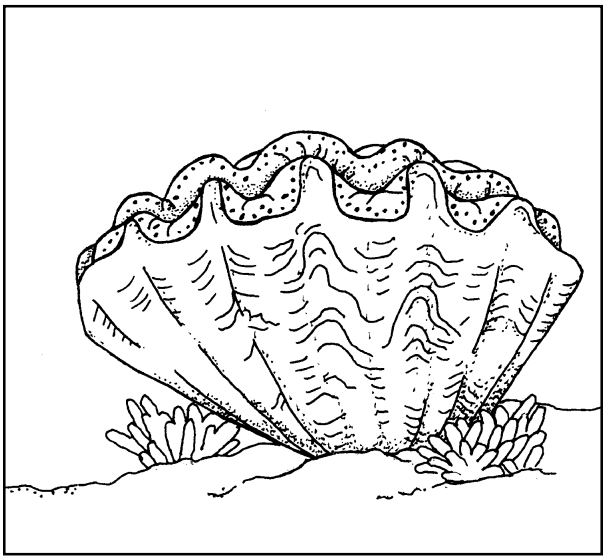
HERBIVORES

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.



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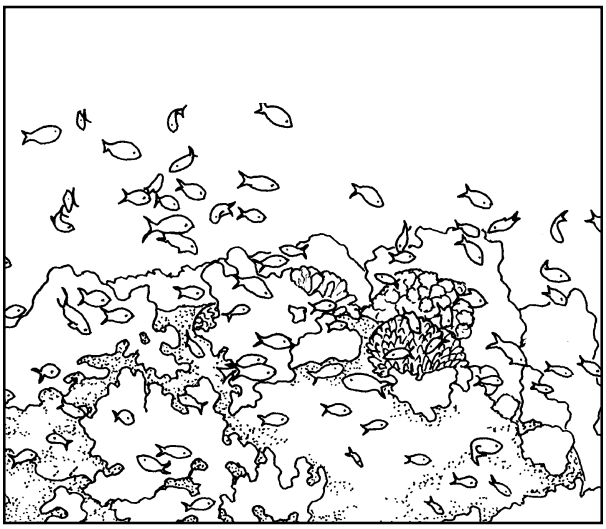


(b)

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.

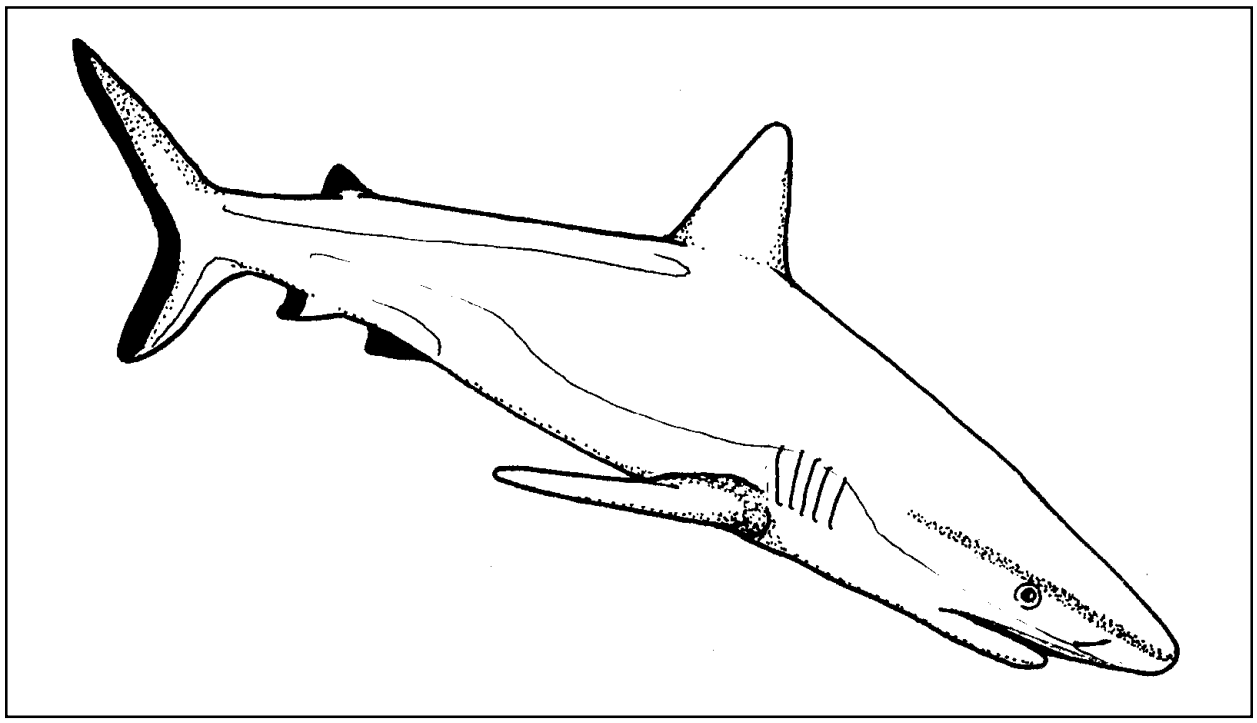


Figure 2-16. Gray reef shark. (Illustration: Wendy Weir)

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.

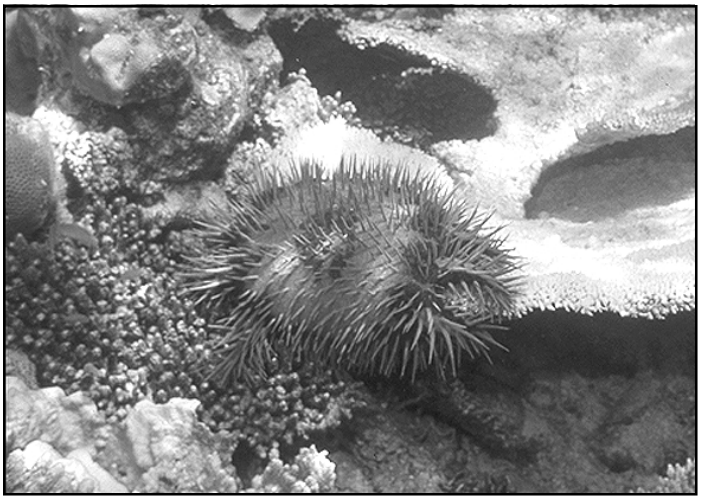
The **lionfish** (Figure 2-17a) uses camouflage to hide itself among the coral and then ambushes unsuspecting prey as it passes. Some sharks and barracuda use speed to chase down their prey. The **trumpetfish** uses stealth, hiding behind another fish or within a waving gorgonian coral in order to sneak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

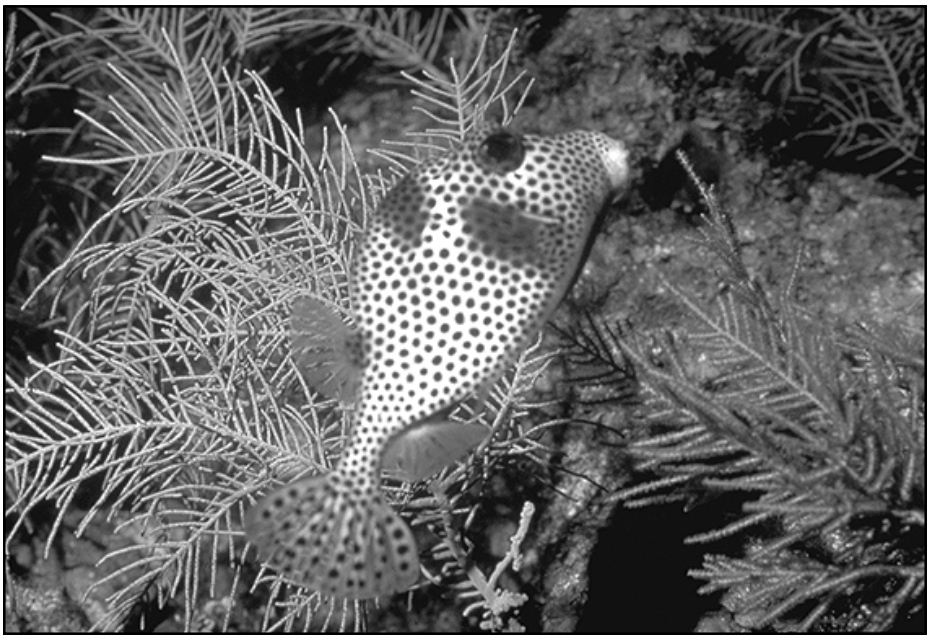
Coral reef animals use many different forms of protection. Some hide in the sand, others hide among the coral. Some swim into the lagoon and hide among the mangrove roots while others swim in schools along the reef face. Some eject poison while others inflate themselves to a much larger size. Some of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

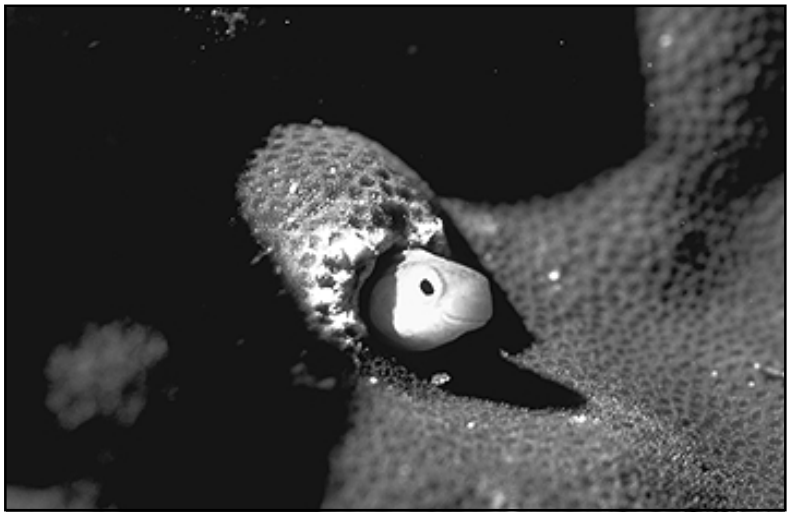
Figure 2-20. (a) Nudibranch, and (b) spotted trunkfish. (Photos: Terry Brown)

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.

Benefits, Threats, and Solutions

Benefits

THE VALUE OF CORAL REEFS

Coral reefs enrich the life of our oceans. They provide food and shelter to countless thousands of species of plants and animals, and they exchange energy and nutrients with other marine ecosystems, such as the open ocean.

But people also directly benefit from reefs in many ways. Coral reefs break waves, protecting shorelines from erosion and keeping beaches and coastal communities intact.

Healthy coral reefs supply finfish and shellfish upon which many national economies depend. Reef-dependent fisheries include subsistence (providing a protein source in coastal people's diets), commercial (providing jobs through supplying the world market demand for fish), recreational (providing jobs through fishing and tourism), and ornamental (providing jobs and income for tropical fish gatherers). The world consumption of seafood exceeds that of either pork or beef.

Tourism is also an economic mainstay for many countries with coral reefs, as people come to dive, snorkel, boat and fish. There are an estimated four million divers around the world, many of whom make more than one dive trip each year (Figure 3-1). The Florida Keys and many other coral reef areas are economically dependent upon their reefs for tourism and fishing. In the Caribbean, coastal tourism generates about US $7 billion each year.

Treatments for cancer, AIDS, infection, arthritis,

Figure 3-1. Scuba diver on Cuban reef. (Photo: Larry Benvenuti)

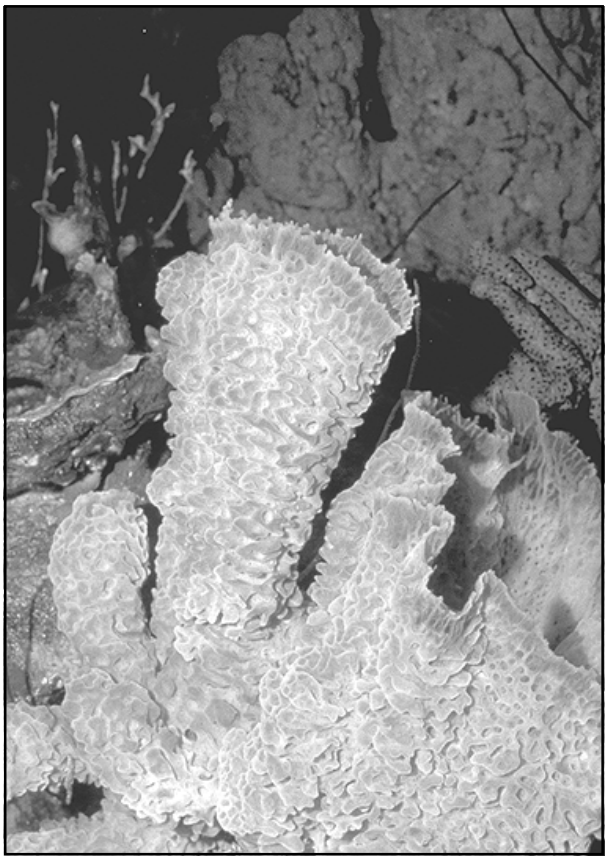


Figure 3-2. Caribbean sponges are used in the treatment of cancer and herpes simplex. (Photo: Milton Beral)

asthma, herpes, and even broken bones are being discovered in coral reef ecosystems around the world. For example, compounds derived from Caribbean sponges are being used in the treatment of cancer and herpes simplex (Figure 3-2). Compounds from sea squirts have been useful in treating tumors, viruses, and immune-related illnesses. Hard corals are being used to replace shattered bones as the human body more readily accepts coral than artificial replacements.

Many commercial products are also derived from coral reefs. Calcium carbonate from the skeletons of coral animals is used to produce lime which when added to mortar and cement helps it set more quickly. The internal shell of the cuttlefish, called cuttlebone, is sold in pet stores to cut calcium deficiency in the diet of pet birds. Chitin, derived from the shells of shellfish, crabs, lobster, and shrimp, is a component of chitosan, which is used in violin varnish to make it dry hard to provide good tone.

Much can be learned from reefs about historical conditions in the marine environment. Annual growth bands, elemental ratios, and isotopic signatures can be used to infer past sea levels, growing conditions, the effects of environmental management and other important phenomena.

The beautiful sand that makes up the beaches of tropical islands is another benefit from coral reefs, formed by the breakdown of dead corals and algae by reef life.

Like rainforests, wetlands and savannas, coral reef ecosystems are integral parts of a healthy environment for all of the Earth's living creatures, including people.

Threats

Corals are highly sensitive to environmental conditions. They grow best in shallow, clear water between 68˚F and 84˚F (20˚C and 29˚C) with normal oceanic salinity. Both natural and human-caused (**anthropogenic**) disasters threaten coral reefs worldwide.

In 1997, the International Year of the Reef, it was recognized that corals around the world are threatened:

- In the Philippines, about 70% of the coral reefs have been degraded seriously and only about 5% are thought to be in good condition;
- In Jakarta Bay, Indonesia, human activities have caused the average coral coverage to diminish from 30% to 5% between 1985 and 1995;
- In Jamaica, where the coral coverage was 50% to 70%, overfishing has accounted for a decline of coral coverage to just 5%;
- In the Florida Keys, coral diseases, massive algal blooms, and a precipitous drop in water visibility on the world's 3rd largest barrier reef reflects the damage from agricultural runoff from Florida Bay and inadequate sewage treatment throughout the Keys.
- Conservative estimates indicate that up to 10% of the Earth's coral reefs are already seriously degraded and a much larger percentage is threatened by the impact of human activities;
- At the current rate of destruction,estimates indicate that 40% of the world's reefs could be destroyed by the year 2020.

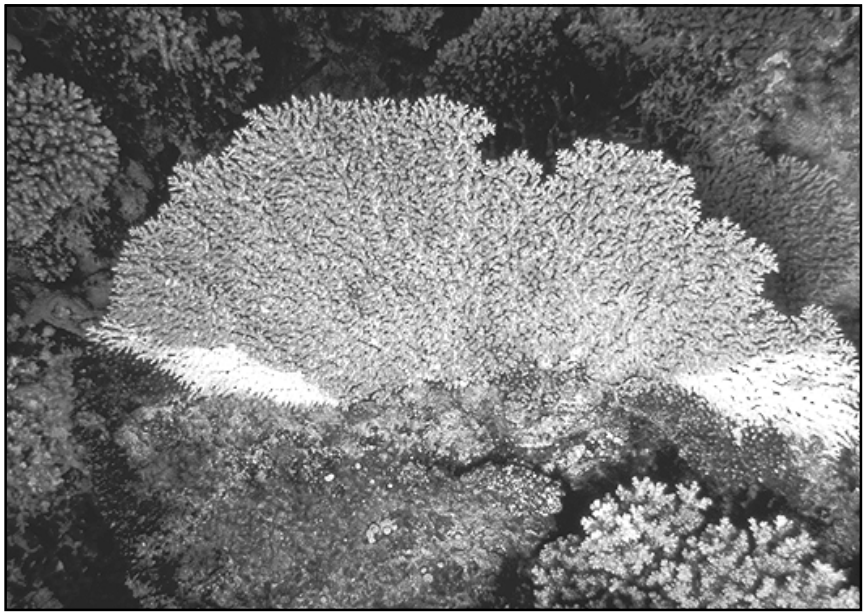


Figure 3-3. White band disease at the bottom of a plate coral. (Photo: Jim Thompson)

While natural impacts such as hurricanes and population

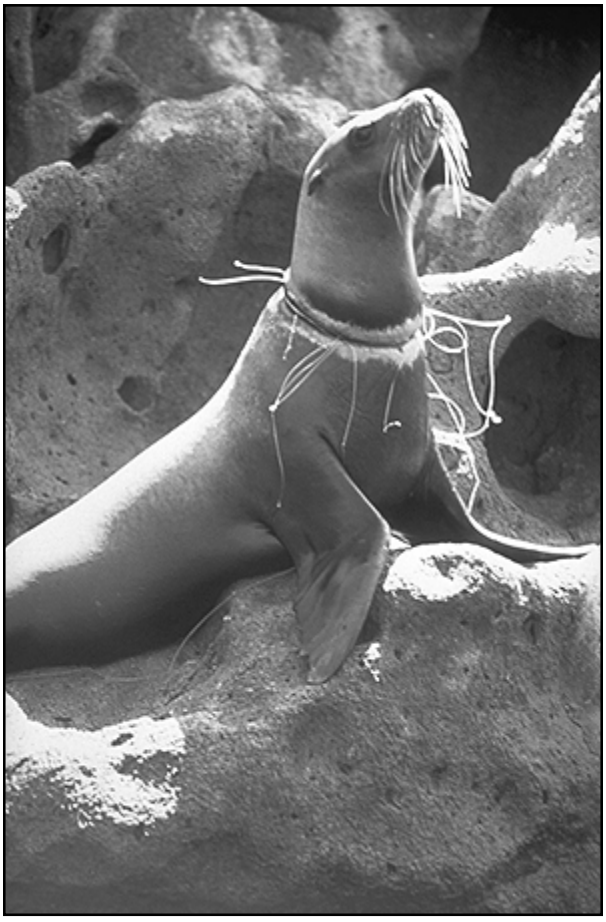


Figure 3-4. California sea lion entangled in fishing net, Sea of Cortez, Mexico. (Photo: Hal Beral)

fluctuations of predators play a role in the degradation of coral reefs, it is becoming increasingly clear that human activities are having the most catastrophic effects on these fragile marine ecosystems. We all know that human population growth is the single greatest threat to global environmental health, but the problem has pointed significance for coastal regions. In 2025 three quarters of the world's population will be living within 50 miles of the world's oceans, seas and lakes.

Natural Threats

Natural threats to coral reefs include **sea level changes, hurricanes, cyclones, abnormal weather patterns, fluctuations in seawater temperatures, heavy rains** that dilute salinity, **extreme low tides** that expose coral, **disease**, and **predator population explosions**, such as crown-of-thorns sea stars. Reefs can sometimes recover from these seemingly disastrous attacks if human-caused stresses do not impede their recuperation process.

Human-Caused Threats

The human impact on the world's coral reefs are widespread and reaching catastrophic proportions. Some scientists believe that the effect of coral reef destruction on global biodiversity is of the same magnitude as that of the destruction of rainforests. Indeed, coral reefs are often referred to as the "rainforests of the sea" because they are the most biologically diverse marine ecosystem.

The most destructive human impacts on coral reefs include overharvesting of fish; destructive fishing practices (cyanide and dynamite fishing); nutrients and pesticides draining onto the reefs from agricultural areas upstream; tourists who unwittingly damage reefs, boat anchors dropped onto fragile corals; raw sewage from coastal areas with insufficient treatment capacity; coral mining for construction materials; sedimentation from deforestation, road construction and dams; and oil pollution from shipping.

• Global Warming and the Greenhouse Effect

Greenhouse gases (carbon dioxide, methane, nitrous oxide and chlorofluoro-carbons) are accumulating in the atmosphere, trapping the heat from the sun and causing the Earth's atmosphere to become abnormally warm. These gases are increasing as people burn more fossil fuels for energy and cut down carbon-dioxide absorbing forests. The resulting increase in sea temperatures, sea levels, and violent storms negatively affect corals. The weakened coral then becomes more susceptible to disease (Figure 3-3). One of these effects, **coral bleaching**, results when the coral is stressed, as when the water temperature becomes too warm for the coral polyps to survive. When the polyps die, the coral loses its color and becomes white.

• Harmful Fishing Practices

Coral reefs provide habitat for marine life, such as fish, turtles, octopus, bivalves (mussels, clams), gastropods (snails, conchs), spiny lobster, shrimp, echinoderms (sea cucumbers, urchins). These are sources of food and income for many coastal people, as well as large commercial fishing operators. Around the world, more

and more fisheries are collapsing (species of fish are disappearing from many areas) due to damaging fishing techniques and overfishing (more fish being harvested than the area can reproduce).

In many places, traditional fishing methods have been replaced with super-efficient modern technologies, often with damaging long-term effects. The introduction of motorized boats and SCUBA gear, such as masks and fins, has increased the catch, often to unsustainable levels. Biodegradable traps and nets woven from vegetable fiber or coconut fronds have been replaced with non-biodegradable nylon, metal and wire. When lost they often become dangerous: entangling and injuring or killing marine life (Figure 3-4), breaking corals, or continuing to catch fish that will never be collected.

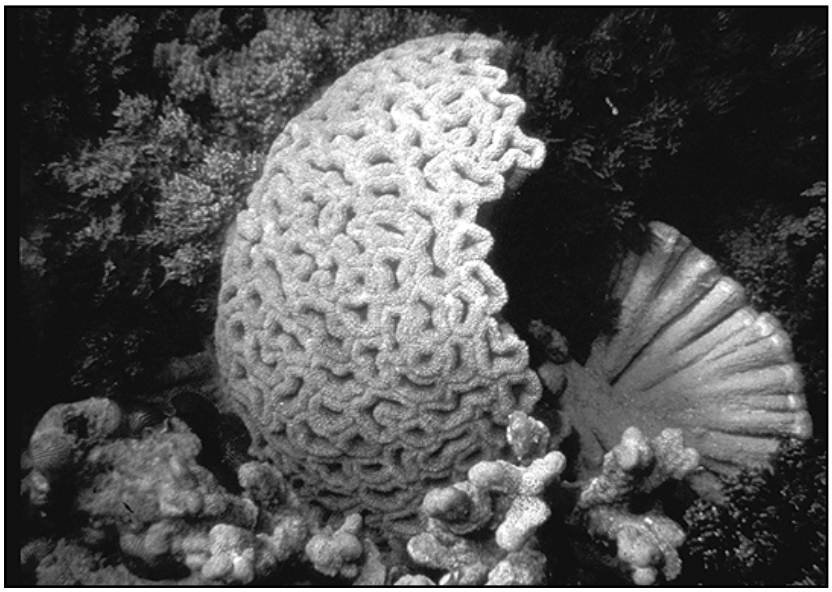


Figure 3-5. Massive coral broken in half by boat anchor. (Photo: Jim Thompson)

Cyanide poison is used by fishers in Indonesia, the Philippines, and other island nations to stun fish, making them easier to catch. **Chlorine bleach** and **quinaldine** are used in the United States. Hunting for food or aquarium fish, the fishers shoot the chemical solutions at reef fish or into coral enclaves where they live. The poisonous residue kills coral, invertebrates, and other fish.

Fishers in the Pacific and southeast Asia often blast reefs with **dynamite** or other explosives that rupture fishes' air bladders so they can scoop them up as they float to the surface. The explosions destroy reef formations, kill non-target fish (by-catch), and often kill or maim the fishers themselves.

Some fishers also use **'Muro-Ami'**, which is the name of the net that fish are driven into when hundreds of boys pound on the coral and wave white plastic streamers. Again, this technique damages the coral and results in huge quantities of by-catch.

- **Mariculture**

Mariculture, the farming of marine plants and animals, is becoming more popular in the tropics, often in response to the loss of wild stocks. Giant clams, fish, conch, seaweed and shrimp are among the many farmed species. Unfortunately, while mariculture provides a means of employment and reduces pressure on overexploited stocks, it can have a negative impact on the reef. In many areas, entire mangrove forests have been bulldozed to make shallow ponds for these farms, eliminating juvenile fish nurseries and habitat for marine birds and animals. In addition, these farms siphon already short fresh water supplies, poison the water with chemicals and antibiotics, and cause a decrease in wild fish populations. Ultimately, the coastal people are left with little protein source since they are unable to afford the mariculture product.

- **Damage from Boats**

In areas that are popular with recreational, diving or fishing boats, the reef is subject to damage from accidents and carelessness. Anchors tossed on coral break the fragile animals (Figure 3-5), and the chains drag a swath of destruction around them. Boats and ships that run aground on the reef can destroy hundreds of corals in an instant. Propellers churn up sediments that smother the reef. Boat bilges and toilets are discharged, dumping an overload of algae-causing nutrients into the water. Some cruise ships and recreational boats have been documented dumping their trash overboard, despite laws against ocean dumping.

Figure 3-6. Abandoned oil drums and tractor tires from coastal construction project leach poisons. (Photo: Christopher McLeod)

• Damage from Divers

Although recreational divers are often the greatest advocates for protection of coral reefs, careless diving can present a hazard to the ecosystem. Popular dive spots often attract more visitors than is healthy for the area. Lack of mooring buoys can result in damage from anchors. Unscrupulous dive charters may use food to lure fish toward their customers, disrupting their normal feeding and behavior patterns. Divers and snorkelers who take souvenirs, touch coral, let their fins and other equipment bash into it, or even kick up excess sediments contribute to the demise of the very reef they came to enjoy.

• Coral Mining

Coral mining is a problem in countries with few resources for construction. Iron bars are used to dismantle entire sections of reef to build roads, walls, homes and office buildings.

• Pollution

After it rains, storm water runoff carries trash, oils, chemicals, and other undesirables from the land into the sea. Fertilizer, pesticides, and herbicides from agriculture also wash out of fields into streams and into the ocean. **Chemicals**, such as chlorine-based cleaning solutions, PCB's and DDT, heavy metals, and minerals from mining and other industrial pollution are known to be poisonous to marine animals (Figure 3-6).

Deforestation and **development** can damage coral reefs offshore, smothered by loosened soils washed by rain into rivers and out to sea. Insufficiently treated or raw sewage introduces excess nutrients on the reef, covering corals with algae.

Warm water discharges from power plants cause corals to bleach. Large sections of reef off Guam and Taiwan have been destroyed by this **thermal pollution.**

Corals are vulnerable to **oil pollution** caused by spills, leaks in tanks or pipelines, ships flushing their tanks

and bilges, offshore oil exploration and land-based sources, such as refineries and gas stations.

Trash from fishing vessels, cruise ships, recreational boaters, ocean dumping and beach visitors inflicts damage on beaches, reefs, and marine animals. Some turtles and seabirds often make the deadly mistake of eating plastic bags and debris because it resembles one of their favorite foods, jellyfish. Every year many marine animals and fish are entangled in nylon fishing nets, six-pack rings and other garbage.

Radioactive pollution, including nuclear bombs, accidents and leaks at nuclear power plants, and nuclear testing, whether atmospheric, underground or underwater, all are known to kill a wide range of reef life.

Dredging to clear channels for shipping, marinas, and ports, or to mine coral rock or sand causes excess silt to contaminate the water. Corals can be damaged by artificially created channels, as they trigger changes in water circulation, tidal flow, and water levels.

Figure 3-7. Coral curios in a gift store. (Photo: Jim Thompson)

- **Coral Harvesting**

Coral is also harvested to make jewelry, gift store curios (Figure 3-7), coffee table knick-knacks, and aquarium habitat. Under optimum conditions, many corals take 37 years to regenerate.

THREATS TO CORAL REEFS IN THE UNITED STATES

In the United States, coral reefs in Florida, Texas, Hawaii, and the U.S. territories of Guam, Puerto Rico, and the U.S. Virgin Islands are threatened by development, sewage, and other problems resulting from too many people too close to a living coral reef.

Florida

In 2003, over 4 million visitors came to the Florida Keys, home to the world's 3rd longest coral barrier reef, which is now protected through creation of the Florida Keys National Marine Sanctuary. This is the most visited coral reef in the world and home to the largest charterboat fleet. It is said, *We are literally loving our reefs to death.*

Visitors can have a negative impact on the coral reef ecosystem in many ways. Careless snorkelers and divers touch, stand or drag equipment over fragile living coral formations, opening them up to infection or nuisance algae that can lead to the loss of an entire coralhead. Any physical contact with coral can crush the fragile coral polyp that lives encased within the calcareous exoskeleton that provides the foundation for coral growth. Divers who feed the fish upset their natural feeding habits, and harvesting marinelife and corals depletes the reef.

Overfishing has led to the creation of restricted species laws governing conch, jewfish, and lobster. Most commercially-harvested fish and marine life are subject to bag-and-take limits. No fishing zones have been established at sixteen heavily-visited reefs in the Florida Keys. Spearfishing is still allowed elsewhere in the sanctuary, although it has led to the depletion of certain species such as the slow-moving jewfish.

Massive development of the Florida Keys is having measurable impacts on the coral reef, the third longest

barrier reef in the world (Figure 3-8). Inadequate sewage treatment from illegal cesspits, shallow injection wells, leaky septic systems and municipal sewage treatment plants that lack nutrient removal release tons of harmful nutrients into the porous limestone substrata of the Keys. Studies have documented that this effluent quickly migrates into nearshore waters.

Petroleum products from boats cause water pollution. Boaters sometimes ground on the reefs, tear up seagrasses in shallow areas with boat propellers, kick up sediment, break corals with anchors (Figure 3-9), and litter the reef with plastic, aluminum cans, fishing gear and other debris that tears, abrades, and smothers the reef.

Agricultural run-off from Florida Bay and the Everglades is even more damaging, since a campaign to increase water flowing into Florida Bay has resulted in tons of nutrients, pesticides and mercury reaching the downstream coral reefs of the Florida Keys. In 1996, over 900 tons of nutrients reached Keys reefs from direct discharges into Florida Bay compared to 35 - 40 tons from domestic wastewater. Agricultural runoff from sugarcane and other agricultural products in South Florida, along with the need to drain former wetlands for urban sprawl, have polluted Florida Bay creating a "dead zone". Litigation has produced a court order that "the polluter must pay."

The traditionally crystal-clear waters of the Florida Keys have become murky and green. Visibility has dropped from over 100 feet to an average of 30 - 40 feet at the reef. Coral diseases, many of them first observed as part of the Reef Relief Photo Monitoring Survey, have increased dramatically along with macroalgal blooms and coral bleaching. Corals require clear, clean, nutrient-free waters to thrive. Only swift action to clean up the pollution will save these coral reefs. Hopefully, the Water Quality Protection Program of the Florida Keys National Marine Sanctuary; in concert with local, state, and other federal agencies, will heed the call issued by Reef Relief that these coral reefs are truly endangered.

Nearby is Biscayne National Park, just north of the Florida Keys and 24 kilometers south of Miami, containing the waters of Southern Biscayne Bay. It is home to numerous patch and bank reefs which are managed with some success by the National Park System, largely because of their undiscovered nature and limits to commercial access imposed by the park system.

Figure 3-8. Marathon Airport in the Florida Keys. (Photo: Larry Benvenuti)

Texas

The Texas Flower Garden Banks National Marine Sanctuary was established in an area of the Northwestern Gulf of Mexico where the clear, warm oceanic water makes possible coral reef development. The sanctuary is located over 200 kilometers southwest of Galveston and features reefs 100 - 200 meters deep, cresting at 20 meters deep. The bank reefs are the most complete and complex coral communities in the Gulf, although coral diversity is low compared to other reefs in Florida and the Caribbean. Oil and gas drilling operations in the area have modified their operations to eliminate any discharge into the marine environment and abandoned rigs are now the site for healthy artificial reefs.

Hawaii

Like elsewhere, coral reefs in Hawaii face problems resulting from human pollution. In Kaneohe Bay, Oahu, macro algal blooms from inadequate sewage

treatment have produced large mats of nuisance algae that has smothered many corals. Fast growing algal blooms out-compete slow growing corals for habitat. Extending the sewer line beyond the harbor has improved the situation, however our oceans should not be used as dumping grounds for storm drainage, sewage, or garbage.

For many years, beaches in Hawaii have been developed as resorts. This development, along with historical pineapple agriculture, has altered many of the shorelines. Airports have been built adjacent to the reefs. The construction of hotels, golf courses, ports, and marinas has resulted in the dredging and destruction of seagrass beds, mangrove forests, and coral reefs. Golf courses require tremendous amounts of irrigation water, herbicides, pesticides and fertilizers which often leach into the seawater damaging the coral reef ecosystem. The creation of the Hawaii Islands Humpback Whale National Marine Sanctuary in Hawaii has resulted in a management plan to help address these impacts.

Guam

In Guam, military defense activities both during World War I and II and military testing thereafter have damaged many of the coral reefs. Development of the island has added to this damage and now a growing tourism economy is creating additional coastal development that is negatively impacting all of Guam's marine ecosystems even further. The extent of living coral reefs in Guam are now very limited.

Puerto Rico

Puerto Rico is working to address the many human impacts to its coral reefs with efforts to create marine protected areas, increase educational efforts, and restrict further development. Relatively healthy coral reefs can be found at Culebra, Culebrita, Mona Island and Parguera. Many other areas of the coast that have been developed have lost the benefits of mangroves resulting in massive siltation and erosion. In addition, industrial development, particularly of pharmaceuticals, has resulted in severe pollution discharges

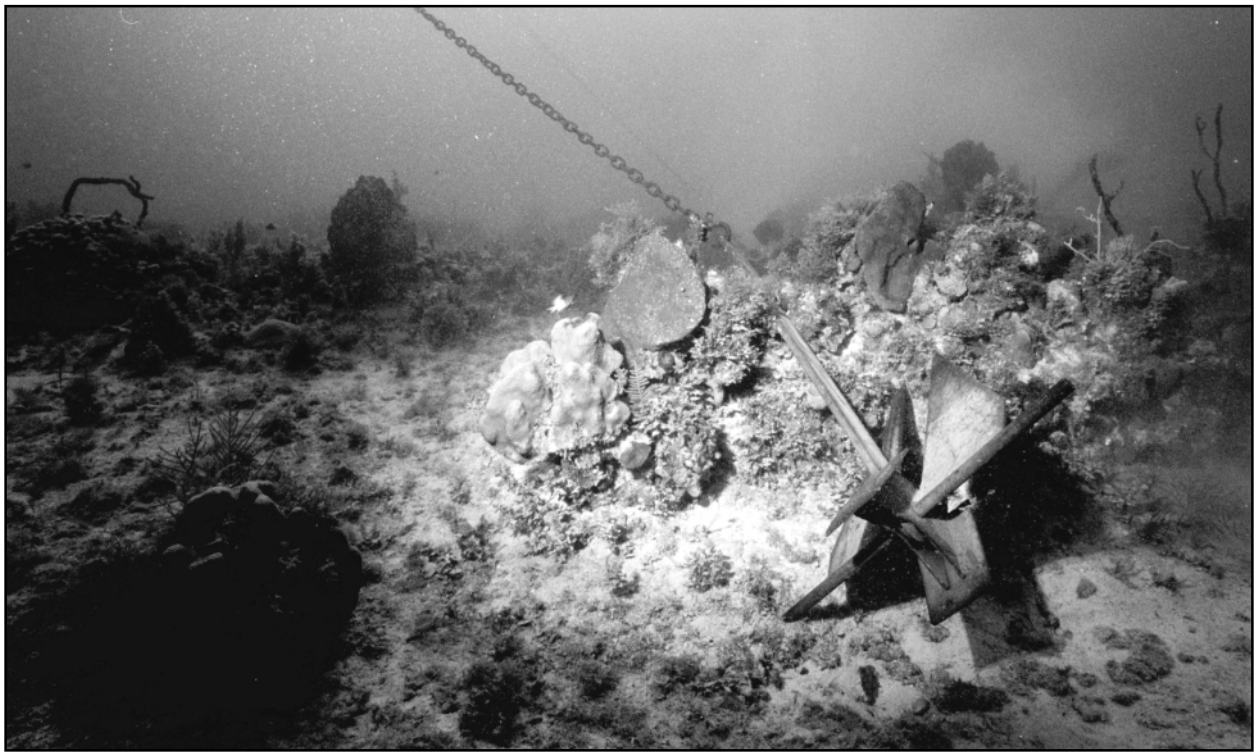


Figure 3-9. Before the widespread application of reef mooring buoy technology, first designed by John Halas and Harold Hudson of the Florida Keys National Marine Sanctuary, anchors were the accepted way of securing a boat above a coral reef. Unfortunately, anchors can tear, crush, and drag fragile corals. (Photo: Craig Quirolo)

from industrialized ports around the island.

U.S. Virgin Islands

The U.S. Virgin Islands has long attracted numerous visitors to the Virgin Island National Park who enjoy the diving and fishing of protected areas. However, these coral reefs, too, are showing the stress of high use, despite management strategies that include installation of reef mooring buoys, education, and no-take zones.

Solutions

EDUCATION AND ACTION

People have lived along the coast in tropical areas since prehistoric times, and they have been dependent upon the coral reefs as a vital part of their existence. Initially, they used the reefs as a source of food, tools, ornament, and building materials. These activities had little impact on the reef ecosystem or the adjacent land because they lived in balance with their surroundings. Only recently have people begun to over-exploit the reef and coastal areas, severely threatening the health and survival of this ecosystem.

In order to preserve coral reefs around the world, it is important that we understand the incredible part that they play in the balance of our Earth's ecosystem and in the diversity of life that they contribute to our existence and evolution. With understanding comes respect, with respect comes a desire to protect, with a desire to protect comes action.

Education and action are integral components of REEF RELIEF's efforts to preserve and protect living coral

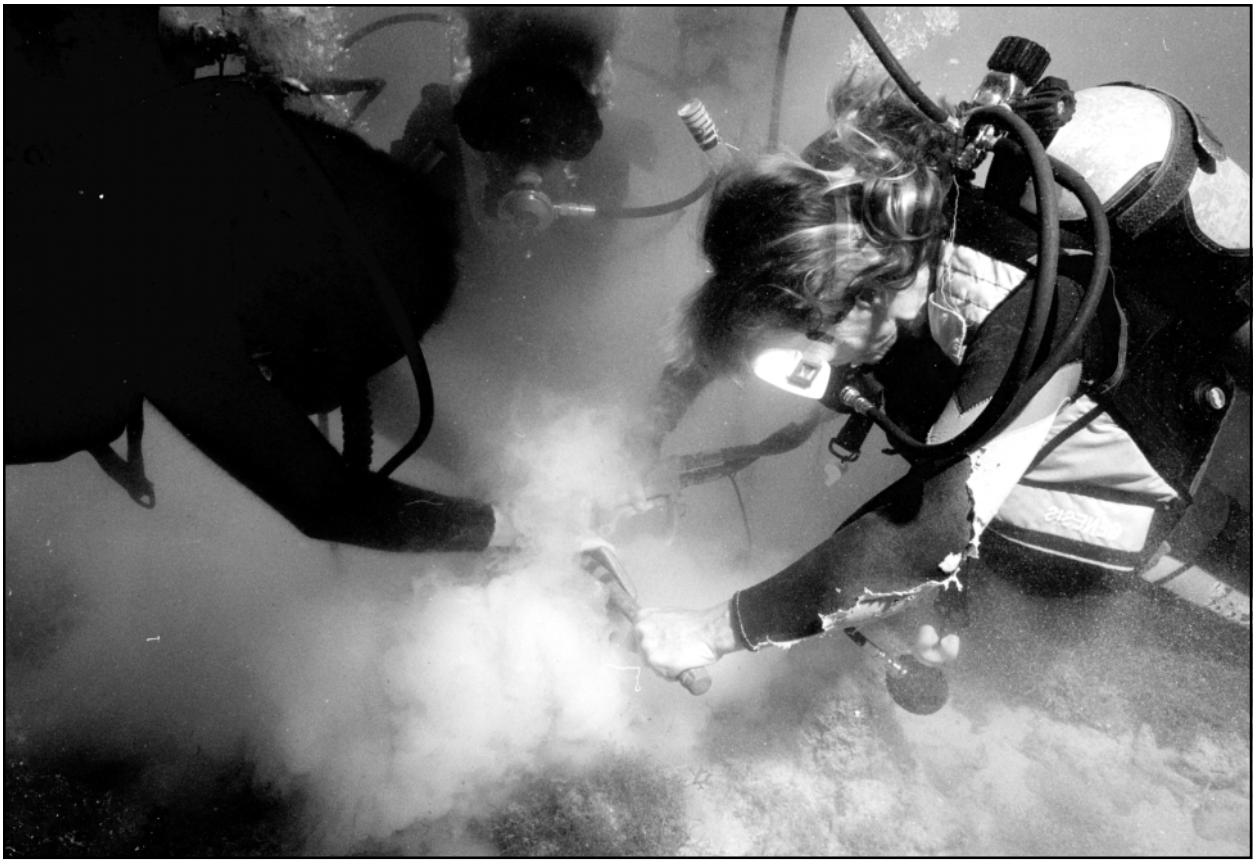


Figure 3-10. Reef mooring buoy installation involves the use of a hydraulic drill to remove a core from the fossilized coral bottom. A stainless steel eyebolt or u-bolt is inserted into the hollow core that is then filled with hydraulic cement to secure it to the ocean bottom. Next, a down line, round buoy float and pick-up line assembly are attached to the eyebolt. Pictured are divers drilling out the cores on the ocean bottom. Reef mooring buoys eliminate anchor damage to coral reefs. Buoys were first installed at Key West-area reefs by Reef Relief. (Photo: Craig Quirolo)

reef ecosystems. This is done with activities and programs both at home and abroad.

REEF RELIEF: PROTECTING NORTH AMERICA'S ONLY CORAL BARRIER REEF

Florida is home to the world's 3rd longest coral barrier reef. It begins south of Miami, parallels the landbase of the Florida Keys, and extends 67 miles southwest to the Dry Tortugas. Patch reefs extend north of Miami to the Palm Beaches. Together with mangroves and seagrasses, this coral reef ecosystem provides habitat for one-third of Florida's threatened and endangered species. Residents and visitors depend upon the reefs for tourism, fishing, recreational activities, an intrinsic wilderness experience and protection from storm surge.

As a result of the natural beauty of the area and convenient location, the Florida Keys is also the most heavily-visited coral reef in the world, the biggest dive destination, and as a result, the coral reefs are amongst the most endangered in the world.

Reef Relief is a nonprofit membership organization dedicated to *Preserve and Protect Living Coral Reef Ecosystems through local, regional and international efforts*. Reef Relief is focused exclusively on saving coral reefs through direct action marine projects, environmental education and policy guidance. It was founded by charterboat captain Craig Quirolo in 1987 and incorporated as a Florida not for profit corporation in Key West, Florida.

The first effort was installation of reef mooring buoys to prevent anchor damage to the heavily-visited coral reefs near Key West. Buoys eliminate anchor damage by providing an easy method of securing a boat at the reef without damaging the fragile coral below. Reef Relief protected Key West's coral reefs from the world's largest fleet of charterboats by installing and maintaining 116 mooring buoys at six Key West-area coral reefs for a period of 10 years. They are now part of the Florida Keys National Marine Sanctuary Reef Mooring Buoy Action Plan.

Next came the Coral Reef Awareness Campaign, an effort to educate boaters, divers, fishermen, and then residents, businesses, students and policymakers on how to protect coral reefs. Even casual contact with the reef from fins, hands or equipment can damage fragile coral polyps, providing a toehold for disease or nuisance algae that could result in the loss of an entire coralhead. Reef Relief maintains *Reef World*, an environmental education center in Key West that introduces residents and visitors and others around the world of the benefits and methods of protecting coral reef ecosystems. A multi-media campaign includes an extensive website at www.reefrelief.org, brochures, special events such as Reef Awareness Week, the *Discover Coral Reefs* School Program, signage, documentary films, radio and television public service announcements, and a small gift shop featuring educational products for teachers and books.

Water pollution is a great threat; corals need clear, clean, nutrient free waters to thrive. The group works with policymakers, media, educators and citizens to increase support for improving water quality and it is a watchdog for policies affecting the coral reef. Reef Relief rallied the community and helped stop plans for offshore oil exploration and development. In 1991, its founders were presented with a Point of Light Award by George Bush who soon declared the area off-limits to offshore oil. Reef Relief was a major supporter of the effort to create the Florida Keys National Marine Sanctuary including the first Water Quality Protection Program of any sanctuary. Reef Relief has worked to upgrade Florida Keys sewage and stormwater treatment systems to nutrient removal tertiary treatment, led the effort to designate Florida Keys waters as a No Discharge Zone for boater sewage, introduced a county-wide ban on phosphate detergents, and promotes the removal of harmful nitrogen from agricultural runoff from the Everglades.

Reef Relief established a Coral Nursery at Western Sambo Reef in the Lower Keys that has salvaged storm damaged corals, secured them to the ocean bottom and elevated so that they may survive. Sanctuary restoration staff used the fragments to restore a boat grounding site.

Since 1993, Reef Relief's founder Craig Quirolo has monitored reef health of many coral reefs near Key West on a slide and video format that has led to the discovery of several new diseases. He collaborates with Reef Relief's Scientific Advisory Board comprised of leading coral reef scientists. The survey provides continuous reef health data invaluable in their studies of coral disease and is incorporated into Reef Relief educational programs to keep the public informed. The images are available on an online database at www.reefrelief.org that is currently being posted. The survey includes coral reefs in Jamaica, Puerto Rico, Cuba, Mexico, and the Bahamas.

In partnership with the City of Key West, Reef Relief created the Key West Marine Park in 2003. Located along the oceanside shore of Key West, it features several no-motor swim areas and access lanes for motorized vessels.

How to use Mooring Buoys

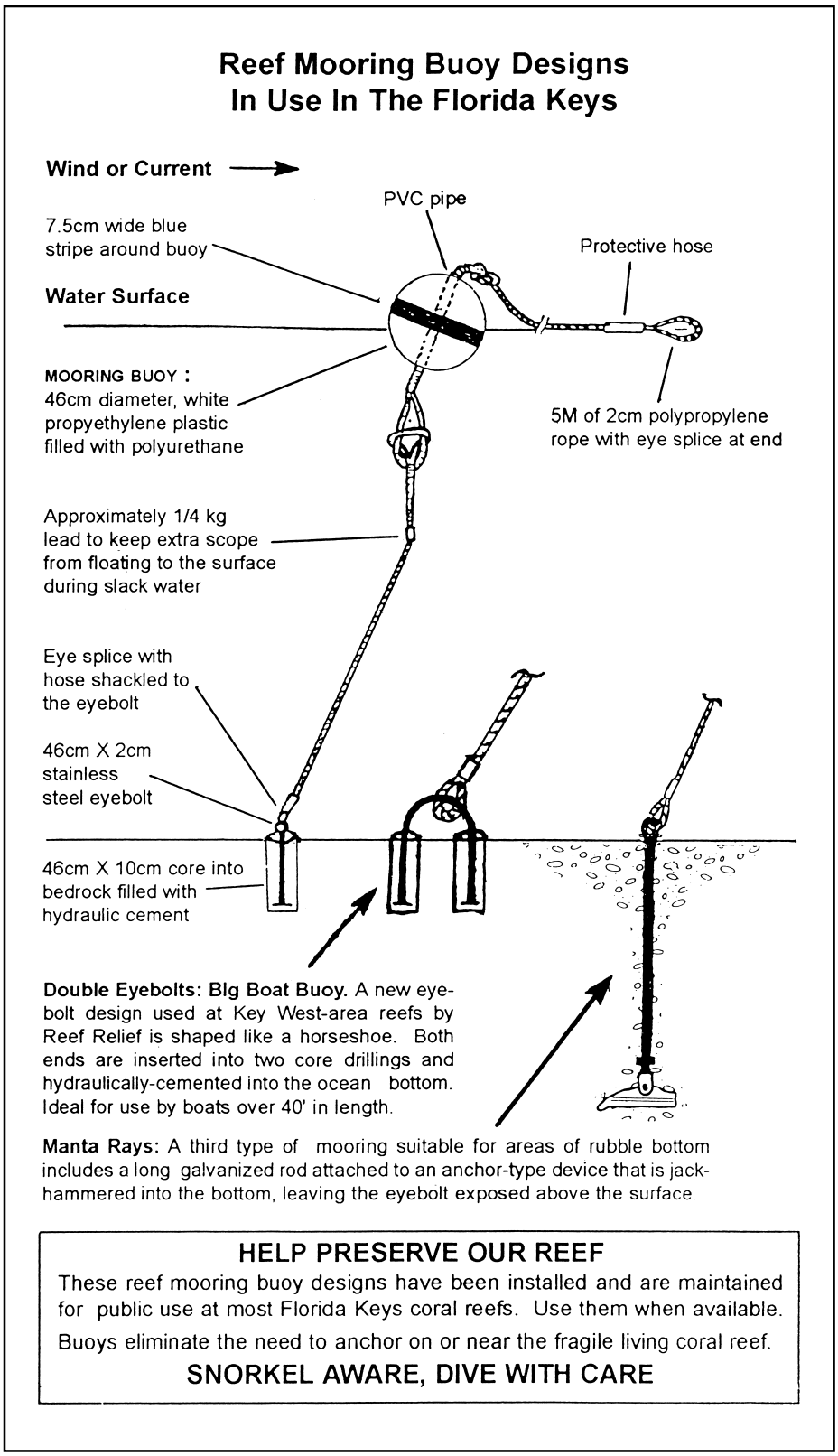


Figure 3-11

Educational signage and brochures help residents and visitors enjoy the nearshore waters in a reef-friendly way.

NEGRIL CORAL REEF PRESERVATION SOCIETY: CORAL REEF PROTECTION IN NEGRIL, JAMAICA

The island of Jamaica is the third largest island in the Caribbean. Its warm, clear, tropical waters provide optimum conditions for an abundance of coral reefs that fringe both the north and south coasts. Jamaican coral reefs include 64 species of hard corals, 38 species of soft corals, and 9 breeding species of sea birds. Major coastal wetlands are home to hawksbill, loggerhead, and green turtles and, on the south coast, the American crocodile. Fishing and tourism is important to the developing economy, although trap fishing, the use of explosives for fishing, hurricanes, overharvesting of reef fish, coral collection, and pollution from sedimentation, coastal development and inadequate sewage treatment have all had measurable impacts on the fringing reefs, seagrasses, and beaches.

One of Jamaica's premier dive/tourism destinations is Negril. Negril is located on Long Bay on the north coast of Jamaica with a coral community that includes both shallow and deep coral reefs and a long sandy beach and cliffs at the north end. Conch, wrasse, parrotfish, edible sea urchin, manatees, green turtles, and hawksbill turtles are all indigenous to the area.

The Negril Coral Reef Preservation Society (NCRPS), founded by Katy Thacker and other concerned divers in the area, contacted REEF RELIEF in 1990 for help in creating a reef mooring buoy program to protect Negril's coral reefs (Figure 3-12). With proceeds from a reggae concert in Key West, matched with volunteer divers and contributions from local resorts, dive shops, and the Negril Chamber of Commerce, a total of 35 reef mooring buoys were installed at Negril's popular dive sites in 1991. The project included a workshop, the first in an annual series, entitled "Protecting Negril's Coral Reefs." Community members heard from fisheries experts, scientists, government representatives, and concerned citizens on ways to protect these coral reefs.

Since that time, the NCRPS has become a leader in coral reef conservation in the Caribbean. It has established its headquarters at the Negril Community Center and launched several successful programs including the Reef Ranger Patrol of the reefs, a buoy maintenance program, annual marine debris clean-ups, a school outreach program, and it has undertaken steps to create the Negril Marine Park with zoned management that includes creation of a swimmer's lane to separate motorized vessels from swimmers.

In 1997, the NCRPS, in cooperation with REEF RELIEF's Craig Quirolo, began efforts to establish a water quality monitoring program for Negril. A laboratory was set up at NCRPS headquarters with the help of Dr. Brian Lapointe of Harbor Branch Oceanographic Institution, Dr. Peter Bell of the University of Queensland, Australia, and Dr. Thomas Goreau with funding from the

Figure 3-12. REEF RELIEF Founder and Director of Marine Projects Craig Quirolo with fishermen from Long Bay, Jamaica. Craig helped design and install a fish attracting device to help improve fisheries production in the area. (Photo: Dr. James Porter)

Figure 3-13. Divers marvel at the deep, plated corals, colorful sponges and beautiful fish they encounter at Guanaja's coral reefs. (Photo: Craig Quirolo)

Figure 3-14. During the summer 1997 installation of reef mooring buoys in Guanaja, Bay Islands, Honduras, local diver Yovanni Bacca spliced lines underwater to attach the buoy line to the eyebolt on the ocean bottom. (Photo: Craig Quirolo)

European Union. The Rangers were trained to identify and collect algae samples and water column samples. Dr. James Porter of the University of Georgia trained the Rangers to set up transects to monitor the coral reefs. In 1998, the Jamaican Government officially designated the Negril Marine Park and identified the NCRPS as the park authority so that they qualify for the additional funding from the European Community Fund.

REEF MOORING BUOYS FOR GUANAJA, BAY ISLANDS, HONDURAS

The Bay Islands of Honduras have some of the world's most beautiful coral reefs. The islands lie offshore of this Central American country and include Roatan, Utila and Guanaja, and the smaller Cayos Cochinos. The islands parallel a deep ocean trench that runs east-west with a nearly continuous fringing reef on the north coast with channels up to 126 feet deep that cut through the reef platform. On the south coast, a discontinuous fringing reef features a 30 - 40 foot deep horizontal reef platform continuing seaward to a drop of 250 feet or greater. The islands are home to leatherback, green, loggerhead and hawksbill turtles, although exploitation is depleting populations. The reefs are dominated by spur and groove formations with massive plate corals, sponges, and other sealife. Conch, lobster and fish are harvested commercially (Figure 3-13).

The business interests of Guanaja recently organized to form the Guanaja Tourism Association. They quickly realized that protecting the island's coral reefs was an important way to promote the economic growth of this tiny island that depends entirely upon diving, fishing, and tourism. A visitor impact fee was implemented to help fund conservation efforts. By 1997, the Tourism Association had approved the first expenditure of these fees to install 30 permanent reef mooring buoys at Guanaja's coral reefs. Now, thanks to a partnership with REEF RELIEF, the buoys are available at popular dive sites (Figure 3-14).

During the summer months of 1997, REEF RELIEF's

Craig and DeeVon Quirolo travelled to the island to provide the equipment and train local divers to install thirty reef mooring buoys at the island's most popular dive and snorkel sites. Sandra Bazley of Pelican Divers coordinated the community project which involved dozens of volunteers, students, and the support of local resorts and businesses who donated boats, fuel, lodging, meals, and supplies. Two types of permanent moorings were installed. First the mantas, anchor-like assemblies with a long rod, were jack hammered into areas of rubble bottom to which the line and float was attached. Next, stainless steel U-bolts were installed in areas of fossilized bottom. A hydraulic drill was used to core out two holes and the stainless steel U-bolt was cemented into the ocean bottom. After allowing the cement to cure, the buoy down-line, float, through-line, and pick-up line were attached. The assembly of the float was accomplished by splicing the individual parts together in a manner that permited parts of it to be replaced as they wear out.

A party to splice lines for the buoys was held that included students from Professor Ruth's Bay Islands Conservation Association Youth Program, local divers, and visitors. Posada del Sol's Dive Shop certified some of the divers,and all were provided with a presentation on coral reefs by REEF RELIEF. The project also involved special presentations to the crew and guests at Bayman Bay Resort and to local citizens at Savannah Bight, during which Professor Ruth translated into Spanish. The professor also offered to manage a video library that REEF RELIEF donated to the community. The buoys are now maintained by the dive shops at Posada del Sol Resort and Bayman Bay Resort. Components are provided with funding from the REEF RELIEF Guanaja Fund, supported through a generous donation by the Richard Munroe Foundation. A bilingual educational brochure on the buoys and how to protect the reef has been produced to encourage reef-friendly activities at Guanaja's coral reefs.

ABACOS, BAHAMAS

The fastest growing area of the Bahamas is the Abacos and Reef Relief has begun a multi-year collaboration

Figure 3-15. Pelican Cays Land and Sea Park is home to a relatively healthy and biodiverse coral reef. (Photo: Craig Quirolo)

Figure 3-16. Splicing Parties to prepare lines for mooring buoys are always cause for a community get together. This one was held at New Plymouth, Green Turtle Cay. (Photo: Craig Quirolo)

with several partners who have helped launch coral reef conservation programs to insure that these coral reefs remain healthy and alive.

Green Turtle Cay is part of a chain of small islands that are located off the eastern side of Great Abaco Island, in the northeastern most part of the Bahamas. Between these cays and Great Abaco is the Sea of Abaco. These coral rimmed cays lie east of the Sargassum Sea which constantly washes them in clean, clear nutrient free waters, perpetuating healthy coral growth. From the northern tip of Great Abacos a shallow body of water stretches westward all the way to West End, Grand Bahama Island, similar to Hawks Channel in the Florida Keys. However (just like the Florida Keys), a growing number of tourists, boaters, and private developments – in combination with agricultural and stormwater runoff from the developed mainland of Great Abaco – present challenges to the long term health and vitality of the coral reefs that abound in the area.

Key West, Florida, and New Plymouth, Green Turtle Cay, are sister cities, so it seemed natural for Reef Relief to assist our sister island in the design and implementation of strategies to protect their coral reefs. In 1998, Reef Relief began with the installation of 18 reef mooring buoys at the most frequently visited coral reefs near Green Turtle Cay.

The following year, additional buoys were installed to expand the system to accommodate an increase in boating activity. In addition, a coral nursery was established to salvage storm-damaged *Acropora Plamata.* Reef Relief's Craig Quirolo used wire ties to stabilize and elevate fragments of the endangered coral that had been buried during hurricanes. He is monitoring the health of the nursery on a video and still format.

Educational efforts in Green Turtle Cay have included school presentations and community workshops that

instructed and informed residents and visitors on the importance of coral reefs and how they can be protected. At ever-popular reef mooring buoy splicing parties, locals learned the nautical art of splicing lines for reef mooring buoys. Charts were produced showing the locations of the buoys and how to use them along with reef tips that are distributed to boaters, residents and visitors.

To insure that educational programs will be offered on an on-going basis for visitors and residents of all ages, Reef Relief opened an environmental center at the Captain Robert's House in New Plymouth, the first historically-restored home in the Bahamas. The facility offers a video classroom, a children's activity room, and educational displays on coral reefs, mangroves, seagrasses, sea turtles and descriptions of the Reef Relief Green Turtle Cay reef mooring buoy, coral nursery and coral survey projects.

CORAL REEFS IN CUBA

by Robin Orlandi, REEF RELIEF Board Member

Monday, June 23rd, watching Key West disappear into the gathering dusk, I think of the Underseas World of Jacques Cousteau specials that mesmerized me as a child. We are on REEF RELIEF founders' Craig and DeeVon Quirolo's sailboat *Stormy Weather* and we are headed for Cuba. Throughout the night as we cross the Gulfstream, watchful for tankers and other sailboat-crushing ships, we hallucinate brine encrusted *Balseros* bobbing on the deep blue. The sea out here is muscular and unforgiving. I think about our origins in this diatomaceous soup and the allegiance all living creatures owe it. *El mare es sin fronteras*. The sea is without boundaries. In both languages, this will become our mantra over the next two weeks.

Our voyage has been federally permitted as a preliminary research trip to examine and document the condition of Cuba's coral reef ecosystems. REEF RELIEF's mission includes outreach throughout the Caribbean to assess coral health and assist local groups in developing their own protection and monitoring programs. This work represents part of a global effort during the International Year of the Reef to conduct rapid assessments of the Earth's coral reefs, the "rainforests of the sea" (Figure 3-15).

In the previous year, ichthyologists from Cuba's Institute of Oceanography had visited Key West to perform baseline fish counts to confirm the conclusions of their research in Cuba. As a result of the patterns of ocean currents, larval spawning cycles of fish, corals and lobsters in Cuba are closely linked to the productivity of fishes in south Florida. REEF RELIEF facilitated the Cuban scientist's work in the Florida Keys, describing local conditions, explaining the impacts that have affected our reefs, and providing boats, fuel, and expertise for their field work.

The relative lack of development and overpopulation in Cuba heightened our hopes of documenting healthy coral reefs, of finding a clean "baseline" against which ailing coral reefs could be measured. We would dive in two different regions, one on the North Central coast in the Archipelago of Camaguey at *Cayo Cocos;* the other near Cuba's southwestern tip at *Maria La Gorda*, adjacent to the Pinar del Rio biosphere preserve.

Before the end of the first day, we realized that Cuba is a country of contradictions, where patience, ingenuity, toilet paper and a sense of humor are a prerequisite. Our guide for the week, marine ecosystem conservation specialist Dr. Juan Pablo Garcia, welcomed us at the Institute. A tour revealed scientists crunching data on aging computers, coping with paper shortages, broken windows and balky telephones. Only the new equipment in the pollution research division benefited from air conditioning. The friendliness and openness with which we were greeted became a hallmark of our trip.

A chronic shortage of vehicles and boats makes field work difficult to accomplish. Our trip would provide an infrequent opportunity for the Havana scientist to visit the Institute's distant field lab at *Cayo Cocos*. One of a chain of coral rock barrier islands, the 370 sq. km. *Cayo Cocos* is separated from the mainland by the *Bahia de Perros* (Bay of Dogs). In 1988, a 27 km (16.7 mile) long causeway was built on solid fill across the Bay to facilitate tourist access. What was once a mangrove estuary filled with flamingos and pelicans has

been turned into a hypersaline wasteland dotted with dying mangroves. Juan Pablo was visibly alarmed by the area's decline. A huge tourist resort had been built directly on the dunes in front of the Institute. Several other new hotels and access roads were under construction. In an all too familiar scenario, the scientists and ecologists at *Cayo Cocos* were running a footrace against the economic forces of tourism and development, trying to gather enough evidence to convince their government that unbridled construction will kill the goose that lays the golden egg.

Our first nearshore snorkel dive at *Cayo Cocos* confirmed our worst fears. The seagrass and patch corals are covered in sediment. The water has the translucent milky lime color that derives from excess runoff and algal overgrowth. Craig and DeeVon shake their heads in disbelief.

The next day we snorkel at *Playa Flamingo* on *Cayo Guillermo*, the westernmost island of the archipelago. It is more isolated but the tour bus parked in the sand and the beachfront concession signal what the future holds. Because of a shortage of boats, we are towed on a paddle boat by a jetski to a patch reef about a half mile offshore. We see a bottom bristling with live staghorn coral. Visibility is over 100 feet. Much of the coral is golden with the glow of living coral polyps. Although the elkhorn grows in profusion, the human impacts are obvious: entire coralheads have been overturned, many branches broken off, and the top of the reef flattened from divers standing on it. The purple sea fans exhibit the browning and fungal slime characteristic of their demise. Of the seven coral diseases identified in the Florida Keys, Craig finds four. Everyone inspects a small brain coral infected with blackband. The Cuban scientists study it intently and talk afterwards to the local divers about what we have seen.

Later in the day, Craig and DeeVon will give a lecture at the Institute describing coral diseases and conditions at Florida reefs. They also talk about the relationship between tourism, the dive industry and the

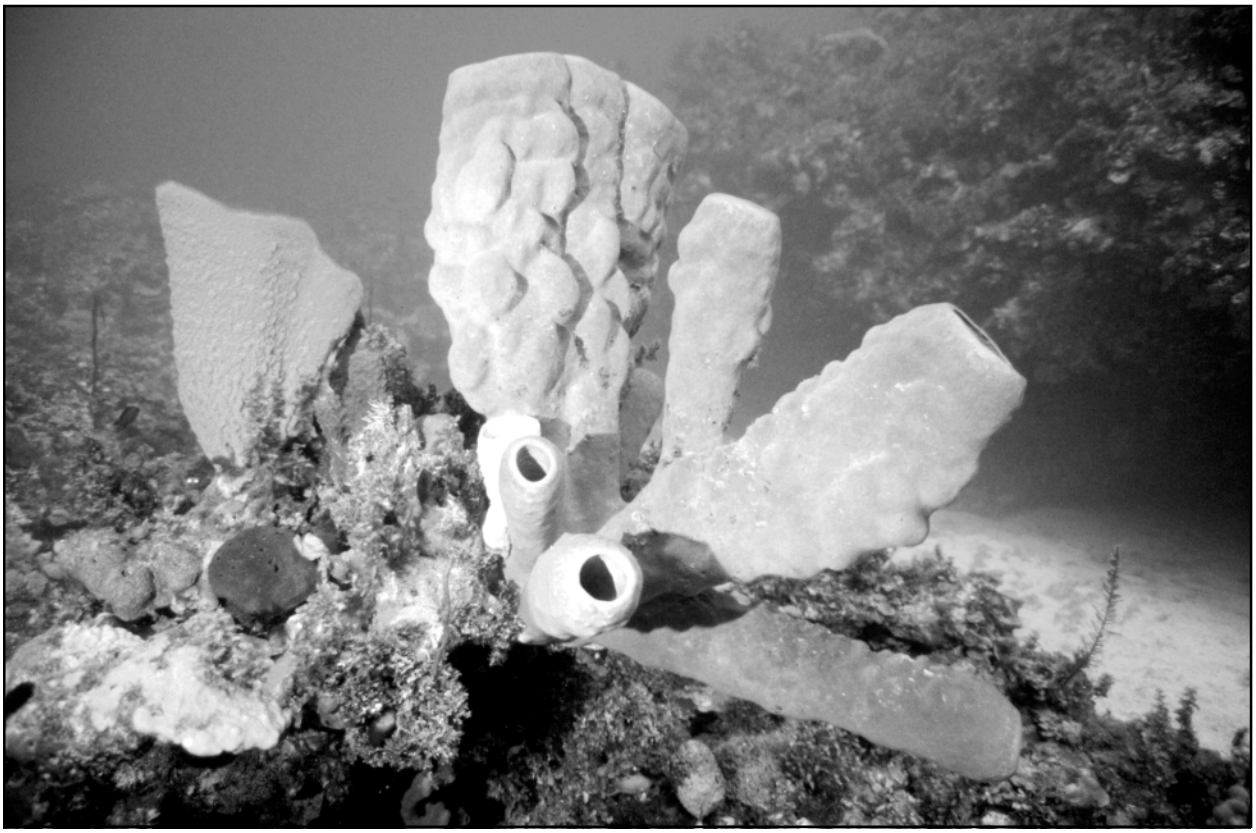


Figure 3-17. Sponges are an important part of the coral reef ecosystem. This photo was taken at Isla Cocos, on the north coast of Cuba during the Reef Relief survey of Summer 1997. (Photo: Craig Quirolo)

health of marine resources and the necessity for education and the cooperative participation of everyone. A slide show of sick corals is derailed by a broken projector but color photocopies showing examples of white pox, black band, yellow band, and white plague type II are passed around. Local dive masters as well as students and researchers from the Institute are in attendance. One dive master looks at the copies and mouths the words, "I have seen these here."

The same dive master will take us on our last dive at *Cayo Cocos*, an offshore reef 40 feet deep. Massive towers of eroded boulder corals greet us, surrounded by gorgonians and iridescent tube sponges. This reef's corals are diverse, but not exempt; there is a heavy overgrowth of algae covering them. Back in the boat, someone asks Craig, "Well, what do you think?" "Not good." He has taken photos of algae spewing out of rocks, potentially indicating an upwelling of nutrient-laden waters. "The Siderastria sideria disease is here." This rapidly progressing white blotching affliction of star corals only recently appeared in the Keys. It is a shock to find it in Cuba. The discoveries of each dive have been documented with numerous still photos.

Figure 3-18. Cuban scientist Juan Pablo Garcia dives the coral reefs of Maria La Gorda as part of the 1997 REEF RELIEF survey of Cuban coral reefs. Sea fans filter the ocean water as they sway and move in the ocean currents. (Photo: Craig Quirolo)

After the disheartening finds at *Cayo Cocos,* we pin our hopes on undeveloped *Maria La Gorda*, shielded from human impacts on the landward side by the deep forests of the biosphere reserve. Two days later, within minutes of descent, our hopes are dashed. The reef is covered in Halimeda algae and like the reefs of *Cayo Cocos*, its fisheries are depleted of commercial species (Figure 3-16). The divemasters talk at length about the changes they have observed and ask for more information to identify the problem.

Like a canary in a coal mine, the conditions of the reef at *Maria La Gorda* can be understood to imply a widespread degradation of Caribbean waters; that distant pollution and nutrient sources are not neutralized by dilution in the ocean currents; and that the ocean's capacity to clean itself is being exceeded. One can point an accusing finger at the unbelievable black oily sludge mixed with raw sewage pouring out of Havana Harbor, the second most polluted harbor in the world; at the oil wells, refineries and chemical plants lining the perimeter of the Gulf of Mexico; at the runoff from South America; at all the Caribbean nations that use the ocean as a dumping ground for sewage, trash and industrial disposal.

Ultimately, we end up pointing the finger at ourselves: in the 1960's Cousteau alarmed the world when he showed footage of Calypso's crew plucking tar balls out of the middle of the Atlantic Ocean. How could the whole thing be dirty? Thirty years later, we have yet to act together in such a way that addresses the reality of the world's oceans as a single body of water. The cooperation of scientists, governments, conservation groups and individuals in conducting research and sharing information locally is critical if we are to understand what is sickening the earth's seas and to develop programs for their recovery.

After returning to Havana, REEF RELIEF representa-

tives sat down with lead scientists at the Institute and drew up a three year project proposal for the rapid assessment and mapping of Cuba's major coral reefs. Pending both U.S. and Cuban government approval, the project will create a win-win situation. Cuban scientists will gain a basic database inventory of their reefs and lay the groundwork for more comprehensive long term research and remediation. For American researchers, information about Cuba's reefs will yield valuable data and permit invaluable comparison between two parallel Caribbean reefs affected by differing levels of development, use, management, and other land-based variables.

With educational, mooring buoy and research projects currently in place in Negril, Jamaica, the Bays Islands of Honduras, and planned for Puerto Rico and Mexico, REEF RELIEF's Caribbean Campaign is well underway. In working with this group, I am constantly reminded that it is through our own efforts that we make a difference. Persistent, informed, honest actions, like the large hearts of the Cuban people, speak a language capable of transcending boundaries. *El mar es sin fronteras.*

THE MISKITO OF LA MOSQUITIA, HONDURAS

The Miskito people of La Mosquitia, Honduras have lived for centuries along the Moskito Coast, hunting in the forest, farming the land, and fishing in the ocean. However, over the last 30 years, colonization of traditional lands by cattle and timber barons and by campesinos practicing slash and burn agriculture have threatened La Mosquitia lands.

In addition, lobster boat fleets from the Bay Islands of Roatan and Guanaja hire Miskito men as swimmers and divers (Figure 3-17a). They provide them with primitive equipment to dive at great depths for lobsters, a dangerous job. Even though most of the money from this $30 million annual business is kept by boat captains and seafood processors, the divers' small incomes account for almost the entire cash economy of La Mosquitia.

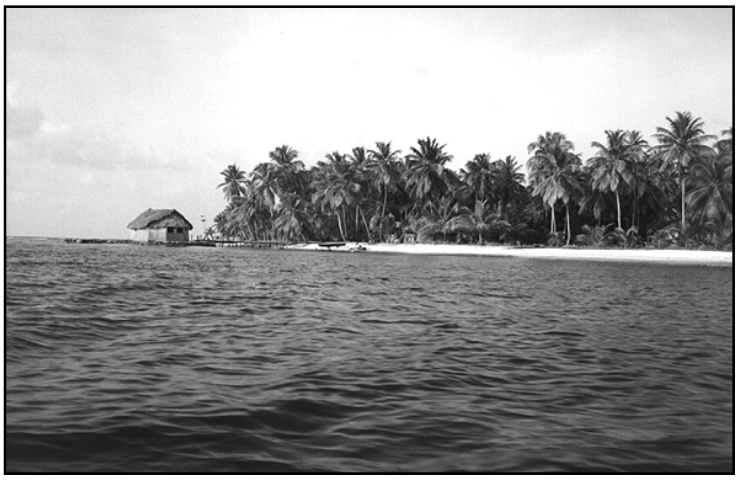
This economic dependence has a number of problems relating to the health of the divers, the sustainability of the ecosystem, and the health of the communities in which the divers live. Most divers have received no education in diver safety and regularly dive all day, every day on two-to-three-week diving trips. Almost all of them suffer some degree of decompression sickness or "the bends", with symptoms ranging from numbness or pain, to incontinence and impotence, to paralysis and death. As lobsters become overharvested (Figure 3-17b), divers must search deeper and deeper, increasing the likelihood of injury. Paralyzed divers are no longer able to work and become a burden to their families and communities. Due to the climate and sanitary conditions of La Mosquitia, paralyzed divers often succumb to infections and die within a few years.

In 1995, Coral Forest started working with MOPAWI (Mosquita Pawisi, Development of Mosquita), a

(a)

Figure 3-19. (a) Lobster boat used by Miskito divers, and (b) spiny lobster tails ready for market. (Photos: Jim Gollin)

Misquito NGO (non-governmental organization), to promote safe diver training and effective marine resource management. To initiate the program, MOPAWI established an extensive diver training school to educate and train local lobster divers and dive boat operators. In 1996 alone, 1,600 divers were trained and certified in advanced scuba diving techniques and 6 new diving instructors were certified. Boat captains and dive boat operators also received training in emergency decompression techniques and proper diving safety and first aid protocols. As part of its continuing education program, the dive school organized a series of training workshops and discussions with injured divers to encourage safe diving practices and minimize diving accidents. After only the first year of the program there was a drastic reduction in the number of diving accidents, and serious injuries were minimized with proper emergency treatment.



(a)

(b)

Figure 3-20. (a) One of the islands of Kuna Yala, and (b) Puksu Igualikinya. (Photos: Marianne Hegeman)

In addition to the diver training program, MOPAWI is exploring economic alternatives to lobstering to help ensure a sustainable harvest level and to protect the marine ecosystem. Studies into the marketability of alternative marine resources, which would reduce the pressure on lobsters, are being planned and strategies for more effective marine resource management are being developed. In the upcoming years there is interest in expanding the diver training and resource management program throughout Honduras and into neighboring Nicaragua.

THE KUNA OF KUNA YALA, PANAMA

Off the Caribbean coast of Panama, the Kuna live on many small islands surrounded by coral reefs (Figure 3-18a). They call these islands Kuna Yala, although they are identified on most maps as the San Blas archipelago. The Kuna sailed to these offshore islands from the coastal rainforest several hundred years ago to escape the severe outbreaks of malaria transmitted by mosquitoes. Today, the Kuna fish the coral reefs for their primary source of food, but they still go daily into the rainforest for fresh water, plants for healing, tree trunks for canoes, and land for fruit trees and vegetable gardens.

The Kuna have successfully fought to preserve their rainforests from destruction which has also helped to preserve their reefs. However, they are now being threatened from the oceanside. The drug trade in the

Caribbean has brought drug runners' boats to their islands, along with guns, cocaine, and violence. As with the Miskito, foreign fishing boats have overharvested their waters, taking huge quantities of spiny lobster and selling them to large restaurant chains in the United States. The sea turtles that used to migrate to their islands have been killed hundreds of miles away for their meat and shells.

The Kuna are taking action against these threats, too. Puksu Igualikinya (Figure 3-18b), a REEF RELIEF advisory board member, is working to establish a marine protected area near his home; to implement a safe-diver training program for the Kuna lobster divers; and, to educate his people about the threat to their coral reefs.

In order to better conserve, protect and properly manage their marine ecosystem, Puksu and a group of Kuna formed the Osiskun Foundation. In 1996 they asked Coral Forest for educational assistance. Joined by the Smithsonian Tropical Research Institute (STRI) in Panama City, the three organizations created the Kuna Marine Environmental Education Program, the first program created by Kuna for Kuna. This program was designed to educate them about the ecology of their coral reefs and related marine ecosystems, and to provide them with methods they could utilize to promote sustainable development.

To implement the program, a series of seminars and presentations were successfully organized for the Kuna teachers, youth, and general public. In the presentations to the teachers, participants practiced coral reef lesson plans and received teaching materials and a teacher's guide (in Kuna) so that they could introduce marine education to their classrooms. In addition, snorkeling trips to the local coral reefs were organized, giving everyone an opportunity to learn about their reefs firsthand. The Osiskun Foundation plans on expanding this educational program to reach more of the Kuna community, including fishermen and lobster divers.

THE FILIPINOS OF THE PHILIPPINES

In the Philippines, native coastal people live in small, independent communities on different islands. Many still use traditional net fishing methods to catch fish, their primary source of food, protein and income. However, fishermen using dynamite and cyanide to harvest the fish are destroying the coral reefs and fisheries.

On the remote island of Palawan in the northern Philippines, the El Nido Marine Reserve and its coral reefs are being threatened on two fronts. In the rainforests above the reserve, trees are cut illegally for sale to resort developments and the thin tropical soil is eroding into once crystal clear waters, covering and smothering the reef. Offshore, the reefs are blasted by fishermen who toss sticks of dynamite into the water and gather the fish that float to the surface.

On the tiny island of San Salvador off the west coast of Luzon, the coral reefs are damaged by fishermen using illegal cyanide, a deadly poison, to harvest saltwater tropical fish for the aquarium trade. The poison is squirted from a bottle to stun the fish, making them easier to catch. However, the cyanide also kills up to 90% of the fish caught, destroying the surrounding coral and other marine life, in addition to causing health problems and even death for the fishers and their families.

San Salvador fisherman Noel Abulag (Figure 3-19a) stated, "We observed that little by little the coral was dying and there were fewer fish. We didn't understand the effects of cyanide. We only knew it was easy. There was no alternative. Now we know it was a big mistake." One by one, Abulag was able to convince three dozen men to switch to catching the tropical fish with small hand nets. Although initially much harder, in the long-run it is more effective because a much higher percentage of the net-caught fish live to reach the aquarium (Figure 3-19b), the damage to the reef is reduced, and no one is hurt. Abulag is also helping to train tropical net-fishing techniques to fishermen in other communities, and he has created a small marine sanctuary where no fishing is allowed. The sanctuary provides a spawning ground for the fish and coral to reproduce and replenish the surrounding seas. There are now three times as many fish in the sanctuary than before it was established.

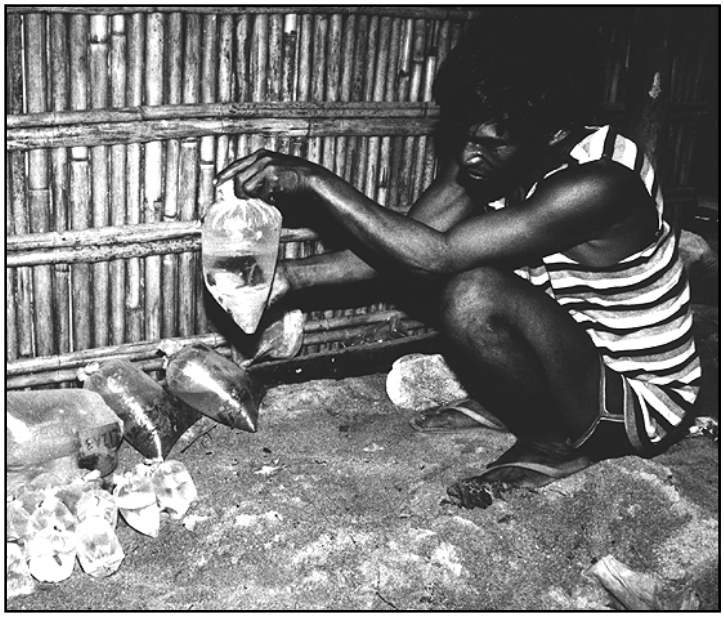
REEF RELIEF is working with international NGO's to stop the use of cyanide in the collection of tropical fish for the aquarium trade. The Haribon Foundation in the Philippines and Ocean Voice International in Canada retrain fishers in traditional net fishing methods

and assist the Federation of Aquarium Fish Collectors of the Philippines in establishing a reliable source of cyanide-free fish. The Hayuma Foundation educates villagers about the importance protecting their marine environment. The International Marinelife Alliance holds training programs in Filipino fishing communities and has developed a Cyanide Detection Test which is used to test fish before export. However, there is still much to be done, as it is estimated that 95% of fishers continue to use cyanide.

(a)

Figure 3-21. (a) Noel Abulag, and (b) net-caught tropical fish being prepared for export. (Photos: Christopher McLeod)

(b)



What You Can Do:

- Learn all you can about coral reef ecosystems and help educate others so that we all do our part to protect them. The first generation to discover coral reefs may be the last to enjoy them unless we all get involved.
- Get involved and volunteer to help protect coral reefs. Coastal and underwater clean-ups are a great way to begin. Many volunteer activities can be done wherever you live (Figure 3-20).
- Be informed and support good policy-making with telephone calls, letters and e-mail messages on important issues. The only way we can influence our government is through public input. The Clean Water Act and the Endangered Species Act has helped us but more must be done. Join the Reef Relief E-Activist List at *www.reefrelief.org*.
- Avoid purchasing products from coral reefs or their inhabitants, such as tropical fish and other marinelife, corals, sponges, and ornamental curios; it depletes coral reefs and encourages international trade in such products (Figure 3-21).
- Be a responsible ecotourist. Do business with those who respect the marine environment and are sensitive to coastal development, have an appropriate infrastructure, have respect for local cultures, and support reef-friendly activities.
- Support reef conservation organizations. Join REEF RELIEF by becoming a member, a contributor, and/or by volunteering your special talents.

TIPS FOR DIVERS AND SNORKELERS

- Before booking a reef trip, check weather conditions; it's best not to go out in rough seas. Poor visibility, strong winds, and waves reduce safe interaction at the reef.
- Remember that even the lightest touch with fins, hands and equipment can damage sensitive coral polyps.
- Snorkelers should wear float coats to allow gear adjustment without standing on the coral.
- To avoid contact with the ocean bottom, divers should only use the weight needed and practice proper buoyancy control. Lifeless areas may support new growth if left undisturbed.
- Avoid wearing gloves and touching or collecting coral or any marinelife. Most tropical fish that are captured die within a year.
- Please don't feed fish, sea birds, mammals or turtles; it destroys their natural feeding habits and teaches them to be receptive to possible predators.
- Choose a dive operator or wilderness guide who uses vessel pump-out facilities, educates the guests, provides safe equipment, and uses proper anchoring.
- Bring back any trash you find and recycle it, if possible.

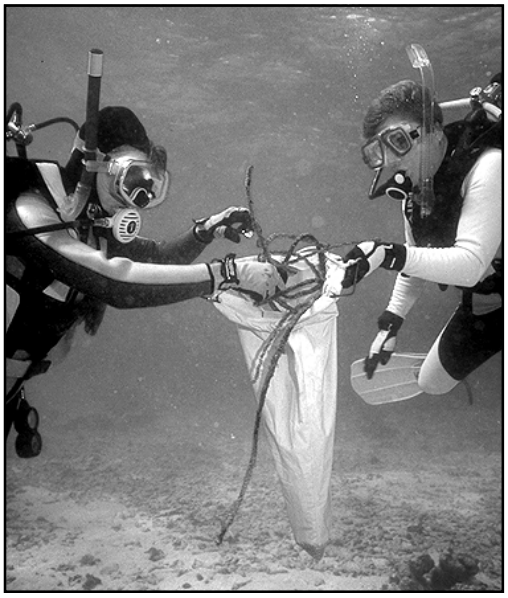


Figure 3-22. Underwater reef clean-up: coral reef sweepers. (Photo: Larry Benvenuti)

Figure 3-23. Saltwater tropical fish in the Philippines ready for export to aquarium dealers and hobbyists. (Photo: Christopher McLeod)

TIPS FOR BOATERS AND FISHERMEN

- Dumping trash at sea is illegal; plastic bags and other debris can injure or kill marinelife. Try to retrieve all fishing gear and equipment, especially monofilament.
- Accidental boat groundings damage the reef. Prop damage destroys shallow seagrass beds. Consult tide and navigational charts and steer clear of shallow areas. Remember: "Brown, brown, run aground. Blue, blue, sail on through. White, white, you just might!"
- Use reef mooring buoys or anchor in sandy areas away from coral and seagrasses so that anchor and chain do not damage the bottom.
- Use sewage pump-out facilities, biodegradable bilge cleaner and bilge absorbent pads, and never discharge sewage or bilgewater on the reef.
- Practice good seamanship and safe boating. Maintain safe distances from fishermen and scuba divers. Observe size and bag limits and no-fishing zones. Release all the fish you can't eat.
- Avoid wildlife disturbance; stay 200 feet or more offshore; keep speed, noise, and wakes to a minimum near mangroves.
- Do not dispose of fish carcasses and wrung lobsters by throwing them overboard or into canals as they degenerate and degrade water quality.
- Camping, campfires, and collecting of any kind are prohibited on all National Wildlife Refuges. Personal watercraft and airboats are illegal in all National Parks and Wildlife Refuges in the Florida Keys and may be restricted elsewhere.

TIPS ON LAND

- Conserve water by filling the washing machine and dishwasher completely before using. Limit shower time; showers use less water than baths. Avoid overfilling the bathtub or running tap water while shaving, brushing your teeth, or lathering your face and hands. Repair leaky faucets promptly and use water-saver faucets and toilets.
- Use biodegradable cleaning, painting, and landscaping products that can be washed down the drain. Avoid the use of toxic cleansers, pesticides, plastics, styrofoam, and other products that are produced or used in ways that poison our waterways and threaten our oceans.
- Landscape using native species that require less water and fertilizers, and design walkways and driveways with porous materials to reduce stormwater runoff. Wash cars on the lawn to prevent runoff.
- Conserve energy whenever possible to reduce global warming. Take public transportation, carpool, walk, or ride a bike to reduce fossil fuel depletion. Use ceiling fans and natural ventilation to reduce air conditioning. Plant a tree. Support forest and green space conservation efforts and limits to urban sprawl.
- Properly dispose of hazardous waste including auto batteries, gasoline, motor oil, paint, chemicals, acids, and household cleaning products. Never discharge them into the street.
- Reduce, reuse, recycle. Recycle aluminum and steel cans, glass, plastic containers, newspapers, and cardboard. If recycling is unavailable in your community, lobby to adopt full recycling.
- Be a smart shopper. Know the source and quality of your seafood purchases.
- If your home is connected to a central sewage system, make sure it removes nutrients and does not contaminate underground sources of drinking water or adjacent bodies of water. If on a septic system, keep it working properly to prevent leaching. Avoid the use of shallow injection wells in areas of porous substrata since they fail to contain the effluent.

If we all do a little, we can do a lot!

PROTECT LIVING CORAL

For specific information about current coral reef threats and whom to write, contact REEF RELIEF at tel: (305) 294-3100, fax: (305) 293-9515, e-mail: reef@bellsouth.net, or go to our web site:

http://www.reefrelief.org

THE CORAL REEF TEACHER'S GUIDE

LESSON PLANS

- **K-5**
- **6-8**
- **9-12**

Gumatj children playing on the beach. (Photo: Wendy Weir)

THE CORAL REEF
TEACHER'S GUIDE

LESSON PLANS FOR K-5:

- **What and Where are the Coral Reefs?**
- **Life on the Coral Reef**
- **Benefits, Threats, and Solutions**

The coral polyp at night with extended tentacles. (Photo: Jim Larson)

The Edible Coral Polyp

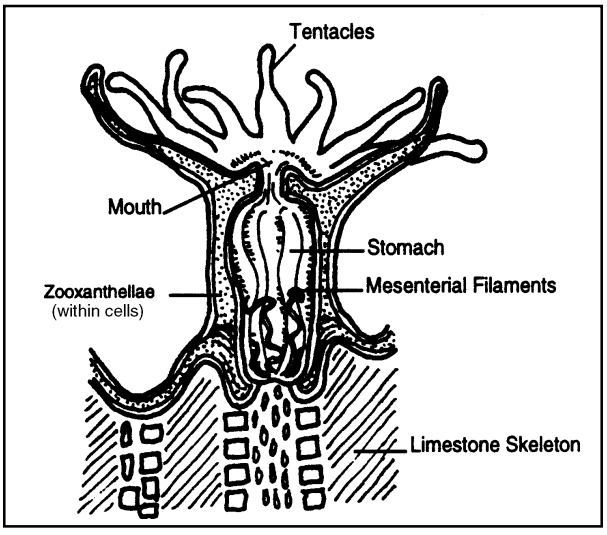
Objective: Students will review the parts of a coral polyp by building an edible coral polyp model.

Interdisciplinary Index: Science, Math, Language Arts

Vocabulary: coral, polyp, limestone, coral colony, coral reef, tentacles, zooxanthellae

Materials:

- white baking chocolate, candiquik mix, or cake frosting (1/2 ounce for each child)
- one marshmallow for each student (substitute: section of banana or strawberry)
- toothpicks
- red licorice (regular or whip): six two-inch strips for each child. If regular licorice is used, cut the pieces into small, thin strips.
- blue, red or green sprinkles
- heat source (microwave or hot plate) for melting candy coating only
- pan for candy coating
- paper plates



PRESENTATION:

You may want to prepare a model colony to show your students before they make their own.

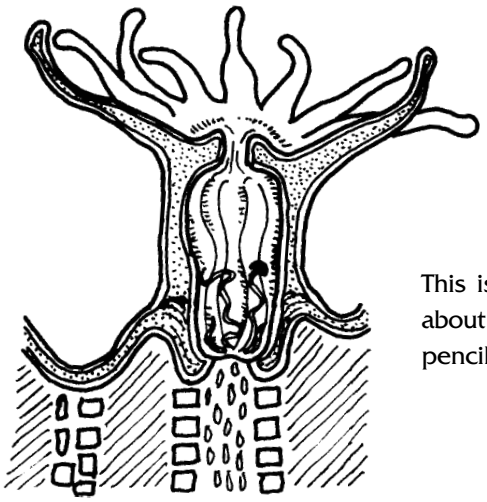
1. Group the students into pairs.
2. Give each pair of students a paper plate. The plate represents the limestone base to which the coral is attached.
3. Give each student a marshmallow on a toothpick and six strips of licorice. The marshmallow represents the polyp body and the licorice represents the tentacles.
4. Give each pair one ounce of melted candy coating from the heat source in a shallow container (the candy represents the limestone skeleton).
5. Have the students work together. Roll the sides of the marshmallow in the melted candy coating and stand the marshmallows on a paper plate. If the marshmallows are placed close enough together, they will attach to each other and resemble a coral colony.
6. Have the students insert six licorice strips around the top of the marshmallow. Children may want to use their toothpicks to help them poke the holes.
7. Slightly dampen the marshmallow with water and sprinkle it with the sprinkles. The sprinkles represent the zooxanthellae. Use only one color per polyp.
8. Discuss the edible polyp model. Explain what the marshmallow, the candy, the licorice, the sprinkles, and the plate represent.
9. Now have the students pretend that they are parrotfish or crown-of-thorns sea stars and eat their polyps. YUM!

Math: Students can count the number of tentacles on their polyp and multiply by the number of students in the class to find the total number of tentacles in the classroom coral colony.

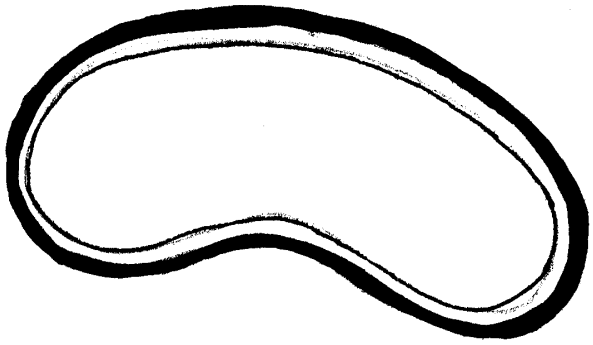
FOLLOW-UP/EXTENSION:

Students may want to write a story about their polyp or draw a diagram. Have them color the **"I'm a Coral Polyp" Color Page**.

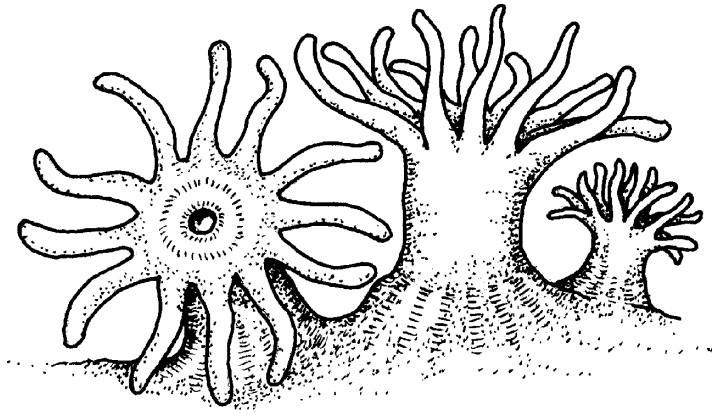
"I'M A CORAL POLYP" COLOR PAGE



This is a coral polyp. It is about the size of a common pencil eraser.



This is a microscopic plant called a zooxanthellae. It lives inside the coral polyp. The picture is greatly enlarged.



Coral polyps join together to make a coral colony. Coral colonies join together to make a coral reef.

Calcium Carbonate and Coral

Objective: Students will understand that coral skeletons are the basic structure of the coral reef, and that these skeletons are made of calcium carbonate, extracted by the polyps of hard corals from seawater to form limestone. They will use a vinegar test to identify calcium carbonate in objects in their classroom environment.

Interdisciplinary Index: Science, Language Arts

Vocabulary: limestone, skeleton, calcium carbonate

Materials:

- a limestone rock or shell
- two rocks other than limestone
- a piece of chalk
- pencil or other common object
- vinegar
- a dish for each specimen

PRESENTATION:

1. The basic element of the coral reef is the coral skeleton which is made of calcium carbonate extracted from seawater by the hard coral polyp to form a limestone base.
2. Explain that a test for calcium carbonate is to pour vinegar over an object and observe it. If the object bubbles and/or makes a fizzing sound, it probably contains calcium carbonate. (Note: sodium bicarbonate also bubbles with vinegar.)
3. Place the first two materials listed in separate dishes. Have the students tell you which ones they think contain calcium carbonate and why.
4. Perform the test, and identify the calcium carbonate object.
5. Have the students choose items from the room that they think might be made from calcium carbonate. If chalk is not chosen, the teacher should add it.
6. Place each of the selected items in a separate dish and pour vinegar over each one.
7. Observe which items cause the vinegar to bubble.
8. Discuss which items are made of calcium carbonate and contain the same material as coral skeletons. Since chalk is made of calcium carbonate, it will bubble.

FOLLOW-UP/EXTENSION:

Have the students write a description of what they observed. **Helpful hint:** If you cannot observe the bubbles, have students hold the container with the calcium carbonate object near their ears and they can hear the fizzing sound of the bubbles.

Where in the World are those Coral Reefs?

Objective: Students will distinguish the different types of coral reefs (fringing, barrier, atoll) and identify the areas of the world where tropical coral reefs occur.

Interdisciplinary Index: Science, Geography

Vocabulary: coral, coral reef, fringing reef, barrier reef, atoll, equator, tropics

Materials:

- globe or large world map
- **Reef Formation** handout and **Where in the World** handout for each student
- pencils, crayons or markers.

PRESENTATION:

1. Use map or globe to familiarize students with the continents, various islands, the equator, the belt of tropics (between the tropic of Cancer at 23°27'N and the tropic of Capricorn at 23°27'S).

Coral Reef Formation:

2. Explain that tropical coral reefs grow only in a special area approximately 20° north and 20° south of the equator called the tropics. Show the students the tropics on a large map. Explain that this is the part of the world where the water temperature is always warm. Explain that corals like warm shallow water and lots of sunlight since their plant partners, the zooxanthellae, need light to make food for the corals.
3. Pass out a **Where in the World** map and a **Reef Formation** handout to each student.
4. Explain that as the coral animals die, their skeletons become the base upon which new corals can grow. Tell them to turn to the **Reef Formations** handout.
5. Review the process of reef formation along a tropical island.
   a) First, corals form a fringing reef along the edge of the island.
   b) With time, the island sinks slightly so that water now separates the coral reef from the island. This is a barrier reef.
   c) Eventually the island sinks completely, leaving a ring of small sandy islands and coral reefs around a central lagoon. This is an atoll.
6. Have the students color the fringing reef red, the barrier reef orange, the atoll purple, the island green, and the surrounding water blue.

Coral Reefs Around The World:

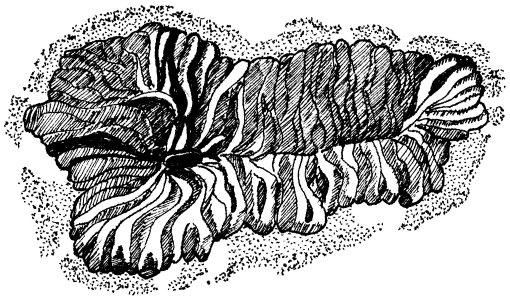
7. Use the **Where in the World** handout to review equator, tropics, continents, etc. Have students use the key to color in coral reefs, water, and land.
8. Locate the Great Barrier Reef and color it yellow. Explain that this is the largest structure built by living organisms on our planet. Tell them that it can even be seen from space.
9. Locate where the students live and mark it with a red dot.
10. Have students complete the "Find and Number" section by marking the locations on the map.
11. Review by asking students where most of the coral reefs occur in the world. Where are they located in relation to where the students live? Ask why they think there are no reefs at the North and South poles. Ask if any students have been to a coral reef. If so, ask them to locate it on the map. Do they know what kind of reef it was?

FOLLOW-UP/EXTENSION:

Have students draw their own reef formation (fringing, barrier, or atoll). Where would they locate it on the map? Have them describe what it looks like, both above and below the surface of the water. How did they get there? What are they doing? What is the water temperature? Is the water shallow and clear or murky and polluted? Why?

REEF FORMATIONS

The dotted areas represent coral.



1) This is a fringing reef where coral grows directly from the shoreline.

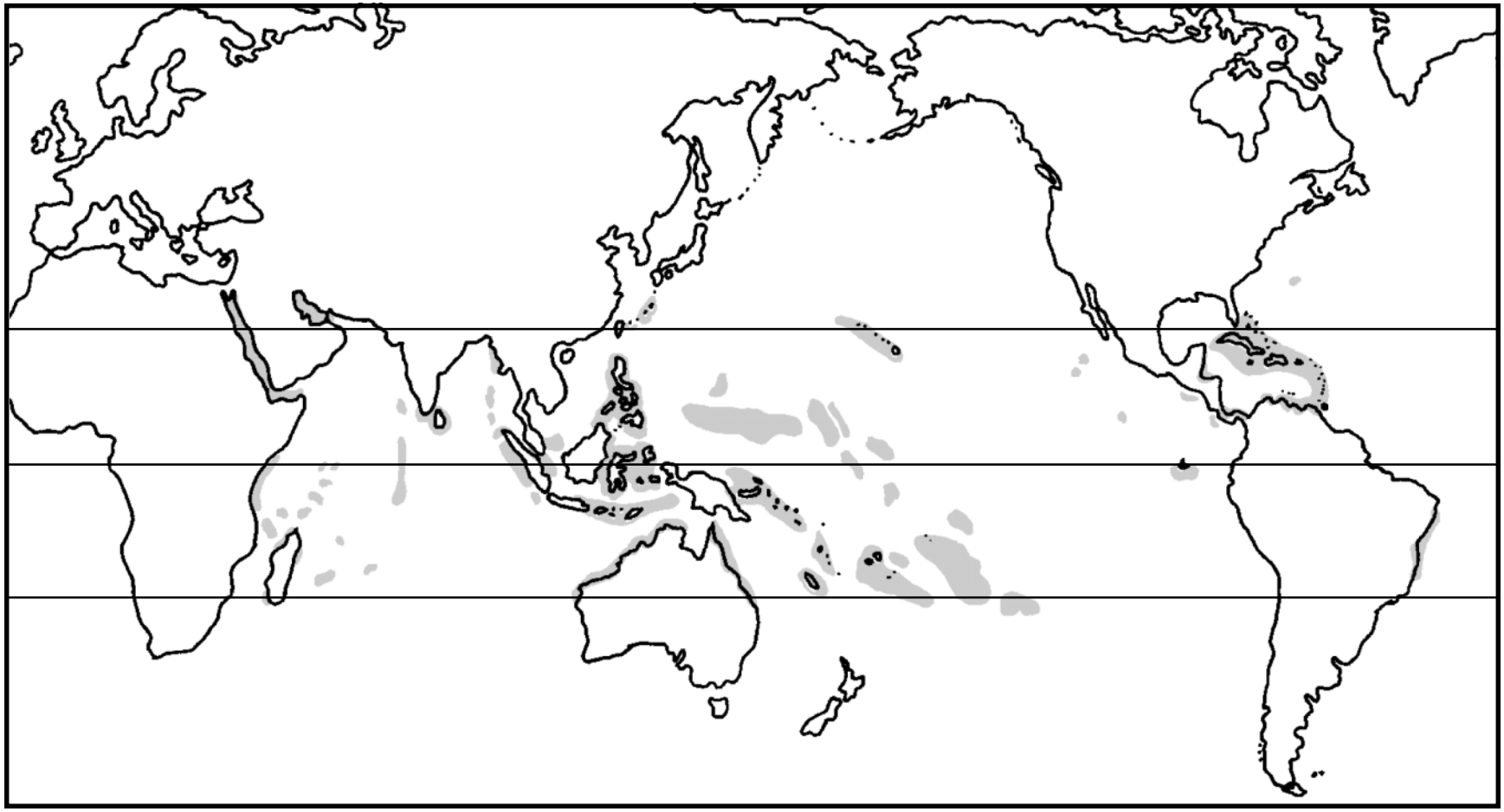
2) This is a barrier reef which is separated from shore by a lagoon.

   A barrier reef forms as the island sinks.

3) This is an atoll. Atolls form when the island sinks below the water, leaving a ring of small sandy islands and coral reefs around a central lagoon.

Color the fringing reef red, the barrier reef orange, the atoll purple, the land green, and the water blue.

WHERE IN THE WORLD ARE THOSE CORAL REEFS?



COLOR KEY TO THE MAP:

Coral Reefs - Pink
Great Barrier Reef - Yellow
Water - Blue
Land - Green
Where You Live - Red

FIND AND NUMBER:

1. Africa
2. Asia
3. Antarctica
4. Australia
5. Europe
6. North America
7. South America
8. Arctic Ocean
9. Atlantic Ocean
10. Indian Ocean
11. Pacific Ocean
12. Equator (0 degrees)
13. Tropic of Cancer (23°27' North)
14. Tropic of Capricorn (23°27' South)

Tempting Tentacle Problems

Objective: The students will use basic math skills to solve word problems related to corals.

Interdisciplinary Index: Science, Math

Vocabulary: octocoral, soft coral, hard coral, polyp, tentacles, colony

Materials:

- a copy of the **Tempting Tentacle Problems** worksheet, one for each student or pair of students
- pencils
- markers, colored pencils, or crayons (optional)

PRESENTATION:

1. Review the terms octocoral, soft coral, hard coral, polyp, tentacles, and colony.
2. Remind the students that octocoral polyps (soft corals) have eight tentacles. Hard coral polyps have tentacles in multiples of six.
3. Have students work out the **Tempting Tentacle Problems** individually or in pairs.

FOLLOW-UP/EXTENSION:

Have students make up their own **Tempting Tentacle Problems**!

Have students draw a picture to go with each problem.

ANSWERS:

Grades 1-2:

1. 3 tentacles
2. 16 tentacles
3. 18 tentacles
4. 32 tentacles

Grades 3-5:

1. 360 tentacles
2. 16,000 tentacles
3. 1,620 tentacles
4. 18,000 tentacles

TEMPTING TENTACLE PROBLEMS

(GRADES 1-2)

REMEMBER! Soft coral polyps have eight tentacles.
Hard coral polyps in these problems have six tentacles.

For each problem, draw a picture to help you find the answer.

1. There was once a hard coral colony growing on a coral reef. A parrotfish came along and bit off three tentacles from one of the hard coral polyps. How many tentacles did that polyp have left?

2. Two soft coral polyps grew next to each other. How many tentacles did they have altogether?

3. A crown-of-thorns sea star ate almost a whole hard coral colony. Only three hard coral polyps were not eaten. How many tentacles did these three coral polyps have?

4. One day a soft coral grew four new coral polyps. How many tentacles did these new coral polyps have altogether?

NAME: _____

TEMPTING TENTACLE PROBLEMS

(GRADES 3-5)

REMEMBER! Hard coral polyps have tentacles in multiples of six.
Soft coral polyps (octocorals) have eight tentacles.

1. There was once an awesome colony of hard corals on a reef in the Pacific Ocean. Each coral polyp in the colony had 12 tentacles. A very hungry parrotfish swam up and quickly munched down 30 coral polyps. How many tentacles did the parrotfish munch if he ate every tentacle on the 30 polyps?

2. A beautiful soft coral swayed gracefully in the water. Along came a boat that dropped its anchor on the soft coral. Sadly, 2,000 coral polyps had their tentacles crushed. How many tentacles were crushed by the careless anchor?

3. A huge hurricane brought rains that smashed into a coral reef. Many corals were crushed by the storm. After the storm was over, only one hard coral with 150 polyps and one soft coral with 90 polyps survived. Each hard coral polyp that survived had six tentacles. If all the surviving hard and soft coral polyps have all of their tentacles, how many total tentacles survived the storm?

4. The crown-of-thorns sea star is a main predator on hard corals. One day a crown-of-thorns busily ate three colonies of hard coral. Each colony had 1,000 polyps. Each polyp had six tentacles. How many tentacles did the crown-of-thorns sea star eat?

NAME: _____

Coral Reef Zones Color Page and 3-D Mural

Objective: The students will be able to identify the following coral reef zones:

a) Lagoon:
   Beach
   Mangroves
   Patch Reef
   Seagrass

b) Reef Crest

c) Reef Face:
   Upper Zone
   Lower Zone

They will also be able to name at least one life form found in each zone.

Interdisciplinary Index: Science, Language Arts

Vocabulary: coral reef zones, lagoon, reef crest, reef face, mangroves, beach, seagrass, patch reef, coral reef plants and animals

Materials:

For the Color Page:

- **Coral Reef Zones** handout for each student
- crayons, colored pencils, and/or markers

For the 3-D Mural:

- overhead projector
- transparency of **Coral Reef Zones** handout
- scissors
- glue
- tempera and watercolor paints
- paint brushes
- butcher paper (all colors)
- construction paper, tissue paper (optional)

PRESENTATION:

For the Coral Reef Zones Color Page:

1. Pass out a copy of the **Coral Reef Zones** to each student.
2. Provide each student with markers, crayons, or colored pencils.
3. Explain to the students that there are many parts to the coral reef, and that all of these parts are interconnected. We call the different parts "reef zones" (areas where different plants and animals live). Direct the student's attention to each reef zone and have him/her add animals and plants and color in each zone as you discuss it.

   a) The seaward facing slope of the reef is called the reef face. This is where life on the reef is most abundant. It is home to corals, fishes, sharks, turtles, and many other creatures.

   b) The reef crest is the highest and shallowest part of the reef. At low tide, shallow pools of water form among the coral and are home to nudibranchs, marine snails, crabs, sea stars, worms and small fishes.

   c) The lagoon is the protected body of shallow water between the beach and the reef. Many coral reef plants and animals live here on patch reefs and among the seagrass, like fish, lobsters, sea turtles, and small sharks. The seagrass serves as a nursery for young fish.

   d) Mangroves grow in the area where the land meets the sea. Mangrove roots grow in the saltwater and serve as an important habitat for many marine animals.

   e) Beaches are often formed from the breakdown of coral skeletons. Animals, such as sea turtles and certain birds, use the beaches to lay their eggs and build nests.

   f) Tropical rainforests often border the beaches. These rainforests are the home of thousands of plants and animals, such as parrots, monkeys, fruit bats, and snakes. Protecting the tropical rainforests also helps to protect the coral reefs. When rainforests are cut down, the sediment that was once held down by the plants and tree roots washes into the water and out to the reefs where it smothers and kills the coral.

   g) Have students draw a picture of their favorite coral reef creature in the box. You can use the **Sample Coral Reef Creature** as an example.

For the 3-D Coral Reef Zones Mural:

1. Make a transparency of the **Coral Reef Zones** handout.
2. Use an overhead projector to project the transparency onto white butcher paper (3 feet by 6 feet). Trace the **Coral Reef Zones** handout onto the paper, deleting the box and words.

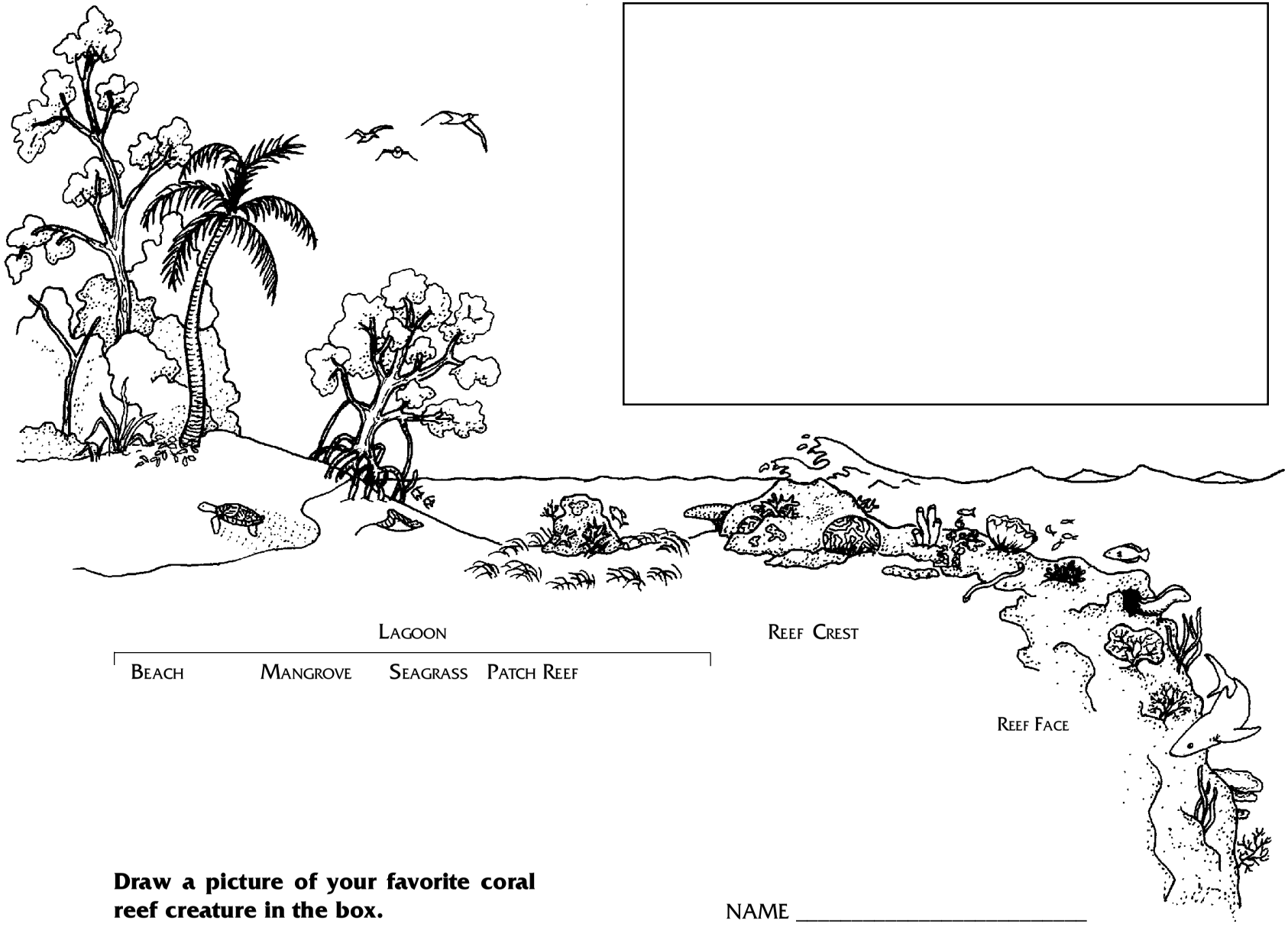
   (If you do not have an overhead projector, lightly trace the **Coral Reef Zones** handout onto the paper.)
3. Let the students work in groups of 6-8. This works well as a learning center activity. You will be creating three or four murals, depending upon the number of students in your class.
4. Have students use watercolors to paint in the water and sky.
5. Let other students use tempera to paint in the corals and other creatures on the sea floor.
6. Using brown butcher paper (or white paper painted brown), twist the paper into long strips that the students can form into mangrove roots and branches. Glue these onto the mural.
7. Have students design a coral reef creature of their choice on construction paper. The teacher can use the **Sample Coral Reef Creature** as an example. Color the creature. Place the colored sheet on top of a plain sheet of construction paper and cut both sheets out together into the shape of the creature. Have students glue the outlines of the creatures together, leaving an opening to stuff in newspaper. Stuff in the newspaper and completely glue the two sheets together. The finished creature should look 3-D, sort of like a pillow.
8. Let students put their finished creatures in the appropriate reef zones.

   (**Suggestion:** You might want to assign different creatures to each student corresponding to different parts of the reef zone. For example, some students might make only young reef fishes that live among the mangrove roots. Other students might make fish that feed on corals. Other students may create worms and sea stars that live on the reef crest, etc.)
9. Discuss the different reef zones and the interdependence of life in these zones.

FOLLOW-UP/EXTENSION:

1. Have students do reports on their creatures.
2. Have students look up more information on each of the coral reef zones and report to the class.

CORAL REEF ZONES



Draw a picture of your favorite coral reef creature in the box.

NAME _____

SAMPLE CORAL REEF CREATURE

Coral Reef Color Page and Mural

Objective: Students will study the abundant life of the coral reef by completing the color page and/or creating a mural.

Interdisciplinary Index: Art, Performing Arts, Language Arts

Vocabulary: coral reef, coral reef ecosystem, coral reef plants and animals

Materials:

For the Color Page:

- copies of **Coral Reef Color Page** handout (both sides) for each student
- crayons, color pencils, or markers
- construction paper
- glue

For the Mural:

- transparency of **Coral Reef Color Page**
- overhead projector
- white butcher paper, approximately 3 feet by 6 feet
- watercolors and tempera paint (option: crayons and/or markers)
- paint brushes
- **The Coral Forest: Diversity of Life on the Coral Reef** poster as a reference and color guide. (To order, refer to **Merchandise** information in the back.)

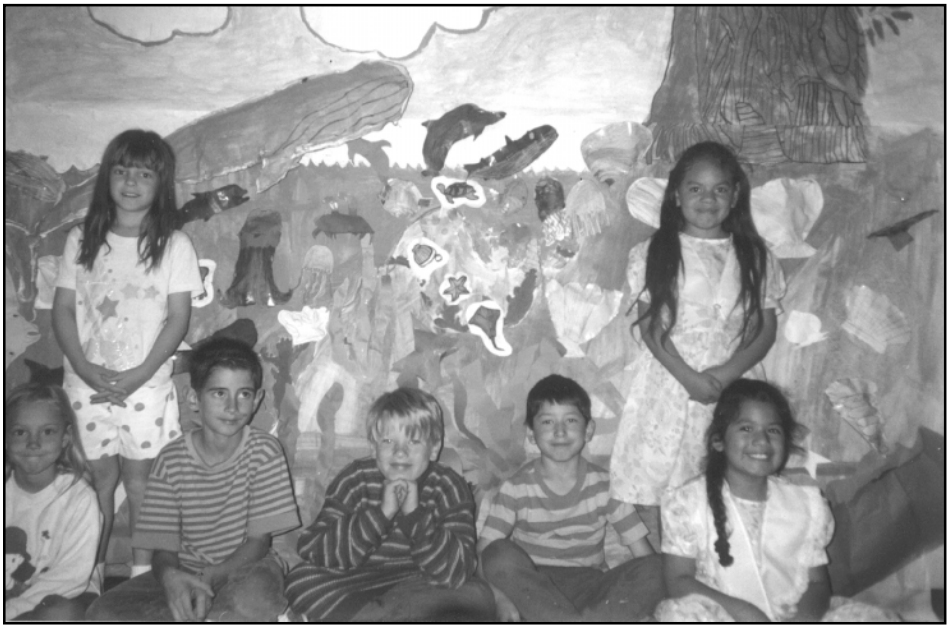
PRESENTATION:

For the Coral Reef Color Page:

1. Pass out a color page to each student.
2. Use the key on the back of the color page to identify the various coral reef plants and animals.
3. Remind students that all life in the coral reef is interrelated, and that the plants, animals, sand and rocks together make up the coral reef ecosystem. Discuss the role of various coral reef creatures pictured on the color page.
4. Have students color in the coral reef plants and animals. You can do this one at a time as you discuss them, or you can have some students color independently while others work on the mural. You can also enlarge different sections of the color page, have the students color them, then place them all together on the wall.

For the Coral Reef Mural:

This activity works best as a small group activity (6-8 children per mural). Use this as a learning center activity, or set up four separate murals that students can work on in small groups.



Coral Reef Mural, by students from Sea View Elementary School, Salton City, CA. (Photo: Joanne Hardesty)

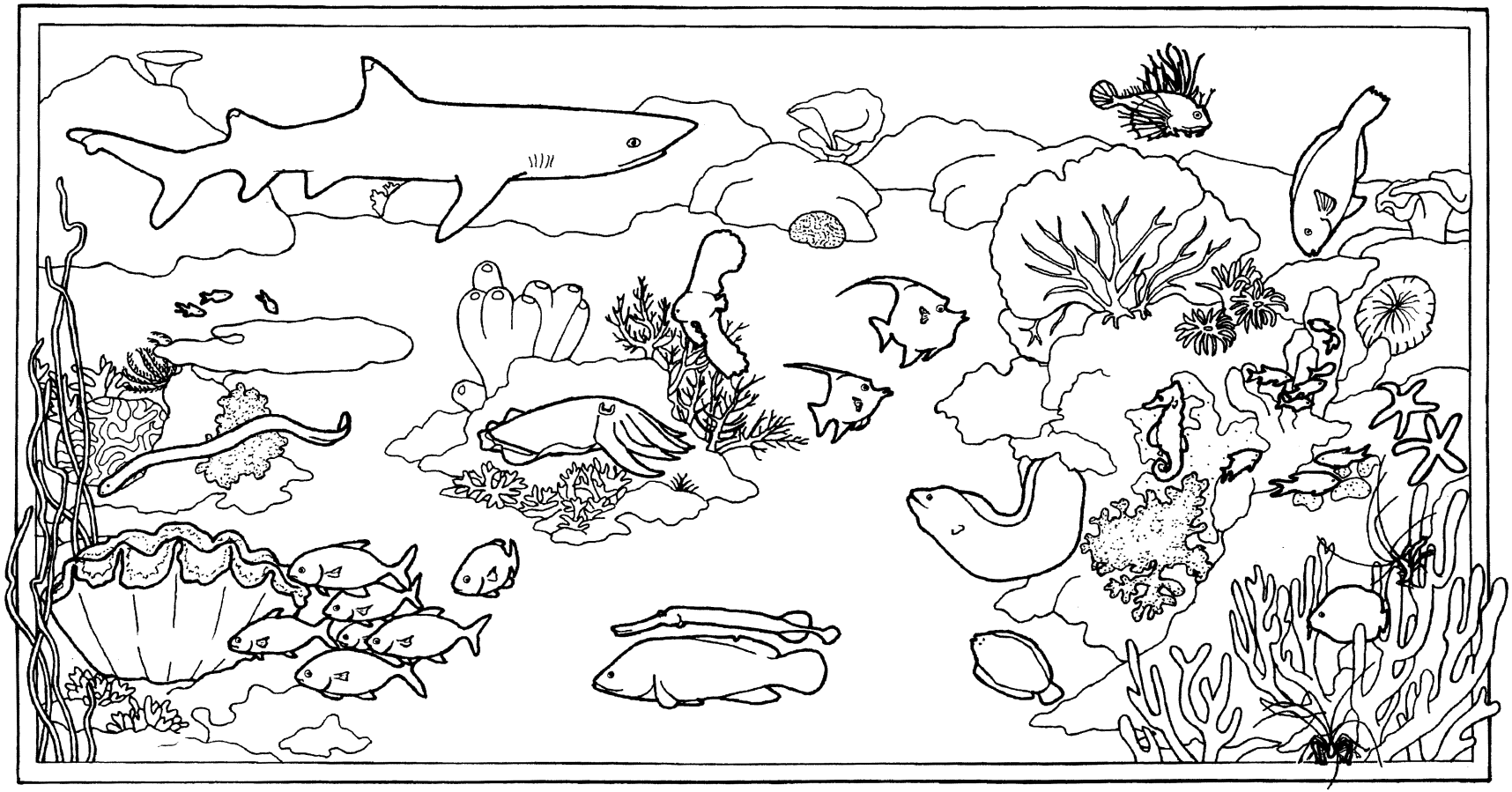
1. Make an overhead transparency of the **Coral Reef Color Page**.
2. Using an overhead projector, enlarge and trace the **Coral Reef Color Page** onto the 3 feet by 6 feet white butcher paper. (If you do not have an overhead projector, lightly sketch the **Coral Reef Color Page** onto the butcher paper.)
3. Give each student watercolors and/or tempera paint and paint brushes.
4. Have students paint in the background using light blue watercolor paints. This gives the mural an aquatic feeling. Show the students how to make wavy lines with the paints to create a sense of motion in the water. For a textured effect, try letting students use watercolor for smaller creatures and tempera for corals and larger creatures.
5. Display the mural(s) for everyone to see!

FOLLOW-UP/EXTENSION:

1. Glue completed color page/mural onto construction paper and let students cut up the color page/mural into a puzzle.
2. Have students work in partners, exchange puzzles, and reconstruct each other's puzzles.
3. Ask each student to choose one of the animals and act it out in front of the class. Have the class guess which animal it is.

CORAL REEF COLOR PAGE

THE CORAL FOREST: *Diversity of Life on the Coral Reef*



NOTE: See next page for information and Key to the Illustration.

CORAL REEF COLOR PAGE

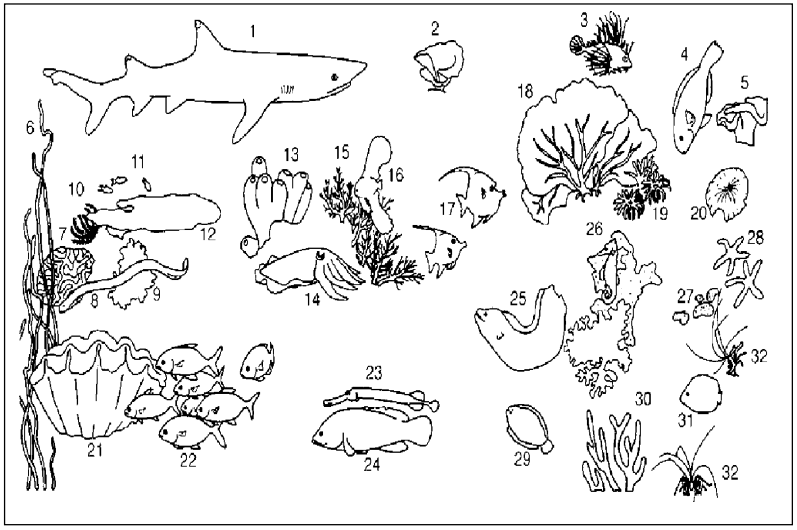
THE CORAL FOREST: *Diversity of Life on the Coral Reef*

Coral reefs were first formed more than 500 million years ago, and since that time they have successfully developed and supported a tremendous array of plant and animal life, earning them the name "rainforests of the sea." Today, reefs are found in 109 countries around the world; however, it is estimated that they are either destroyed or damaged by human activity in 93 of them. Like the rainforests, their survival is threatened. With the rainforests, they form an interrelated ecosystem whose health and balance is critical to ensure the biodiversity of species, protection of the coastlines, and an ongoing supply of food and medicinal resources. Enjoy the beauty of the coral reef, learn about its vast diversity of life, and help to preserve it for generations to come.

KEY TO THE ILLUSTRATION

Location: The Great Barrier Reef, Australia

Key Fact: The Great Barrier Reef is the largest structure built by living organisms on Earth, and it is the only living structure visible from outer space. Located along the northeast coast of Queensland, it is 1,240 miles (2,000 km) long and consists of more than 2,500 major reefs.



1. White tip reef shark
2. Lettuce coral
3. Butterfly cod (lionfish)
4. Parrotfish
5. Soft coral
6. Sea whips
7. Brain coral
8. Olive sea snake
9. Soft coral
10. Feather star
11. Damselfish
12. Plate coral
13. Vasiform sponge
14. Cuttlefish
15. Needle coral
16. Batfish (juvenile)
17. Moorish idol
18. Gorgonian fan coral
19. Sea anemone
20. Mushroom coral
21. Giant clam
22. Six-banded trevally
23. Trumpetfish
24. Coral cod
25. Yellowmargin moray eel
26. Spotted seahorse
27. Sponge
28. Blue sea star
29. Flowery flounder
30. Branching coral
31. Emperor angelfish (juvenile)
32. Banded coral shrimp

Coral Reef Life Cards

Objective: Students will learn about the various animals of the coral reef by using **Coral Reef Life Cards** in a series of games and exercises.

Interdisciplinary Index: Science, Language Arts, Art

Vocabulary: coral, coral reef, names of coral reef animals

Materials:

- copies of **Coral Reef Life Cards** for each student
- crayons or markers
- scissors
- construction paper
- glue

PRESENTATION:

Coral Reef Identification Game:

1. Copy one set of **Coral Reef Life Cards** for each student.
2. Cut out each **Coral Reef Life Card**.
3. Have students color the cards using crayons or markers.
4. Have each student hold up each card as you discuss a fact about the animal on the card. Refer to the following **Fact Sheet** for information.
5. When you are done, have each student hold up a picture of the animal that they like the best and discuss why they like it.

Coral Reef Memory Game:

Preparing for the Game:

1. Copy one set of **Coral Reef Life Cards** for each student.
2. Cut out each **Coral Reef Life Card**.
3. Glue the cards onto construction paper (optional).
4. Have students color the cards using crayons or markers.

Playing the Game:

1. Students put their cards together (two sets per two students).
2. Cards are shuffled face down and spread out in rows in front of the players.
3. Each player turns up two cards. If the cards match, the player keeps the pair and continues picking two cards at a time until he/she does not have a match. Unmatched cards are returned to their original positions in the row.
4. The game continues until all cards are matched.

CORAL REEF LIFE CARDS FACT SHEET

FOR USE BY THE TEACHER.

Blue Dash Butterflyfish - The butterflyfish is shaped like a thin pancake so that it can hide easily among the coral and be safe from predators. The blue dash butterflyfish is bright yellow with a blue streak on its body and a "fake eye" on its tail to confuse any predators that try to attack. The predator thinks that it is aiming for the head when in reality it is aiming for the tail, enabling the butterflyfish to swim forward quickly and escape.

Clown Triggerfish - The clown triggerfish is marked with large white polka dots which help to break up its outline and camouflage it against the reef. It is also very poisonous so predators do not try to eat it. The clown triggerfish attacks small reef animals, such as fish that hide in the sand and sea urchins, by blowing streams of water out of its mouth to uncover or overturn its prey.

Clownfish and Sea Anemone - The clownfish, a small orange damselfish often marked with one or two white stripes, has a symbiotic relationship with its partner, the sea anemone. The clownfish lives among the stinging tentacles of the anemone. The fish protects the anemone from being eaten by predators and drops bits of food into its mouth, and the anemone protects the clownfish with its poisonous tentacles.

Damselfish - Damselfish come in many colors, from dull brown and gray to brilliant yellow and blue. They are found abundantly on the reef and are very territorial. Some species are "farmers", actively guarding and growing small patches of algae on an area of coral to serve as a food source.

Giant Clam - The giant clam has a symbiotic relationship with its zooxanthellae, enabling it to grow its own food in the tissue of its mantle. It can reach more than 40 inches (1m) in length and weigh more than 1,000 pounds (453kg). Humans have destroyed populations of these clams in the Pacific, harvesting them for their meat and shells. Projects are now underway to farm giant clams and return them to the reefs.

Gray Reef Shark - The gray reef shark hunts for food along the coral reef during the night and rests in caves during the day. Sharks are powerful carnivores, hunting large and small marine animals including fish, crustaceans, and mollusks. Some of the larger species even hunt marine mammals, sea birds, sea turtles, and other sharks. Sharks have very sharp teeth, keen vision, and a highly-developed sense of smell. Although they are at the top of the food chain, most sharks are not dangerous to humans unless provoked.

Hard Coral - Hard coral builds reefs by secreting a hard external limestone skeleton. There are three types of hard (stony) corals: branching, massive and plate. Most hard coral polyps have tentacles in multiples of six and can be found individually or in colonies. During the daytime, the hard coral polyp retracts into its limestone base for protection but at night it comes out to feed on floating plankton.

Hawksbill Turtle - The hawksbill turtle is a species of sea turtle with its nose shaped like the sharp beak of a hawk. Most sea turtles are herbivores (vegetarians) feeding on seagrass. Many lay their eggs in nests on the beach. Sea turtles are endangered because many of them are caught and drowned in fishing nets each year, their eggs and flesh hunted for food, and their shells and skin used for ornament.

Lionfish - The lionfish has spectacular orange and white markings which help to camouflage it from predators, however the spines on its fins are highly poisonous. Lionfish are mostly stationary during the daytime but active at night, feeding primarily on crustaceans and small fish. Because of its beauty and uniqueness, it is often photographed by divers.

Mollusk - The mollusk is an animal with an unsegmented muscular "foot" that is protected by a

shell. This is a giant triton, the natural predator of the crown-of-thorns sea star which eats coral polyps. The triton has been overharvested for its meat and beautiful shell. Scientists believe that this might be one reason for the explosion in the crown-of-thorns population which has caused extensive damage to reefs in parts of Australia and the Philippines.

Moray Eel - The moray eel has a long muscular body that propels it through the water like a snake, and a large mouth with sharply pointed teeth. It hides in coral holes along the reef face where it waits for unsuspecting fish to come close enough to attack. It also eats mollusks and an occassional octopus. The moray eel is not dangerous to humans unless provoked.

Parrotfish - The parrotfish is often brightly colored with a hard beak that resembles a parrot's. It is an herbivore and uses its beak to attack the coral for food, scraping the limestone base to extract nutrition from the algae (zooxanthellae) in the coral polyps. The limestone base is digested along with the polyp, broken down in the stomach, then excreted as sand. The parrotfish is an important source of sand for tropical beaches.

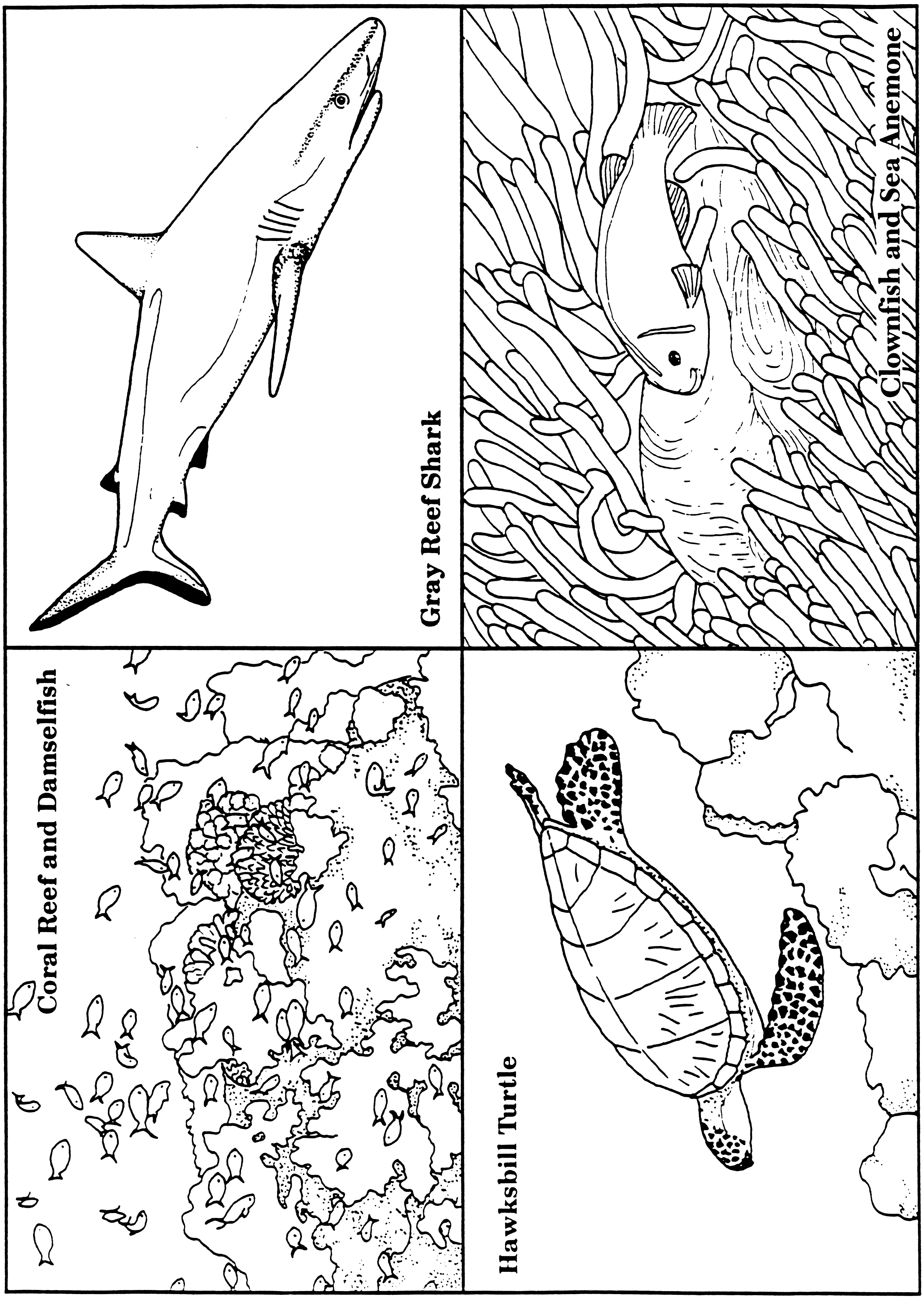
Plankton: Zooplankton and Phytoplankton - Plankton consists of microscopic drifting animals (zooplankton) and microscopic drifting plants (phtyoplankton) which are swept onto the reef face by upwelling currents from deeper parts of the ocean, supplying the reef life with easy access to food.

Sea Stars - Sea stars are characterized by radial symmetry wherein the body parts are repeated around a center, like the spokes of a wheel. They eat coral polyps and mollusks by wrapping their stomach and arms around the food. The crown-of-thorns sea star can be a threat to coral reefs because it eats the coral polyps, thereby killing the coral. If a sea star loses part of its body, it can grow the missing part back quickly.

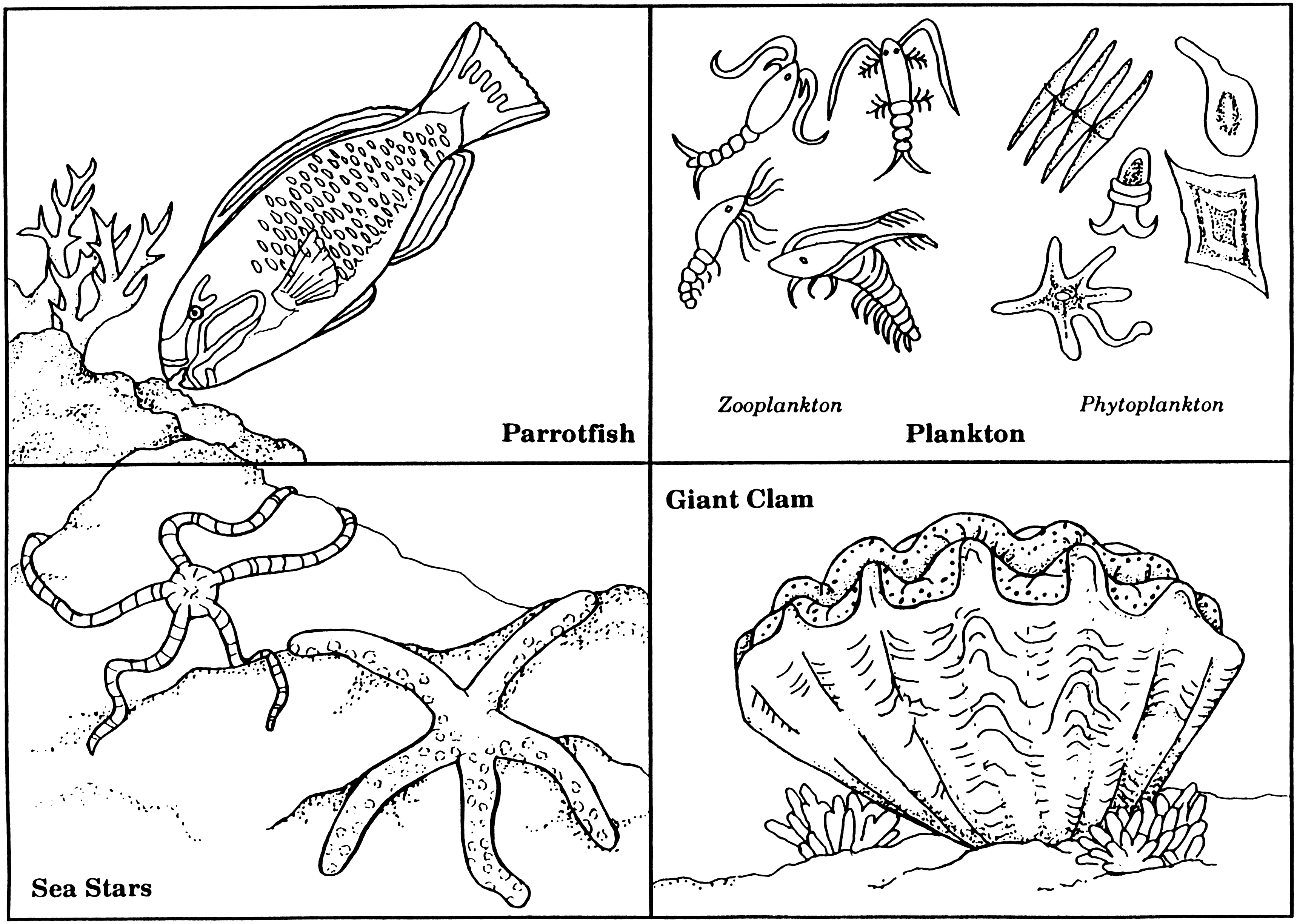
Soft Coral - Soft corals do not build reefs. They secrete a flexible or soft skeleton which enables them to bend and sway in the water. They are also known as octocorals because each polyp has eight tentacles. Soft corals thrive in strong currents where they have access to lots of plankton. They also grow in dark caves and overhangs where hard coral cannot grow.

Spotted Eagle Ray - The eagle ray is often found swimming gracefully along the perimeter of the reef face, either alone or in small groups. It has two wings or flaps and a long, hard tail with poisonous spines near the base. Its powerful jaws enable it to feed on mollusks, especially clams, mussels, and oysters. It is also hunted for food by native coastal people.

CORAL REEF LIFE CARDS



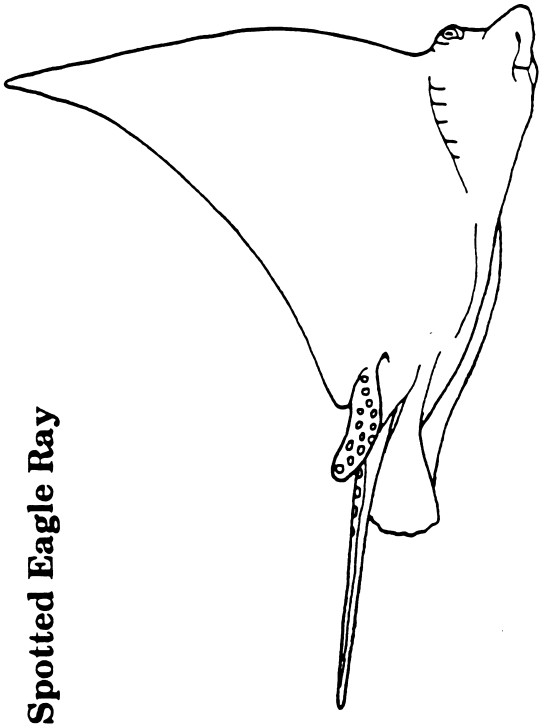
CORAL REEF LIFE CARDS



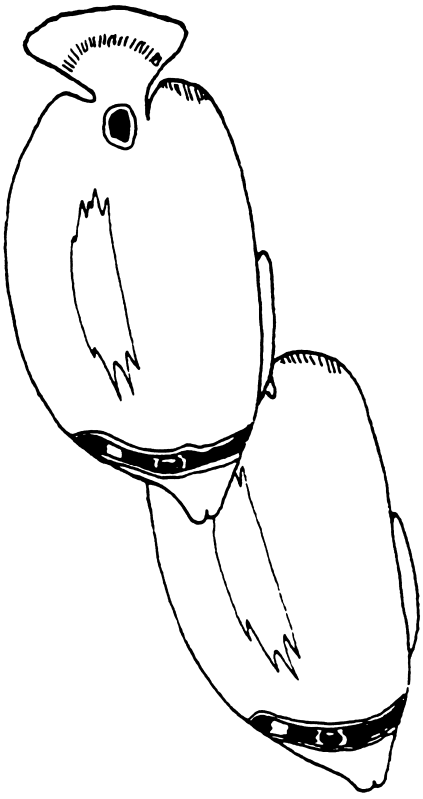
CORAL REEF LIFE CARDS

Mollusk

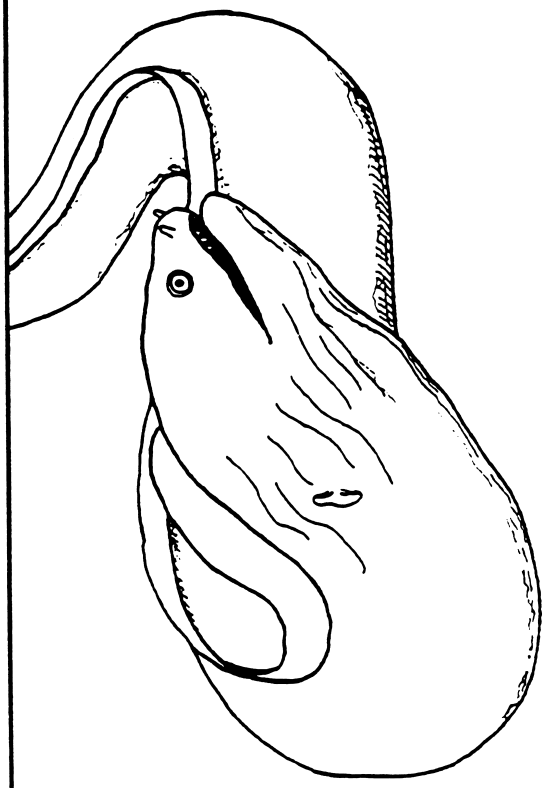
Spotted Eagle Ray



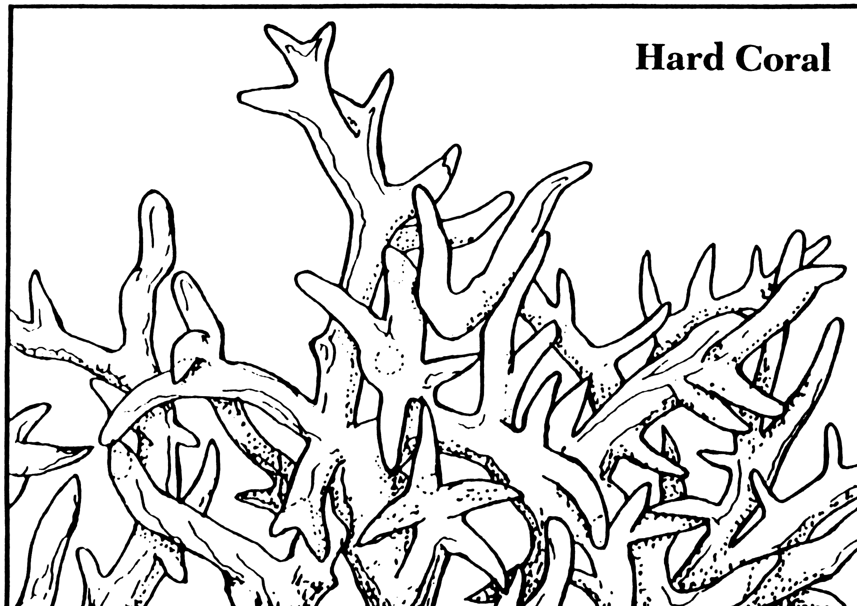
Blue Dash Butterflyfish



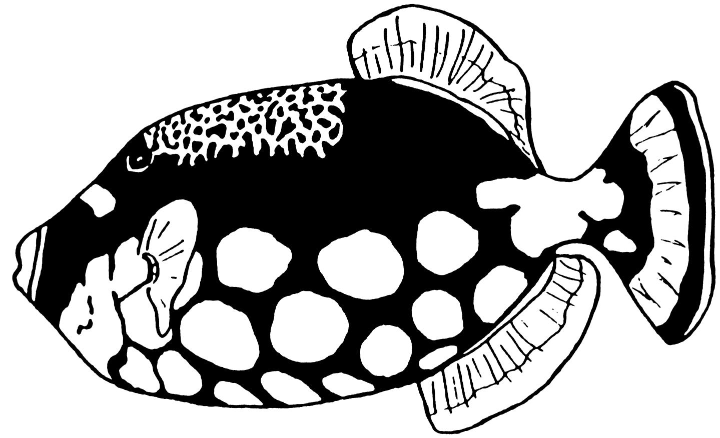
Moray Eel



CORAL REEF LIFE CARDS

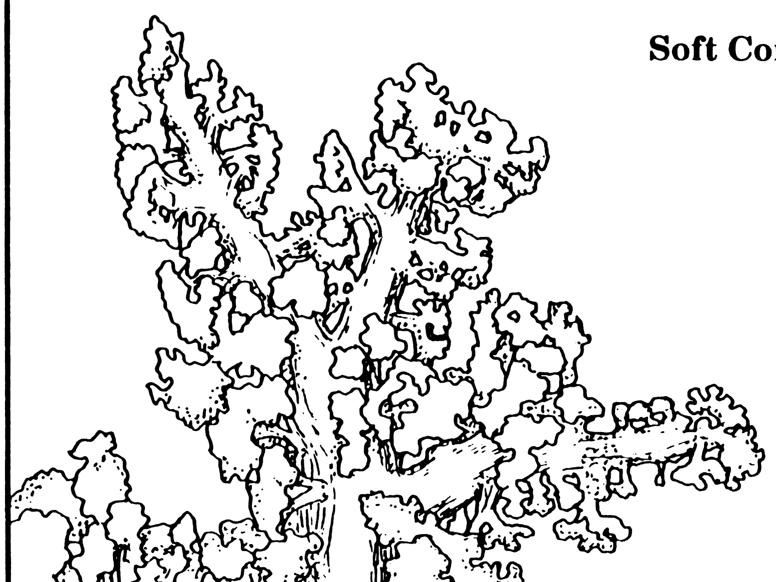


Hard Coral



Clown Triggerfish

Lionfish



Soft Coral

Coral Reef Poetry

Objective: Children will express the beauty of the coral reef using simple poetic formulas.

Interdisciplinary Index: Language Arts, Science, Art

Vocabulary: coral, coral reef, names of coral reef plants and animals

Materials:

- **Coral Reef Life Cards**
- paper
- pencils or pens
- poster board (optional)
- crayons

PRESENTATION:

1. Have students close their eyes and imagine that they are swimming among the creatures of the coral reef. AND/OR show the students the **REEF RELIEF Slide Presentation** or the videos listed in the **Resources** section of this **Guide**. AND/OR use the music side of the cassette tape that goes with **Baru Bay: Australia** by Bob Weir and Wendy Weir for aquatic inspiration.
2. Working as a whole class or in groups, let students discuss the underwater pictures evoked in their minds. Refer to the **Coral Reef Life Cards**. Then ask each student to contribute a word or short phrase to describe his/her thoughts. This "brainstorming" session is recorded on the chalkboard or a large piece of poster board for everyone to see.
3. Arrange students to work individually, in pairs, or in small groups.
4. Using words from the brainstorming session as well as additional words of their own choice, students will work individually or in groups to compose short poems. (See poem formulas on the following page.) Once the poems are complete, students should recopy the poems onto construction paper.
5. Each person in the group now adds a picture on the construction paper to illustrate the poem.
6. Each poem is now shared with the whole group.

POEM FORMULAS:

Haiku

First line of 5 syllables

Second line of 7 syllables

Third line of 5 syllables

Cinquain

First line — 1 word title

Second line — description of title in 2 words

Third line — 3 words that describe an action related to the title

Fourth line — 4 words that describe a feeling related to the title

Fifth line — 1 word that is a synonym of line 1 (means the same as the word in line 1).

Diamante

This is a poem formed in the shape of a diamond.

noun

adjective adjective

participle participle participle

noun noun noun noun

participle participle participle

adjective adjective

noun

(Beginning and ending nouns are opposites; the four nouns in the middle are related to the beginning and ending nouns.)

FOLLOW-UP/EXTENSION:

1. Bind all poems into a big book. (See **Loads of Life Big Books**.)
2. Share poems with other classes.
3. Use the poems for choral reading.
4. Send poems to elected officials to inspire coral reef preservation.
5. Give each child a **Coral Reef Life Card** and have him/her write a poem about his/her plant or animal.

SAMPLE POETRY

By Students from Sea View School, California

HAIKU:

Coral reefs are neat
Attaching, swaying, living
Endangered species.

— Ryan Dominguez
Age 11

The clownfish is bright
He swims in anemone
He hunts in poison.

— Andrea Staley
Age 11

One coral two and
Ten corals twenty corals
More and more and more.

— Maria Hardesty
Age 11

CINQUAIN:

Coral
Big grand
Flowing growing playing
Bright living greeting feeling
Invertebrates.

— Andrea Staley
Age 11

Coral
So hard
Swishing washing singing
Lovely atoll reef home
Limestone.

— Kyle Dinsmoor
Age 10

DIAMANTE:

Sharks
Some big, some small
Chewing, killing, swimming
Gills, scaly skin, sharp teeth, dark eyes,
Listening, eating, fighting
Ancient, silent
Sharks.

— Ryan Dominguez
Age 11

Coral
Hard soft
Growing dying living
Fish oceans seaweed sharks
Multiplying growing breaking
Hard soft
Coral.

— Maria Hardesty
Age 11

Coral Reef Pop-Up Cards

Objective: Students will create pop-up cards of coral reef creatures and write coral reef messages/facts to share with friends.

Interdisciplinary Index: Science, Art, Language Arts

Vocabulary: coral reef, coral, coral reef plants and animals

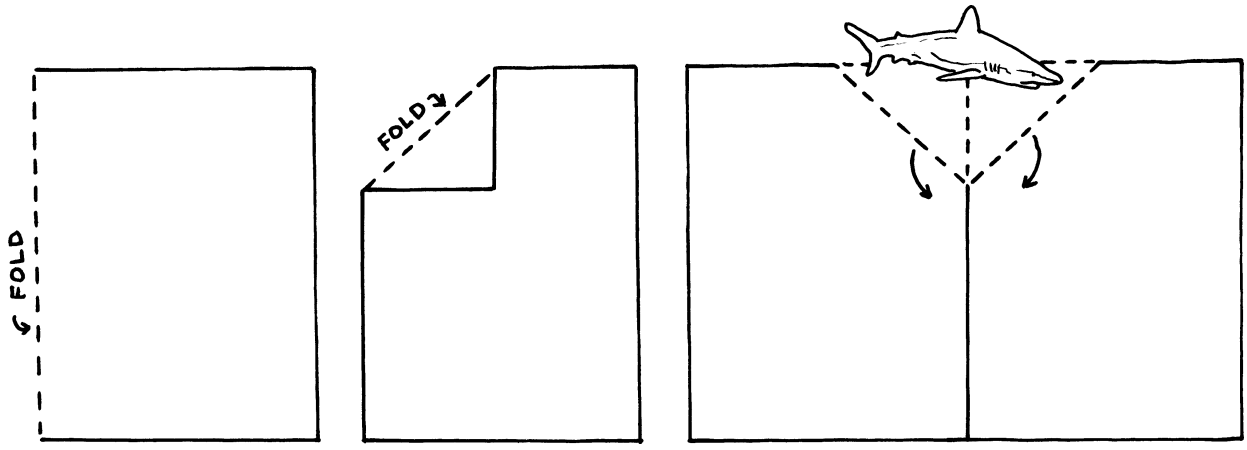
Materials:

- **Coral Reef Life Cards**, one card per student
- pencils
- crayons, colored pencils, markers
- scissors
- glue
- construction paper
- glitter, ribbons, buttons, other found materials (optional)

PRESENTATION:

Make a pop-up card before class so the students have a model to follow. Here is the basic pop-up pattern:

1. Fold card (8 1/2" x 11" works well) in half. Fold a triangle at the top corner, placing the fold 2 1/2" in from the top left corner.
2. Fold triangle towards you and away from you.
3. Open card and pull large triangle shape downward as you close the card. Reopen the card and lay flat on a table.
4. Cut out a **Coral Reef Life Card** and glue it between the left and right fold lines on the inside of the open card, as shown.
5. Fold and press the card down. Reopen.
6. Decorate the background to match the creature.
7. Add a catchy message to the front of the card. Example: What coral reef creature hunts at night? (open the card) A SHARK! (shark pops out).
8. Add an interesting creature fact to the front of the card. Have fun!



Coral Reef Connections

Objective: By taking on the roles of different coral reef animals, students will understand how animals in the coral reef ecosystem are interconnected.

Interdisciplinary Index: Science, Language Arts, Art

Vocabulary: names of coral reef animals

Materials:

- **Coral Reef Life Cards**, one card per student
- construction paper, all colors
- tissue paper (optional)
- glitter (optional)
- glue
- crayons
- scissors
- large ball of string
- one popsicle stick (or other stake, stick) per child

PRESENTATION:

Students will design a Coral Life Headband to wear while playing the **Coral Reef Connections** game.

Making the Headband:

1. Pass out a **Coral Reef Life Card** to each student. Explain that the student will use his/her imagination to create a headband to match his/her coral reef animal. One child should be chosen ahead of time to be the sun, and should create a headband to represent the sun.
2. Have each student color his/her **Coral Reef Life Card**.
3. Provide each student with a strip of construction paper, 1 1/2" x 24". Have the student measure the strip around his/her forehead to form a snugly-fitting band and glue the ends of the strip together.
4. Glue a **Coral Reef Life Card** onto the front of the headband.
5. Provide students with construction paper in colors to match their particular animal. Glitter and tissue paper are also fun to use if available. This activity works very well as a learning center where all supplies are readily available and the teacher monitors a small group of students at a time.
6. Tell the students that they are to decorate their headbands to match their animal card, so they feel like they are ready to become that animal. Explain that they will be speaking for the animal that they become. Once the headbands are finished, students are ready to play **Coral Reef Connections**.

Students from Sea View Elementary School, Salton City, CA, wearing Coral Life Headbands (Photo: Joanne Hardesty)

Playing the Game:

1. Have students put on their headbands.
2. Have them form a circle and sit down. Give each student a stake and have him/her either secure it firmly in the ground or hold the stake in his/her hand.
3. Have students look around the circle and think about how life in the circle is connected. Tell them that they have now become their animal, and they are to take turns passing a ball of string to an animal that they are connected to, saying the following:

   I am a _____. I am connected to _____ because _____. (Example: "I am the Sun. I am connected to the Hard Coral because I give its zooxanthellae energy to make food." Then the Hard Coral might say, "I am the Hard Coral. I am connected to the Butterflyfish because I try to protect it from predators." Then the Butterflyfish might say, "I am the Butterflyfish. I am connected to the Shark because he eats me." And so on.) Model this with the students, and then explain that as they make a connection, they are to wrap the ball of string securely around their stake and then pass it on to the animal that they are connected to. Tell them that it is okay to have more than one connection to each animal. As the game progresses, encourage students to involve each animal in the circle. The teacher can refer to the **Coral Reef Sample Connections** to assist the students.
4. After students have played for some time, have them stop and discuss which animals seem to have the most connections. Discuss why this might be the case. If done carefully, the web can be lifted up and actually saved for some time. It is fun to bring in another class and share the completed web with them.

FOLLOW-UP/EXTENSION:

Have students write a play about **Coral Reef Connections.** They can wear their headbands as costumes for the performance.

CORAL REEF SAMPLE CONNECTIONS

FOR USE BY THE TEACHER.

Sun - The sun is vital to the zooxanthellae in the hard coral and the giant clam for photosynthesis. Since hard coral forms the foundation of the coral reef, without sunlight coral reefs and all life dependent upon these reefs could not exist.

Blue Dash Butterflyfish - The butterflyfish uses camouflage for protection like the clown triggerfish and the lionfish. It can be eaten by the shark and the moray eel. Like the damselfish and the lionfish, it hides among the hard coral to stay safe from predators.

Clown Triggerfish - The clown triggerfish uses camouflage for protection like the blue dash butterflyfish and the lionfish. It is also poisonous like the lionfish, the sea anemone, and the spotted eagle ray so predators won't eat it. It can be eaten by the shark.

Clownfish and Sea Anemone - The clownfish and sea anemone have a symbiotic relationship with each other, like the giant clam and its zooxanthellae. The clownfish can be eaten by the shark and the moray eel. Like the polyps of the hard coral and soft coral, the anemone is an invertebrate with tentacles and a mouth. The anemone uses poison for protection like the lionfish, the clown triggerfish, and the spotted eagle ray.

Damselfish - Some damselfish farm algae on the hard coral. They also hide in its branches like the butterflyfish. It can be eaten by the shark and the moray eel.

Giant Clam - Like the clownfish and sea anemone, the giant clam has a symbiotic relationship with its zooxanthellae. Like the mollusk (giant triton) and the sea turtle, it has been overharvested by humans for its meat and shell. Like the hard coral, it contains zooxanthellae in the tissue of its mantle. It also eats plankton like the hard coral, the soft coral, and the spotted eagle ray.

Gray Reef Shark - The gray reef shark hunts for food at night like the polyps of the soft coral and the hard coral. It can eat the butterflyfish, the clown triggerfish, the damselfish, the clownfish, the lionfish, the parrotfish, the spotted eagle ray, and the moray eel. Some of the larger species hunt hawksbill turtles and other sharks. Sharks have sharp teeth like the moray eel, and like the moray eel, most sharks are not dangerous to humans unless provoked.

Hard Coral - Its polyps are eaten by the parrotfish and the crown-of-thorns sea star. Its branches protect the butterflyfish and the damselfish from predators. The damselfish farms algae on parts of it. It is an invertebrate with tentacles and a mouth like the soft coral and sea anemone. Its polyps come out to feed at night like the lionfish, the soft coral and the shark. Like the spotted eagle ray, the giant clam, and the polyps of the soft coral, it feeds on floating plankton. Like the giant clam, it contains zooxanthellae in its tissue which are dependent upon the sun for photosynthesis. Without the sun, there would be no coral reef and no reef life.

Hawksbill Turtle - Like the mollusk (giant triton) and the giant clam, it is protected by a shell and has been overharvested by humans for its meat and shell. Like the parrotfish, it is an herbivore (vegetarian). Like the gray reef shark and spotted eagle ray, it swims in the lagoon and along the reef face. Some sharks eat it.

Lionfish - The lionfish uses camouflage for protection like the clown triggerfish and the butterflyfish. It can be eaten by the shark and the moray eel. Like the damselfish and the butterflyfish, it hides among the hard coral to stay safe from predators. Like the sea anemone, the clown triggerfish, and the spotted eagle ray, it is very poisonous. Like the gray reef shark and the polyps of the hard coral and soft coral, the lionfish is mostly stationary during the daytime but actively feeds at night.

Mollusk - The mollusk is protected by a shell like the giant clam and the sea turtle and like them, it has been overharvested by humans for its meat and shell. Some types of mollusks are eaten by sharks, moray eels, and sea stars. It uses its "foot" to move itself over hard coral.

Moray Eel - Like the shark, the moray eel has pointed teeth and is not dangerous to humans unless provoked. It can eat the butterflyfish, the damselfish, the clownfish, and the lionfish.

Parrotfish - The parrotfish eats the algae in the hard coral polyps. Like the hawksbill turtle, it is an herbivore. It can be eaten by the gray reef shark.

Plankton: Zooplankton and Phytoplankton - Plankton is eaten by the hard coral, the soft coral, and the spotted eagle ray.

Sea Stars - Sea stars eat hard coral polyps and mollusks.

Soft Coral - Soft coral polyps eat plankton. Like the gray reef shark, the lionfish, and the polyps of the hard coral, the soft coral polyps are nocturnal, actively feeding at night. Like the sea anemone and the hard coral polyps, the soft coral polyp is an invertebrate with tentacles and a mouth.

Spotted Eagle Ray - Like the hawksbill turtle and the gray reef shark, the eagle ray swims in the lagoon and along the perimeter of the reef face. Like the sea anemone, the clown triggerfish, and the lionfish, it is very poisonous. Like the polyps of the hard coral and the soft coral, it eats plankton. It can be eaten by the shark.

Loads of Life
Big Books to Share

Objective: The student will create coral reef stories to share using **Coral Reef Life Cards** as inspiration for characters.

Interdisciplinary Index: Art, Language Arts, Science

Vocabulary: review names of coral reef animals

Materials:

- **Coral Reef Life Cards**, one per student
- white construction paper (12" x 18") — at least one sheet per student
- pencils, markers or crayons
- scissors
- glue

PRESENTATION:

1. Tell students that they will each be contributing one page to a big book about coral reef life.
2. Review the role of each of the coral reef animals pictured in the form of a guessing game. (Example: Who remembers how a parrotfish eats?) Please see **Background Information** for facts about coral reef animals.
3. Give each student one **Coral Reef Life Card**, one sheet of construction paper, drawing materials, scissors, and glue.
4. Have the student think of a caption to go along with his/her animal. The student then copies the caption neatly at the bottom of the page. (For younger students, the teacher may choose to copy the sentence onto the page for the child.)
5. Have the student plan a coral reef scene to go with the animal and its caption.
6. The student then cuts out the animal, glues it onto the paper, and draws a scene around it.

   (Steps 4, 5, and 6 can be done in any order).
7. Once all students have finished their pages, the teacher or a student adds the title page. It is recommended that the covers be laminated.
8. Bind the book at the top, using either a book binding machine or punching three holes at the top of the book and lacing yarn or metal rings through the holes. This is an excellent way to create a number of big books for the class library.

FOLLOW-UP/EXTENSION:

Once you have created a big book together, try one or more of the following variations:

1. Have students work together in cooperative groups. Divide the animal cards evenly among the students and have them brainstorm a story using all the cards. Have one student act as a recorder to write down the story line. Each student creates the pages for his/her cards.

   Have the group design a title page. Bind all pages together.
2. Each student can use all of the animal cards to create his/her own book.
3. Choose only one type of animal and have the students brainstorm a story with only one main character. (Example: **The Adventure of the Timid Sea Turtle.**)
4. The students can then take their big books to other classrooms to share. This works especially well when older students create the big books and share them with the younger grades.

Sample That Reef Life!

Objective: Students will sort out the different types of coral reef creatures (represented by "found" objects) and find the number of individuals of each type of creature.

Interdisciplinary Index: Science, Math, Language Arts

Vocabulary: spiny lobster, clownfish, angelfish, sea turtle, moray eel, shark, sample, endangered species

Materials:

- different types of small "found" objects, such as shells, pebbles, beans, bottle caps, seeds, etc.
- a large container for mixing objects
- paper
- pencils

PRESENTATION:

1. Teacher mixes found objects together in a large container.
2. Give each student (or pair of students) a large handful of the found objects. Explain that these objects represent a sample of the different kinds of animals that live on the coral reef (Reef 1).
3. Write the following chart on the board or a large sheet of paper for the class to see:

★ Animal	Found Object
* spiny lobster	bottle cap
clownfish	bean
angelfish	small rock
* sea turtle	shell
moray eel	seed
shark	small piece of wood

★ The teacher may substitute the marine life and found objects in her/his area for the animals and objects listed.

* Add only a few found objects to represent these species since they are endangered or threatened.

4. Have students sort out each type of object into separate piles.
5. Have each student count the different objects and make a chart like this one.

Reef 1:

Kind of Animals Found	Number of Each Kind
spiny lobster	2
shark	5
clownfish	8
sea turtle	0
moray eel	2

6. Have student put a ★ next to the most abundant animal and an ⊗ next to the least abundant animal.
7. Discuss the findings. Ask students to explain why they think a certain animal might be more/less abundant on the reef. Introduce/review the concept of endangered species. How/why does this happen?
8. Gather up the found objects and repeat the activity. Tell students they are now taking a sample from a different reef (Reef 2). Students can then compare their two charts.
9. Older students can use their charts to write a story about the differences/similarities between the two reefs.

FOLLOW-UP/EXTENSION:

Have students create a bar graph or pie chart representing the number of individuals of each type of creature.

Careful With Your Plastics!

Objective: Students will identify plastic items that are often thrown away, and discuss how these items can be harmful to coral reef creatures. Students will discuss how these items should be recycled, reused, or reduced (used less).

Interdisciplinary Index: Science, Language Arts

Vocabulary: recycle, reuse, reduce, plastic, pollution, coral reef plants and animals

Materials:

- **Coral Reef Life Cards**
- plastic items (food containers, six-pack rings, grocery bags, plastic forks, fishing line, sandwich bags, etc.)
- **Plastics Worksheet**, one for each student

PRESENTATION:

1. Tell students that every day, people all over the world throw unwanted things (trash) on the ground and in the water. At sea, careless boaters often dump garbage over the side of the boat. People visiting the seashore sometimes leave piles of trash on the beach which can be swept into the ocean by wind and waves. In this way trash can end up on the coral reef and sea creatures can be killed when they try to eat it. For example, sea turtles think that plastic bags look like jellyfish, and eat the bags. Small sea creatures can become trapped in plastic containers dumped in the sea. Other animals become hopelessly tangled in nylon fishing lines and nets. Thousands of animals die each year when they are caught in plastic six-pack rings, causing them to be choked or cut.
2. Display the **Coral Reef Life Cards** in front of the class.
3. Have a sack with the plastic items listed above in it.
4. Have a student pull out a plastic item from the sack, and explain how it would harm one of the coral reef animals on display.
5. When you have gone through all of the plastic items, discuss how each of the items could be reused, recycled, or reduced (used less). Discuss alternatives to the disposable plastic items.

   Examples:

   - plastic grocery bags: use canvas bags instead to reduce plastic use
   - plastic fork: use metal silverware, even when on vacation
   - plastic six-pack ring: always cut up six-pack rings and dispose of properly
   - plastic food containers: reuse for other things or recycle
   - plastic sandwich bags: use reusable food containers instead

   Encourage students to be creative at reusing plastic items!
6. Pass out the **Plastics Worksheet**. Have each student complete it and share his/her completed worksheet with the class.

FOLLOW-UP/EXTENSION:

Have students check the use and disposal of plastic items at their homes and report to the class.

PLASTICS WORKSHEET

Plastic trash can be very dangerous to coral reef creatures.

Draw a picture showing different plastic things that are sometimes thrown away at sea.

Choose one of the plastic items you just drew and show a coral reef creature in trouble because of that item.

Now draw a picture showing how you can reuse or recycle your plastic garbage so that it doesn't end up in the ocean!

Coral Reef Word Find

Objective: Students will review and become familiar with words related to the coral reefs in the **Benefits, Threats and Solutions** section of the **Background Information**.

Interdisciplinary Index: Language Arts, Science

Vocabulary: food, shelter, beach, tourism, medicine, hurricane, sediment, disease, cyanide, dynamite, pollution, boats, divers, extinct, endangered, cleanup, sustainable, sanctuary, conserve, education

Materials:

- A blank **Coral Reef Word Find**, one for each student
- pencils

PRESENTATION:

1. Review the vocabulary.
2. Tell students they are going to make their own **Word Find**.
3. Have students place the review words (one letter in each square) randomly across or down on the grid.
4. When all of the words have been placed on the grid, students will fill in the empty squares with letters.
5. Have students exchange **Word Finds** and solve.

FOLLOW-UP/EXTENSION:

Give each student another **Word Find** sheet as homework. The student can make a word find for a friend or relative to solve. Encourage students to add their own coral reef words.

CORAL REEF WORD FIND

NAME _____

Use the words related to coral reef benefits, threats, and solutions to make a word search. See if someone else can solve your puzzle.

food	hurricane	pollution	cleanup
shelter	sediment	boats	sustainable
beach	disease	divers	sanctuary
tourism	cyanide	extinct	conserve
medicine	dynamite	endangered	education

Unsettling Sediments

Objective: Through experimentation, students will understand how the destruction of tropical rainforests can cause extra amounts of soil to be washed onto the coral reefs, resulting in damage to the reefs.

Interdisciplinary Index: Science, Language Arts

Vocabulary: sediment, coral reef, tropical rainforest, clear-cut

Materials:

- a clear, large jar
- water
- small, clear container filled with muddy water
- household sponges (you can use various colors of sponges to represent coral reefs)
- rock to weight down the sponges (option: if sponges are not available, rocks can be used instead).

PRESENTATION:

1. Tell the students that corals grow in very clear, clean water. Discuss rainforest vegetation. Explain that when it rains, the plant and tree roots help to hold the soil in place. When the forest and trees are cut down, the soil washes into the water and eventually reaches the coral reef. Coral polyps can survive if some soil washes on top of them and is then swept away by the current. However, when too much soil remains on the coral polyps, it smothers them. A whole coral reef can be killed in only a few weeks.
2. Cut several household sponges into various shapes resembling coral and place them on the bottom of a clear glass or plastic jar. Weight the sponges down with a rock, then fill the jar with water.
3. Tell students to imagine that the sponges are corals.
4. Ask students to imagine that they are in a tropical rainforest. Tell them that bulldozers are coming to cut the trees down. Have students make sounds of bulldozers and trees crashing to the ground.
5. Tell students that all of the trees have been clear-cut and that the soil is now exposed.
6. Have students imagine that a big rain storm comes in. Have them make the sounds of a storm.
7. Stop here and ask the students what they think will happen to the soil.
8. Explain that the rain washes the soil into the water and currents carry it out to the reef.
9. Pour the muddy water into the jar of clear water. Tell the students that this is sediment washing onto the coral reef because trees have been cut down.
10. Explain that when water loaded with extra sediment drifts onto the coral reef, the added dirt smothers the corals.
11. Watch the sediment spread throughout the jar.
12. Notice how the "corals" become covered with sediment. Imagine the polyps trying to survive with all of that dirt on top of them.

FOLLOW-UP/EXTENSION:

1. During the day, observe how the sediment settles onto the "coral reef". Keep track of how long it takes for the water at the top to become clear.
2. Have students write a letter to a world leader explaining the importance of the tropical rainforests to the coral reefs based on this lesson. Younger students can draw a picture of corals being smothered by sediment.

How You Can Help Reef Relief!

Objective: Students learn that there are many things that they can do to help preserve life on the coral reefs. They use their knowledge of anthropogenic threats to coral reefs to communicate their concerns to elected officials.

Interdisciplinary Index: Science, Language Arts, Political Science

Materials:

For the Direct Action Letter:

- a copy of the **Sample Direct Action Letter**, one per student
- pencils/pens
- paper

For the Artwork for the Reefs:

- a copy of the artwork page, one per student
- crayons, color pencils, or markers

PRESENTATION:

1. Choose one or more of the current threats to coral reefs and discuss with the students. Also, discuss the value of taking direct action as a way to protect the reefs. Review the **Sample Direct Action Letter**.
2. Based upon this information, ask the students to write a direct action letter and/or color the **Artwork for the Reefs** page. Students can also create their own page of coral reef art. Have them imagine that they are snorkeling or diving on a coral reef and describe or draw the scene around them. Is it beautiful? Is there pollution or damage?
3. Send the finished letters and/or artwork to elected officials. (Ask them to protect our coral reefs.) Then, wait and see if they respond.

Sending the direct action letters and artwork to elected officials does have a tremendous impact. In California, it is estimated that for every person who writes a letter to a Senator, there are 5,000 other people who have not written letters but share the same view. Here are some addresses to get you started, along with the one on the sample letter.

Name
President of the United States
The White House
1600 Pennsylvania Ave. NW
Washington, DC 20500

Name
Vice President of the United States
United States Senate
Washington, DC 20510

Your Senator _____
United States Senate
Washington, DC 20510

Your Representative _____
U.S. House of Representatives
Washington, DC 20515

Name
Administrator
Environmental Protection Agency
401 M Street, SW
Washington, DC 30460

For specific information about current coral reef threats and whom to write, contact REEF RELIEF at tel: (305) 294-3100, fax: (305) 293-9515, e-mail: reef@bellsouth.net, or go to our web site:
http://www.reefrelief.org

SAMPLE DIRECT ACTION LETTER

Students can use any or all of the suggested sentences below to create their own direct action letters.

President
The White House
1600 Pennsylvania Avenue, N.W.
Washington, DC 20500

Dear Mr. President:

I am writing to ask you to please protect America's coral reefs in _____*(Florida; Hawaii)*. Coral reefs are important to people because _____ *(they protect shorelines from crashing waves; they are a source of medical treatments; they are beautiful places to study and enjoy)*.

I have visited a coral reef in_____ *(location)*. I saw _____ and _____ *(colorful coral and sponges; pretty fish; endangered turtles; sharks)*. My favorite part was _____ *(seeing a funny-looking trunkfish; swimming with all the marine creatures; taking underwater pictures)*.

I have never visited a coral reef, but I would like to one day. I can't wait to _____ *(see a shark; swim underwater with all the colorful fish; take underwater pictures)*. I hope there will still be reefs to visit by then!

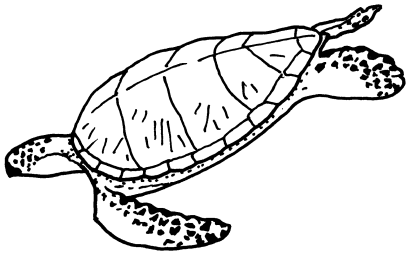
Many people make their living from coral reefs through _____ and _____ *(fishing; tourism)*. Healthy reefs are important for their survival.

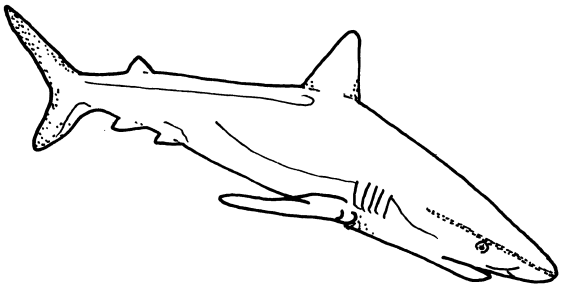
Thousands of different kinds of marine plants and animals depend on coral reefs for food and a safe place to live. But, _____, _____ and _____ are destroying coral reefs *(pollution; sewage; siltation from deforestation; development; careless boaters and divers)*. Please do everything you can to stop the destruction. Please protect our environment and our coral reefs.

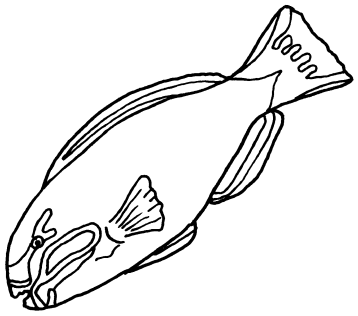
Sincerely,

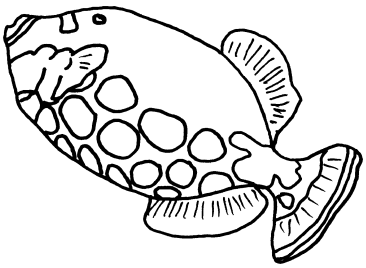
Student's Name
Grade
Name of School
City, State

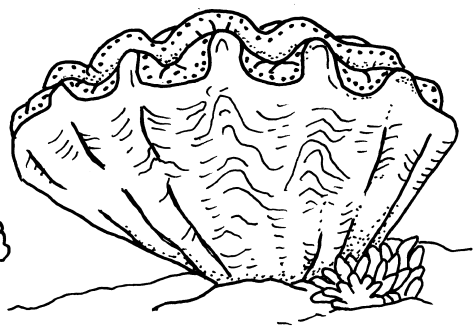
ARTWORK FOR THE REEFS

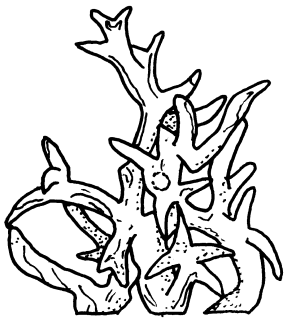












Student Assessment

Tell and Show What You Know

Objective: Students will review what they have learned about the coral reef by illustrating their knowledge and sharing it with others.

Interdisciplinary Index: Science, Language Arts, Art

Materials:

- writing paper or butcher paper for each student
- colored pencils, pens, crayons, and felt pens

PRESENTATION:

1. Have students fold paper into 4, 8, or 16 equal parts.
2. Tell students that they are to think of the 4, 8, or 16 most interesting things that they have learned about the coral reefs.
3. Have students draw or write down their thoughts in the 4, 8, or 16 parts of the paper.
4. Have students share their thoughts/pictures in small groups or with the class.
5. The finished product can be used as a mural.

FOLLOW-UP/EXTENSION:

Ask students to repeat the activity based on one of the following formats:

What would happen if...

What would you do if...

How I can help...

The 4, 8, 16 most interesting coral reef creatures are...

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PUZZLES AND STAMPS

Life In the Coral Reefs. New York: Judy/Instructo, Simon & Shuster. 50 piece floor puzzle.

Life On a Coral Reef. National Geographic Society, (800-647-5463, Product no. 81154) 1994. 33 rubber stamps depicting marine life on a coral reef, sticker labels, and a washable blue ink pad.

Ocean World Puzzle. Hope, Arkansas: Fink & Co./ EDUCA. 100 large size pieces with an illustrated guide to identify marine life.

VIDEOS AND SLIDES

Cities of Coral. Stamford, Connecticut: NOVA Video Library, 1975. (Footage of Caribbean coral reefs, available for rental at Blockbuster Videos.)

Coral Forest Slide Show. San Francisco: Coral Forest (415) 788-REEF; color slides with scripted presentation, one for K-5 and one for 6-12.

Coral Sea Dreaming–an Evolving Balance on Australia's Great Barrier Reef. Nashville, Tennessee: Small World Music (800-757-2277), 1993. 55 mins. (Excellent footage of the Great Barrier Reef without narrative. Outstanding for bilingual/multilingual classrooms.)

Dive to the Coral Reefs, A Reading Rainbow/PBS Home Video. New York: Lancit Media Productions., Ltd., 1992.

Life on the Reef. Nashville, Tennessee: Small World Music (800-757-2277), 1994. 53 mins. (Excellent narrated footage of life on the Great Barrier Reef, with incredible coverage of coral spawning.)

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THE CORAL REEF TEACHER'S GUIDE

LESSON PLANS FOR 6-8:

- **What and Where are the Coral Reefs?**
- **Life on the Coral Reef**
- **Benefits, Threats, and Solutions**

Gray angelfish. (Photo: Larry Benvenuti)

Introductory Lesson

Objective: Students read about and review some basic background information about **What and Where are the Coral Reefs?**

Interdisciplinary Index: Science, Language Arts

Vocabulary: coral reefs, Great Barrier Reef, polyp, nematocysts, herbivore, carnivore, spawning, planula, budding, octocorals, soft coral, hard coral, external skeleton, symbiotic relationship, zooxanthellae, fringing reef, barrier reef, atoll, coral reef regions

Materials:

- pencils/pens
- copies of **What and Where Are The Coral Reefs** section in the **Background Information** (the number depends upon how you want to present this information)
- copies of the **Review Worksheet** for each student

PRESENTATION:

1. Read the background material. Select a method that is best for your class, having the students read individually, in small groups, or as a whole class.
2. Have students complete the **Review Worksheet**. This can be done while you read the information or as a review after the reading.

REVIEW WORKSHEET

1. How do polyps eat?

2. Explain the two ways polyps reproduce.

3. What is the difference between soft and hard corals?

4. Describe the symbiotic relationship between the zooxanthellae and the polyps.

5. What is the difference between a fringing reef, a barrier reef, and an atoll?

Mapping the Reefs

Objective: Students locate coral reefs on a world map.

Interdisciplinary Index: Geography, Science

Vocabulary: longitude, latitude, equator, tropic of Cancer, tropic of Capricorn

Materials:

- a map of the world
- a copy of the coral reef map, Figure 1-6, on page 1-6 of the **Background Information**, per group of two students
- copies of the **Coral Reef Map** and the **Geography Map Key** (one for every two students)
- two copies of the list of **Geography Clues**
- thin color markers (ink pens may be substituted)

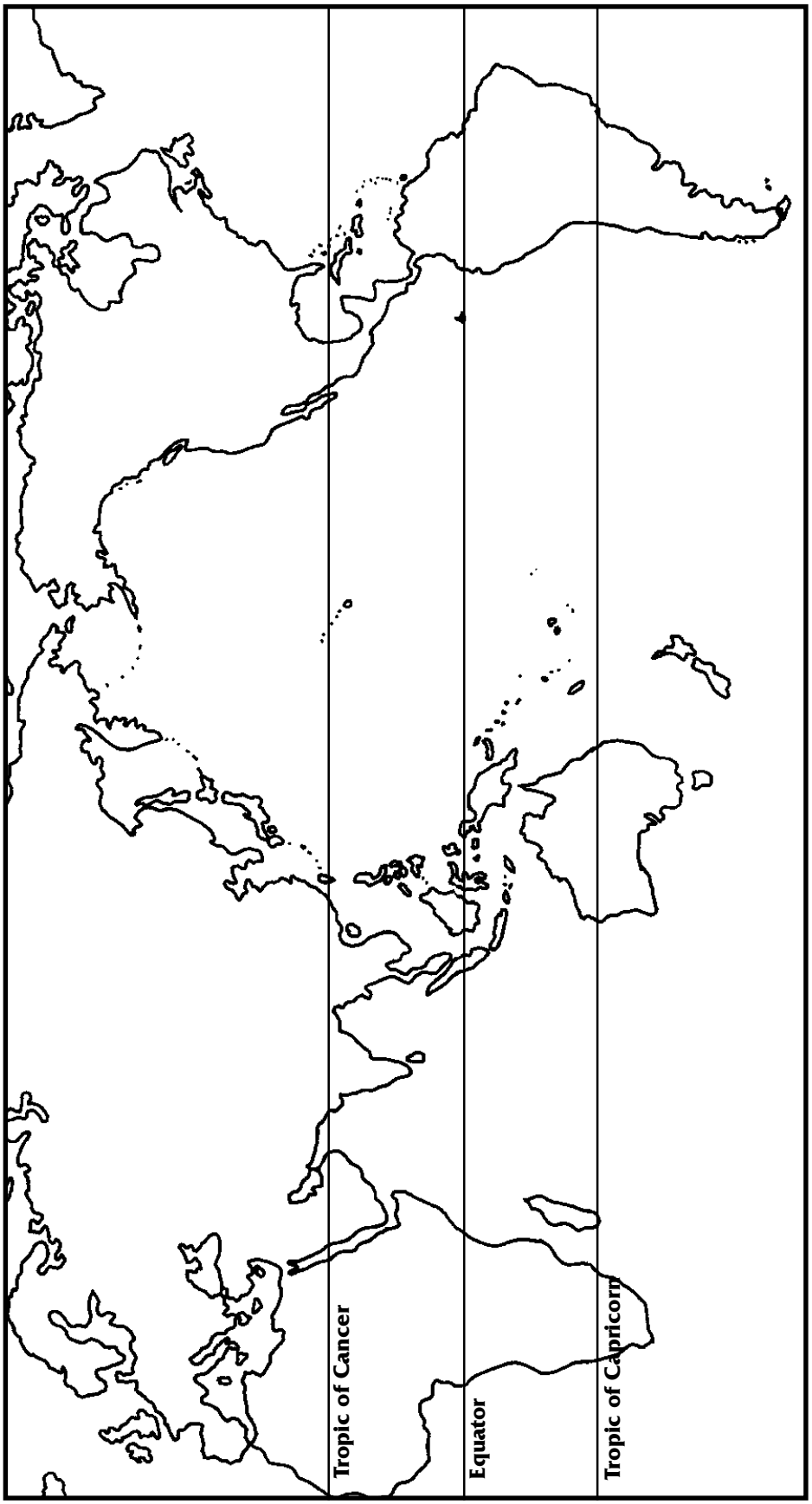
PRESENTATION:

1. Before class, cut the two copies of the **Geography Clues** sheet into strips with one clue per strip.
2. Divide the class into groups of two.
3. Hand out a copy of Figure 1-6, a **Coral Reef Map**, and a **Geography Map Key**, one for every two students. Hand out one clue strip per group.
4. Referring to the coral reef map, Figure 1-6, students should mark the location of coral reefs around the world using a colored marker. Referring to the world map, students then need to answer the geography clues and mark their location on the **Coral Reef Map** with the clue number.
5. Then they should record the name of the location on the **Geography Map Key**. The number of letters in the location will also serve as a clue.
6. After completing both of these steps for a clue, one member of the team should exchange the original clue for another clue. This process should be repeated until all thirteen clues have been used.
7. As each group completes the locating and recording section, have them work together (or separately) to complete the follow-up question.

ANSWERS TO GEOGRAPHY CLUES:

1. Bahama Islands
2. Belize
3. Caribbean
4. Madagascar
5. Pacific
6. Great Barrier Reef
7. Jamaica
8. Panama
9. Florida
10. Hawaii
11. Philippines
12. Red Sea
13. Marshall Islands

CORAL REEF MAP



GEOGRAPHY MAP KEY

1. __ __ __ __ __ __ __ __ __ __ __ __ __ __ __
2. __ __ __ __ __ __
3. __ __ __ __ __ __ __ __ __
4. __ __ __ __ __ __ __ __ __ __
5. __ __ __ __ __ __ __
6. __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __ __
7. __ __ __ __ __ __ __
8. __ __ __ __ __ __
9. __ __ __ __ __ __ __
10. __ __ __ __ __ __
11. __ __ __ __ __ __ __ __ __ __ __
12. __ __ __ __ __ __
13. __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

Follow-up: Describe in general terms where these coral reefs are located.

_____

_____

_____

_____

_____

GEOGRAPHY CLUES

Each of these locations has coral reefs.

1. Group of islands northeast of Cuba

2. Central American country bordering the Caribbean and Guatemala

3. Fifteen percent of the world's coral reefs are located in this sea

4. Large island off the eastern coast of Africa

5. Largest ocean in the world

6. Largest barrier reef in the world, located off the eastern coast of Australia

7. Island country south of Cuba

8. Central American country adjacent to South America

9. United States peninsula state

10. United States island state

11. Collection of many islands located in the South China Sea

12. Body of water between Africa and Asia

13. A group of islands in the Pacific where Kwajalein, the world's largest atoll, is located

Coral Reef Two-Syllable Poetry

Objective: Students express an understanding and appreciation of the coral reefs through poetry. Students write about each of the three topics to be covered during this unit. This lesson is designed to be completed in three stages. The first stanza of the poem will address the topic **What and Where are the Coral Reefs?** Have the students complete the second and third stanza of the poem after each group of corresponding lessons is completed (**Life on the Coral Reef** and **Benefits, Threats, and Solutions**). The final draft should be written leaving space for illustrations.

Interdisciplinary Index: Science, Language Arts

Vocabulary: stanza

Materials:

- paper
- pencil
- dictionary/thesaurus (optional)

PRESENTATION:

1. Share an example of two-syllable poetry with the class such as the sample following. Mention that the sample contains only one stanza, whereas the final poem will contain three stanzas. Each stanza will address a different topic about the coral reefs.
2. The primary rule for this form of poetry is that each line is limited to two syllables (either one two-syllable word or two one-syllable words). This will require some creativity since a first-choice word may violate this rule and others will have to be used (ie. creature instead of animal).
3. Today's goal is to create a first draft for the first stanza of a poem that will be completed, in stages, during this unit.
4. The first stanza of the poem will address the topic **What and Where are the Coral Reefs?** It should include information gained during the first set of lessons.
5. Each stanza should be about twenty to thirty lines in length.

SAMPLE TWO-SYLLABLE POETRY

Coral Reefs
by Mary Meyer

Between
the poles
of our
planet
is a
life belt.
Beneath
the waves.
Life teems
in the
salty,
warm, clear,
shallow,
sunlit
waters.
Here the
polyps
build a
stony
coral
city.
They need
algae.
Algae
needs them.
We see
beauty
in their
colors.
Orange,
yellow,
purple,
blue, white,
red, green,
browns and
olives
brighten
the calm
waters.

Diving Expedition

Objective: Students learn to construct bar graphs from compiled data and interpret these graphs.

Interdisciplinary Index: Math, Science

Vocabulary: expedition, population, data

Materials:

- **Coral Reef Life Cards** (make 2 or 3 copies of each card and use only reef life that one can see with the human eye)
- graph paper
- colored pencils, crayons or markers.

PRESENTATION:

1. Cut up **Coral Reef Life Cards** and, on each one, write a number from one to twenty. Discuss facts about each **Life Card** with the students. You can use the following **Fact Sheet** as a reference.
2. Arrange desks in a circle and place life cards randomly on the floor, face down, in the middle of the circle.
3. Tell students they will be going on a diving expedition to gather data on the population of coral reef life. Explain to students that the "reef" they will be diving is in the middle of the circle (a patch reef).
4. Have students one at a time "dive into the water" and take a card. They will then report to the class what they observed. For example, if they drew a parrotfish card with the number 12 on it, they would say to the class, "I observed 12 parrotfish." Repeat this process several times.
5. Each student, as well as the teacher, should be keeping a tally of how many of each animal is observed.
6. When sufficient data has been collected, have students construct a bar graph depicting the number of each animal that was observed. Represent each animal with a different color on the graph.
7. Once the graphs are done, the teacher can ask comparative and quantitative questions about the graph.

FOLLOW UP/EXTENSION:

Have students calculate what percentage of the total population was comprised by parrotfish, sharks, sea stars, etc. Once these figures are calculated, have students construct a pie chart showing this data.

See the following pages for **Coral Reef Life Cards**.

CORAL REEF LIFE CARDS FACT SHEET

FOR USE BY THE TEACHER.

Blue Dash Butterflyfish - The butterflyfish is shaped like a thin pancake so that it can hide easily among the coral and be safe from predators. The blue dash butterflyfish is bright yellow with a blue streak on its body and a "fake eye" on its tail to confuse any predators that try to attack. The predator thinks that it is aiming for the head when in reality it is aiming for the tail, enabling the butterflyfish to swim forward quickly and escape.

Clown Triggerfish - The clown triggerfish is marked with large white polka dots which help to break up its outline and camouflage it against the reef. It is also very poisonous so predators do not try to eat it. The clown triggerfish attacks small reef animals, such as fish that hide in the sand and sea urchins, by blowing streams of water out of its mouth to uncover or overturn its prey.

Clownfish and Sea Anemone - The clownfish, a small orange damselfish often marked with one or two white stripes, has a symbiotic relationship with its partner, the sea anemone. The clownfish lives among the stinging tentacles of the anemone. The fish protects the anemone from being eaten by predators and drops bits of food into its mouth, and the anemone protects the clownfish with its poisonous tentacles.

Damselfish - Damselfish come in many colors, from dull brown and gray to brilliant yellow and blue. They are found abundantly on the reef and are very territorial. Some species are "farmers", actively guarding and growing small patches of algae on an area of coral to serve as a food source.

Giant Clam - The giant clam has a symbiotic relationship with its zooxanthellae, enabling it to grow its own food in the tissue of its mantle. It can reach more than 40 inches (1m) in length and weigh more than 1,000 pounds (453kg). Humans have destroyed populations of these clams in the Pacific, harvesting them for their meat and shells. Projects are now underway to farm giant clams and return them to the reefs.

Gray Reef Shark - The gray reef shark hunts for food along the coral reef during the night and rests in caves during the day. Sharks are powerful carnivores, hunting large and small marine animals including fish, crustaceans, and mollusks. Some of the larger species even hunt marine mammals, sea birds, sea turtles, and other sharks. Sharks have very sharp teeth, keen vision, and a highly-developed sense of smell. Although they are at the top of the food chain, most sharks are not dangerous to humans unless provoked.

Hard Coral - Hard coral builds reefs by secreting a hard external limestone skeleton. There are three types of hard (stony) corals: branching, massive and plate. Most hard coral polyps have tentacles in multiples of six and can be found individually or in colonies. During the daytime, the hard coral polyp retracts into its limestone base for protection but at night it comes out to feed on floating plankton.

Hawksbill Turtle - The hawksbill turtle is a species of sea turtle with its nose shaped like the sharp beak of a hawk. Most sea turtles are herbivores (vegetarians) feeding on seagrass. Many lay their eggs in nests on the beach. Sea turtles are endangered because many of them are caught and drowned in fishing nets each year, their eggs and flesh hunted for food, and their shells and skin used for ornament.

Lionfish - The lionfish has spectacular orange and white markings which help to camouflage it from predators, however the spines on its fins are highly poisonous. Lionfish are mostly stationary during the daytime but active at night, feeding primarily on crustaceans and small fish. Because of its beauty and uniqueness, it is often photographed by divers.

Mollusk - The mollusk is an animal with an unsegmented muscular "foot" that is protected by a

shell. This is a giant triton, the natural predator of the crown-of-thorns sea star which eats coral polyps. The triton has been overharvested for its meat and beautiful shell. Scientists believe that this might be one reason for the explosion in the crown-of-thorns population which has caused extensive damage to reefs in parts of Australia and the Philippines.

Moray Eel - The moray eel has a long muscular body that propels it through the water like a snake, and a large mouth with sharply pointed teeth. It hides in coral holes along the reef face where it waits for unsuspecting fish to come close enough to attack. It also eats mollusks and an occassional octopus. The moray eel is not dangerous to humans unless provoked.

Parrotfish - The parrotfish is often brightly colored with a hard beak that resembles a parrot's. It is an herbivore and uses its beak to attack the coral for food, scraping the limestone base to extract nutrition from the algae (zooxanthellae) in the coral polyps. The limestone base is digested along with the polyp, broken down in the stomach, then excreted as sand. The parrotfish is an important source of sand for tropical beaches.

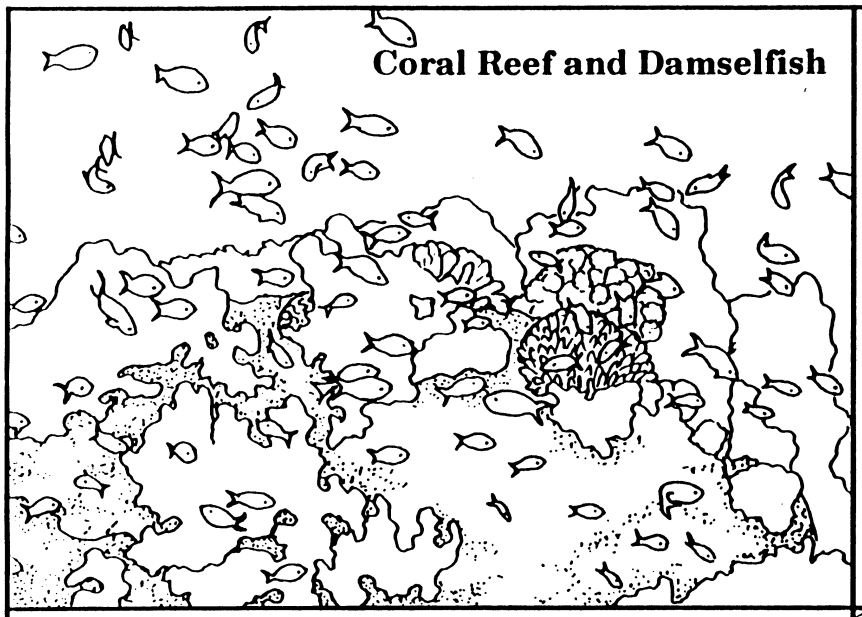
Plankton: Zooplankton and Phytoplankton - Plankton consists of microscopic drifting animals (zooplankton) and microscopic drifting plants (phtyoplankton) which are swept onto the reef face by upwelling currents from deeper parts of the ocean, supplying the reef life with easy access to food.

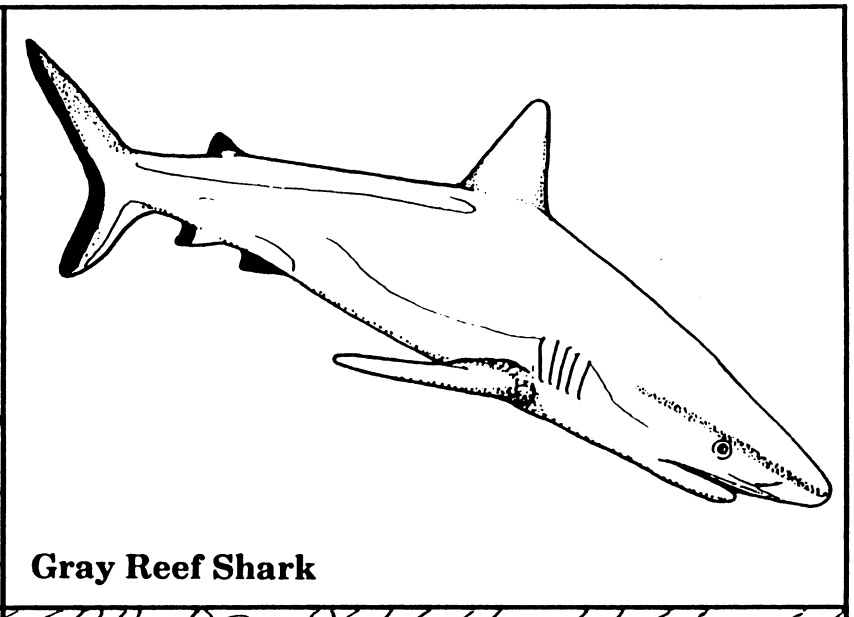
Sea Stars - Sea stars are characterized by radial symmetry wherein the body parts are repeated around a center, like the spokes of a wheel. They eat coral polyps and mollusks by wrapping their stomach and arms around the food. The crown-of-thorns sea star can be a threat to coral reefs because it eats the coral polyps, thereby killing the coral. If a sea star loses part of its body, it can grow the missing part back quickly.

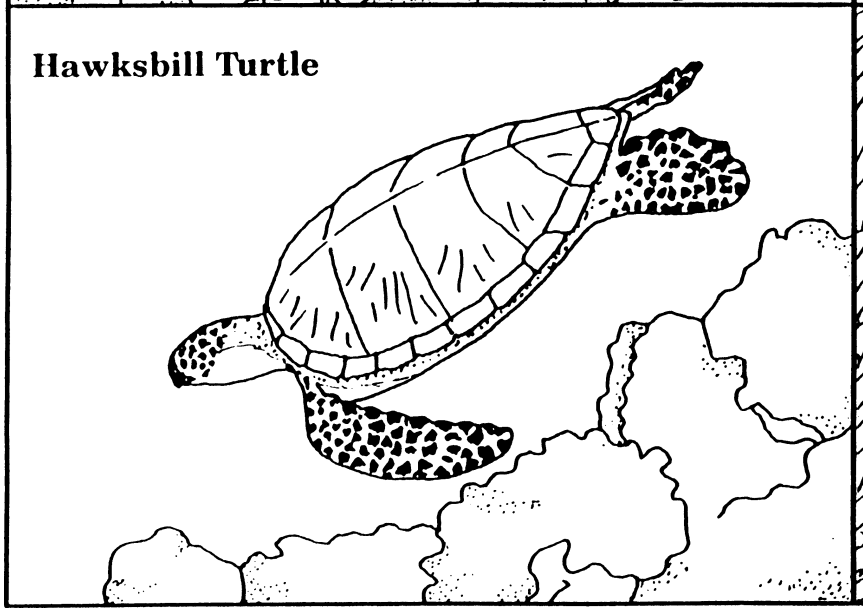
Soft Coral - Soft corals do not build reefs. They secrete a flexible or soft skeleton which enables them to bend and sway in the water. They are also known as octocorals because each polyp has eight tentacles. Soft corals thrive in strong currents where they have access to lots of plankton. They also grow in dark caves and overhangs where hard coral cannot grow.

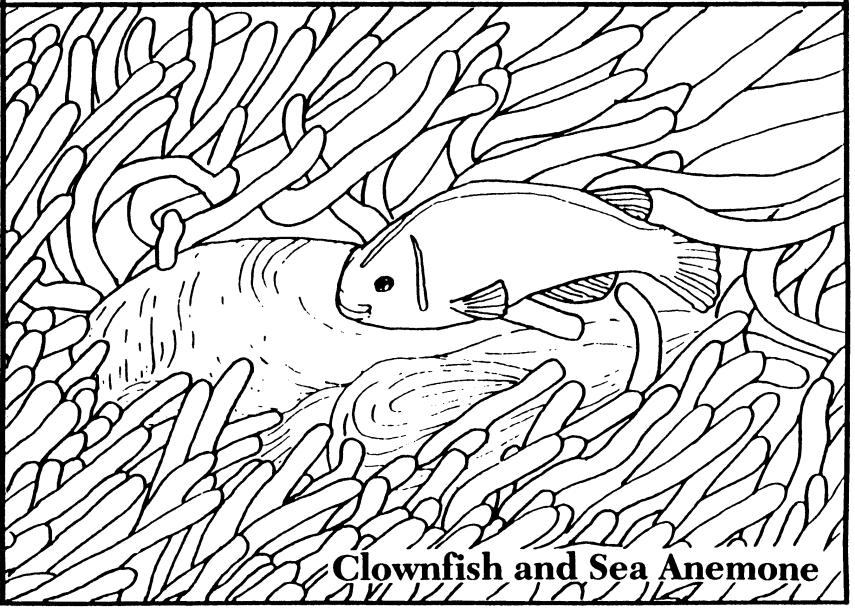
Spotted Eagle Ray - The eagle ray is often found swimming gracefully along the perimeter of the reef face, either alone or in small groups. It has two wings or flaps and a long, hard tail with poisonous spines near the base. Its powerful jaws enable it to feed on mollusks, especially clams, mussels, and oysters. It is also hunted for food by native coastal people.

CORAL REEF LIFE CARDS

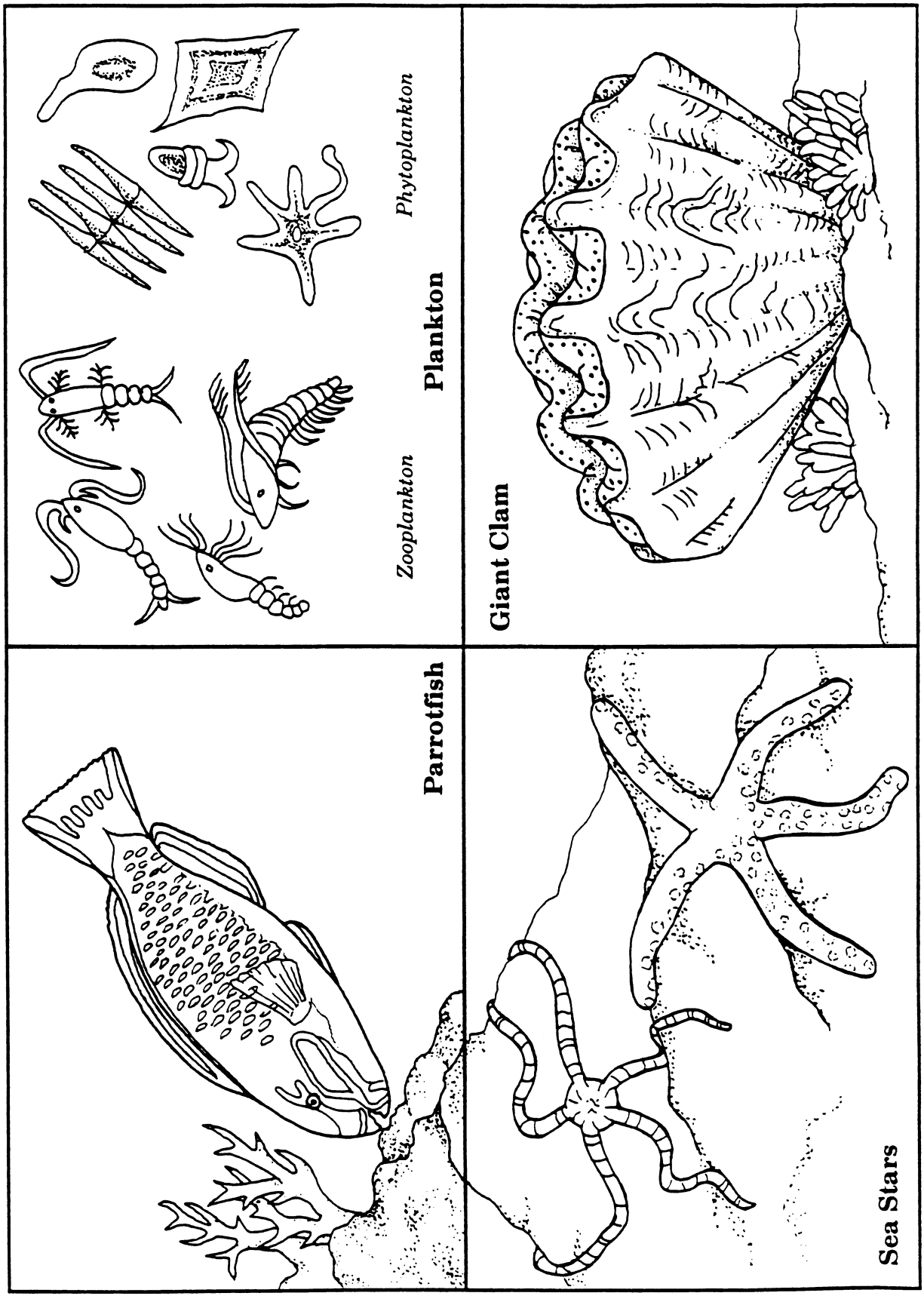




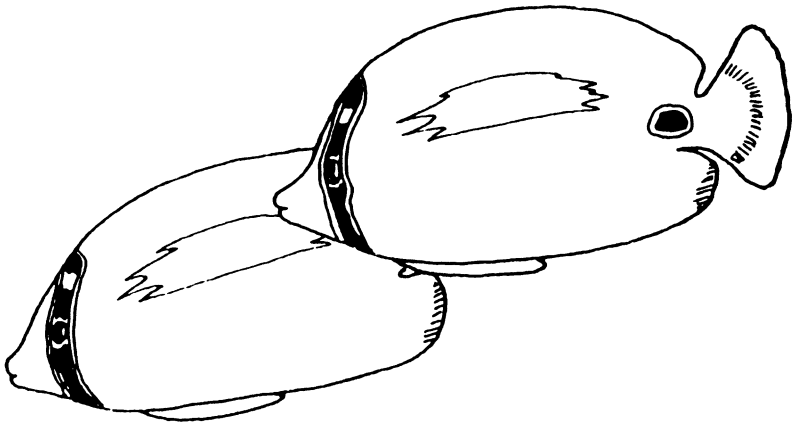




CORAL REEF LIFE CARDS

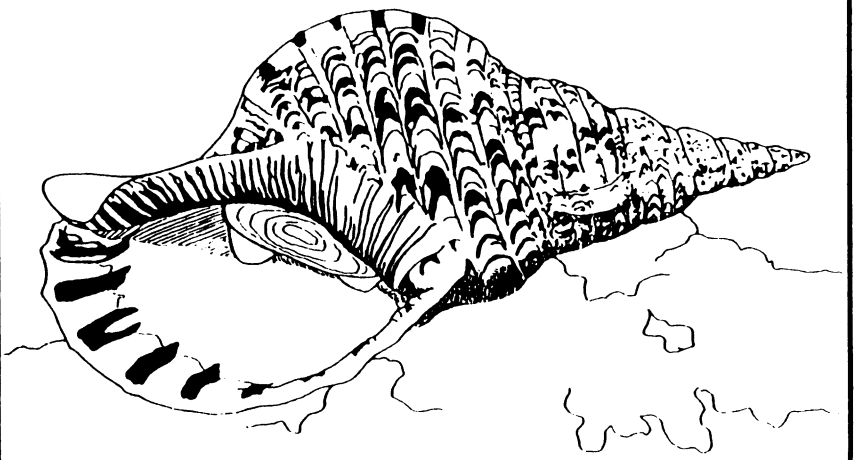


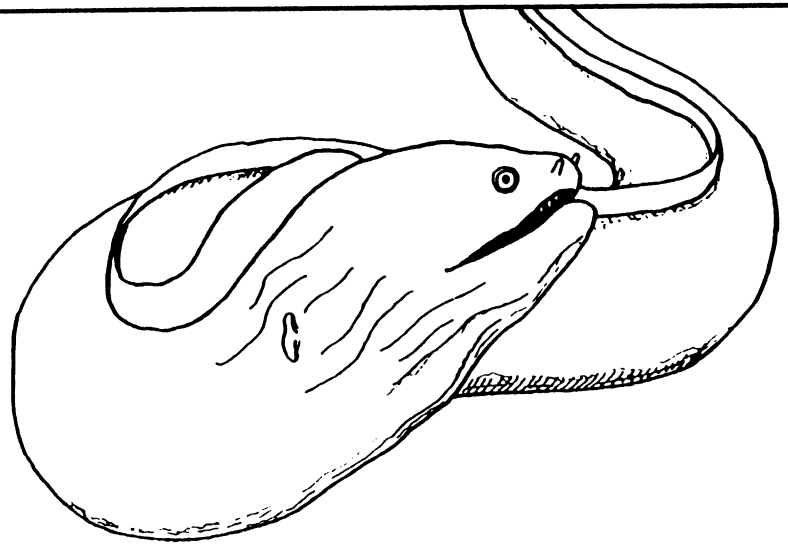
CORAL REEF LIFE CARDS



Blue Dash Butterflyfish

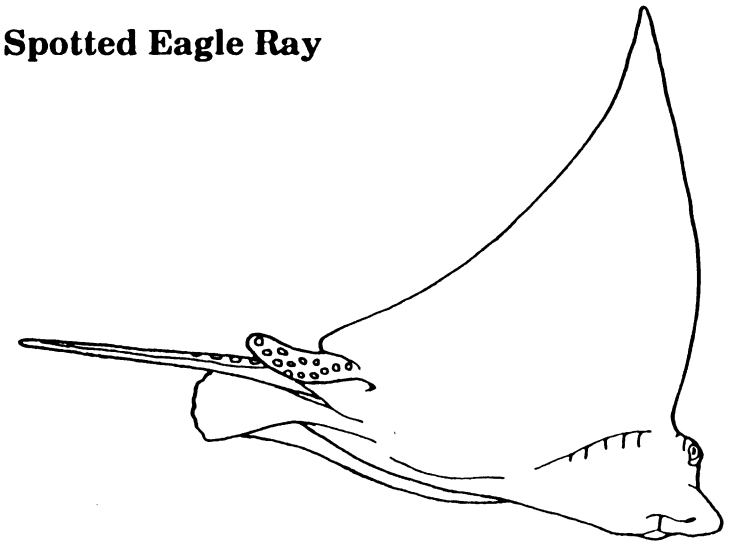
Mollusk





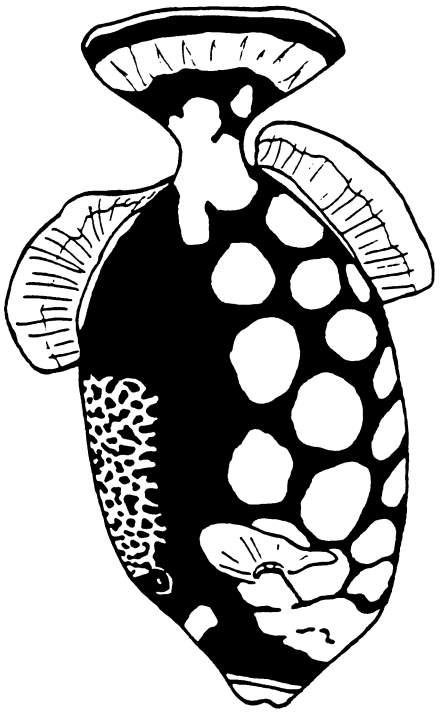
Moray Eel

Spotted Eagle Ray

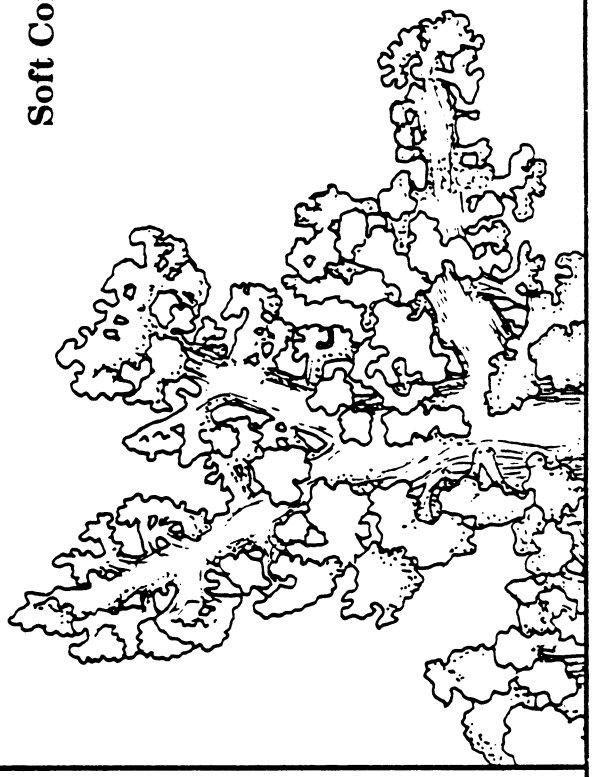


CORAL REEF LIFE CARDS

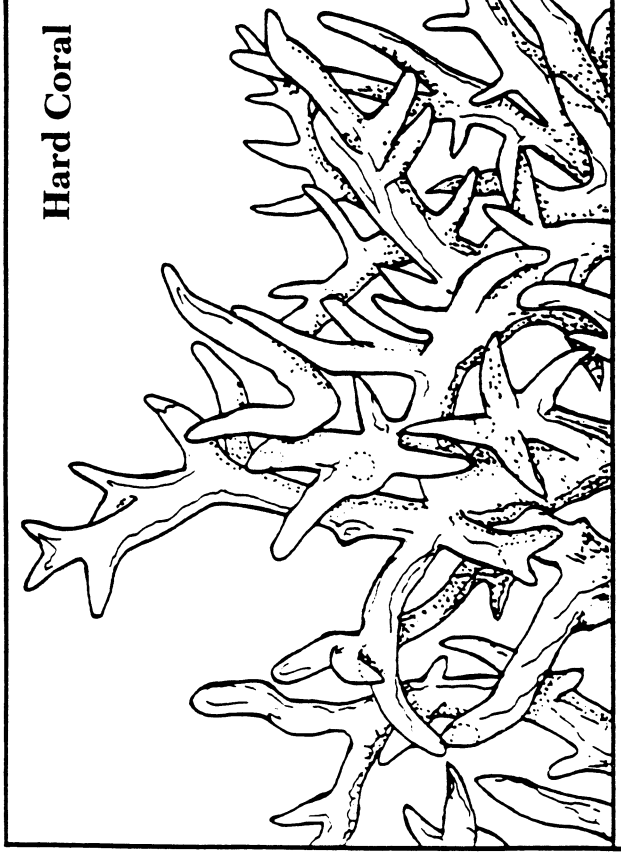
Clown Triggerfish



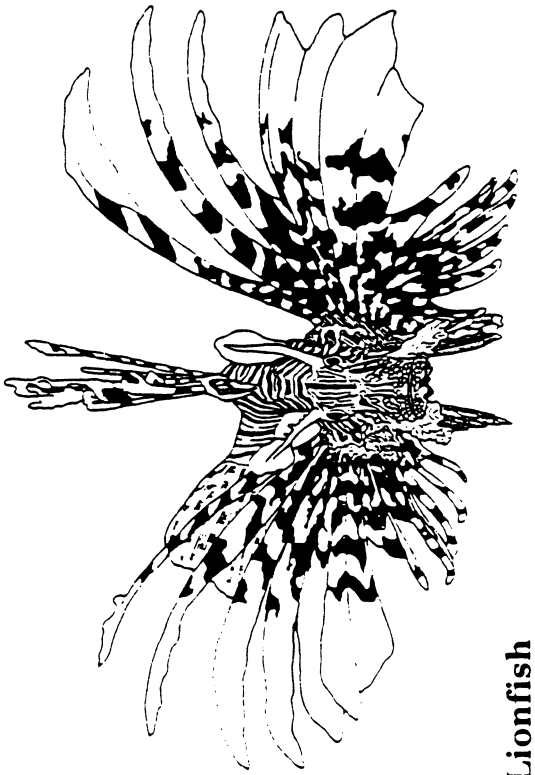
Soft Coral



Hard Coral



Lionfish



Create a Creature

Objective: Students use what they have learned about coral reef animals and their own imagination to create a fictitious creature designed to live on a coral reef.

Interdisciplinary Index: Science, Art, Language Arts

Materials:

- pencils/pens
- drawing paper
- crayons/markers/colored pencils
- writing paper

PRESENTATION:

1. Discuss how different types of animals obtain food and defend themselves from becoming someone else's lunch. There are several examples in the section **Life on the Coral Reef** in the **Background Information**. Other resources will add to the lesson.
2. Have the students brainstorm a variety of methods creatures could use to obtain food. You may want to break this down into ideas for herbivores, omnivores and carnivores. Consider the obstacles and ways to overcome them.
3. Have the students brainstorm methods of defense. Include passive and aggressive methods such as camouflage, poisons, teeth, "smoke screens," etc.
4. Have the students use their imagination to create their own coral reef creatures, incorporating characteristics that have been discussed. Then have them write a brief description by selecting several characteristics to describe their own invented creature. Size, coloring, methods for obtaining food, methods for defense, and a description of the specific habitat should be included. Don't forget to name the newly created creature.
5. Each student should then draw a picture of the invented creature based upon the written description. The picture can also include a scene showing the creature in its habitat, defending itself, or obtaining food. You can use the **Sample Coral Reef Creature** as an example.
6. Now that the drawing is complete, have the student review the written description. A final draft should include all of the previously mentioned information and should refer to the drawing as an illustration for the written section.
7. Have the students share the creature they have "discovered" by giving an oral presentation or displaying the work on a wall.

SAMPLE CORAL REEF CREATURE

Windows to the Sea

Objective: Students create a three dimensional, water based representation of underwater life.

Interdisciplinary Index: Science, Art

Materials:

- blue construction paper
- markers, crayons, colored pencils
- permanent markers
- blue food coloring
- sand (optional)
- water
- laminating material
- heavy duty freezer self sealing baggie (one per student)
- thin cardboard (two pieces) or two paper plates per student

PRESENTATION:

1. Student should begin with the frame for the underwater scene. For this, each student will need two pieces of thin cardboard (local warehouse stores frequently have this for the asking). One piece of cardboard will serve as the backing, while the second piece will need to have the center cut out so that it can serve as the front of the frame. Allow the students to be creative. Some may want to use a traditional oval or rectangle opening, but others may choose to cut the opening into some other design.
2. Have the students decorate the blue construction paper using sand, crayons, markers, and/or colored pencils to serve as the background for the underwater scene. Glue this to the backing.
3. Have the students draw their own coral reef creatures to fit in the baggie. Laminate the artwork and cut out each creature.
4. Pour some water that has been mixed with blue food coloring into the baggie. (The amount of water will depend on the size of the baggie and the frame.)
5. Place the cut out creatures in the baggie. Seal the baggie taking care to remove all of the air.
6. Place the baggie between the two cardboard pieces and tape the edges to complete the frame.

Coral Reef Mural

Objective: Students work together to complete a colorful, inspirational coral reef mural. A video on the coral reefs or numerous photos/color drawings of coral reefs would be an excellent introduction to this project as it would help the students to visualize the final product. (This is a difficult project to complete as a whole class and may be more easily completed by assigning small groups to specific tasks.)

Interdisciplinary Index: Science, Art

Materials:

- overhead projector
- overhead projector pens
- transparency of **Coral Reef Color Page** or transparency paper
- butcher paper – approximately 3 feet by 6 feet
- optional media: crayons, markers, colored pencils, watercolors, tempera paints, food coloring, tissue paper, scissors, glue, construction paper, etc.
- **The Coral Forest: Diversity of Life on the Coral Reef** poster as a reference and color guide.*

PRESENTATION:

1. Before class make a transparency copy of the **Coral Reef Color Page** or trace the artwork by placing transparency paper over the design.
2. Prepare the area where the mural will be completed by covering it with butcher paper. (You may wish to use a light blue paper to act as a watery background.)
3. Use the butcher paper as the screen for the overhead projector transparency that you created.
4. Have students use a pencil to draw the image on the butcher paper. (Depending on your class you may want them to copy all of the details, only the background, or only the major features.)
5. Decorate the mural. Use the **The Coral Forest: Diversity of Life on the Coral Reefs** poster as well as videos or other artwork as a color guide. Combine your skills and talents with those of your students to create a unique class mural.

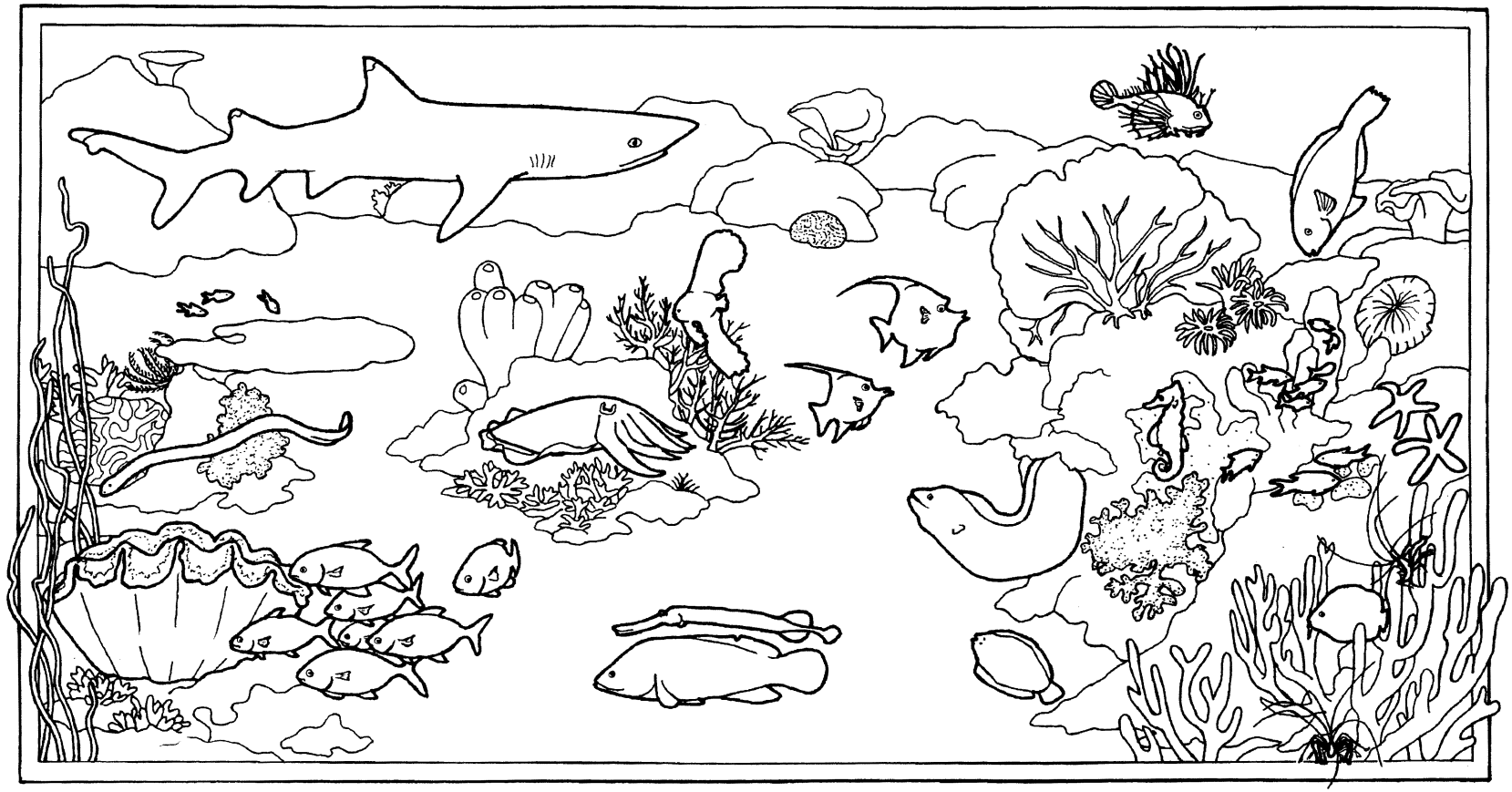
SUGGESTIONS:

1. Use a variety of materials to create a two or three dimensional mural.
2 Create a soft-colored background by using colored pencils, light colored tissue paper, water colors, light colored construction paper, or food coloring on dampened paper towels/coffee filters.
3. Create a vivid foreground by using temperas, markers, bold colored tissue paper, crayons, or bold colored construction paper.
4. Optional: Add student invented creatures to the mural. (See **Create a Creature**.)

* To order, refer to **Merchandise** information in back.

CORAL REEF COLOR PAGE

THE CORAL FOREST: *Diversity of Life on the Coral Reef*



NOTE: See next page for information and Key to the Illustration.

CORAL REEF COLOR PAGE

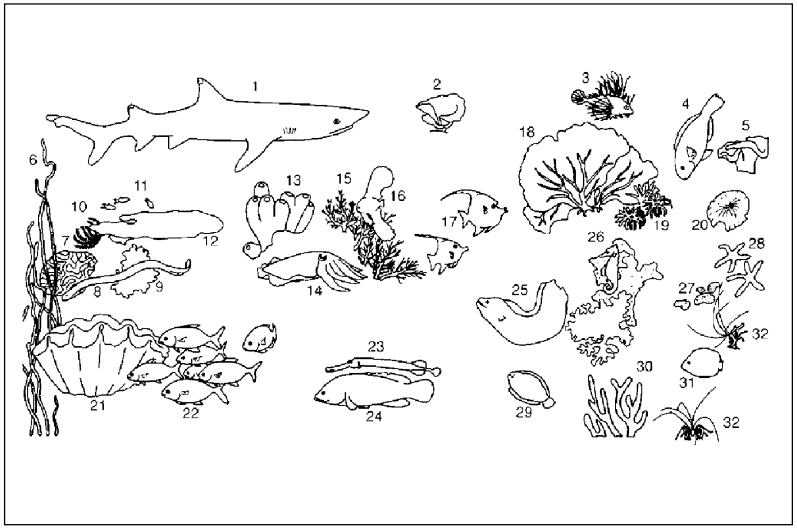
THE CORAL FOREST: *Diversity of Life on the Coral Reef*

Coral reefs were first formed more than 500 million years ago, and since that time they have successfully developed and supported a tremendous array of plant and animal life, earning them the name "rainforests of the sea." Today, reefs are found in 109 countries around the world; however, it is estimated that they are either destroyed or damaged by human activity in 93 of them. Like the rainforests, their survival is threatened. With the rainforests, they form an interrelated ecosystem whose health and balance is critical to ensure the biodiversity of species, protection of the coastlines, and an on-going supply of food and medicinal resources. Enjoy the beauty of the coral reef, learn about its vast diversity of life, and help to preserve it for generations to come.

KEY TO THE ILLUSTRATION

Location: The Great Barrier Reef, Australia

Key Fact: The Great Barrier Reef is the largest structure built by living organisms on Earth, and it is the only living structure visible from outer space. Located along the northeast coast of Queensland, it is 1,240 miles (2,000 km) long and consists of over 2,500 major reefs.



1. White tip reef shark
2. Lettuce coral
3. Butterfly cod (lionfish)
4. Parrotfish
5. Soft coral
6. Sea whips
7. Brain coral
8. Olive sea snake
9. Soft coral
10. Feather star
11. Damselfish
12. Plate coral
13. Vasiform sponge
14. Cuttlefish
15. Needle coral
16. Batfish (juvenile)
17. Moorish idol
18. Gorgonian fan coral
19. Sea anemone
20. Mushroom coral
21. Giant clam
22. Six-banded trevally
23. Trumpetfish
24. Coral cod
25. Yellowmargin moray eel
26. Spotted seahorse
27. Sponge
28. Blue sea star
29. Flowery flounder
30. Branching coral
31. Emperor angelfish (juvenile)
32. Banded coral shrimp

Student-Generated Research Fold-Out Book

Objective: Students create a booklet of information about life forms in and related to the coral reefs.

Interdisciplinary Index: Science, Art, Language Arts

Vocabulary: plagiarism

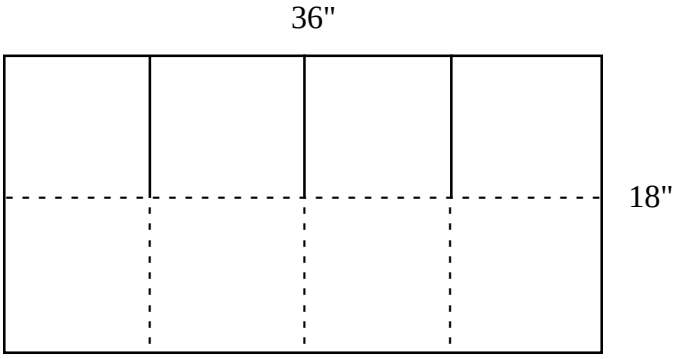
Materials:

- copies of **Life on the Coral Reef** (second section in **Background Information**)
- butcher paper
- plain paper/construction paper
- writing paper
- pencils/pens
- markers, crayons, colored pencils

PRESENTATION:

Before class, construct a sample fold-out book so that students have a model to follow. Also cut out the butcher paper into strips which the students will fold and cut into books.

Here is the basic pattern:



A. Fold on the dotted line.

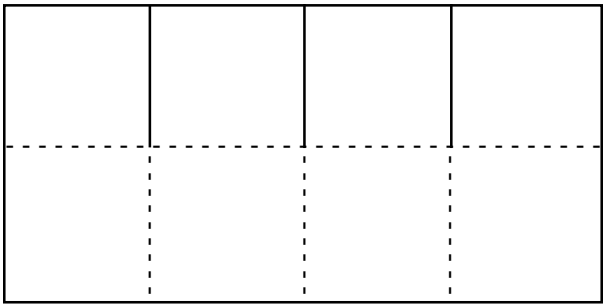
B. Cut on the solid line.

C. Each section should be a 9" by 9" square.

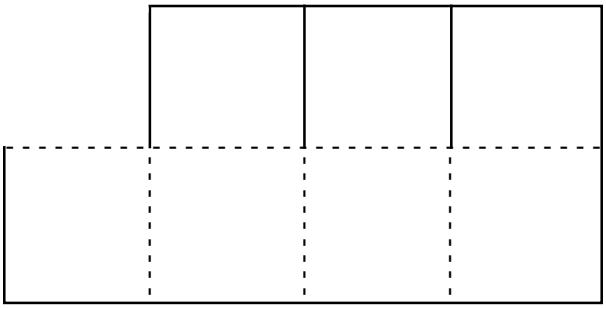
1. Demonstrate the folding and cutting pattern for the fold-out book.
2. Have students prepare the book. Set aside.
3. Read the **Life on the Coral Reef** section. This can be done as a whole class, or in small groups.
4. Students will need to take notes on the four topics to be covered in the book.
    a. lagoon, reef crest, and reef face
    b. food chains, herbivores, omnivores, and carnivores
    c. methods of predation and protection
    d. creatures of the coral reef (corals, anemones, clownfish, nudibranchs, sea stars, sharks, angelfish, giant clams, etc.)
5. You may wish to have students complete additional research on any and/or all of the topics in order to complete the book.
6. Using the notes, students should write a summary of the information for each of the sections.
7. Have students create an illustration for each of the four sections and for the cover of the book. (You may choose to use the art from the lesson plan **Window to the Sea** for the cover.)
8. Follow the guide on the following page. Paste the illustrations to the "flap" and the summary information to the section under the "flap."
9. After the glue has dried, fold the book.

Follow these illustrations:

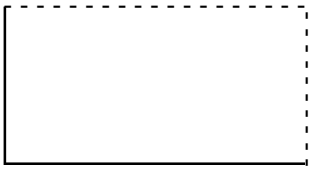
1. Glue the information onto the lower sections and dry.



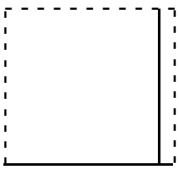
2. Fold down each of the flaps. (This shows only one flap down.)



3. Glue the illustration onto the flap and let it dry.
4. Fold in half lengthwise, bringing the right edge over to the left edge.



5. Fold in half lengthwise, bringing the left edges over to the right edge.



Reef Links Crossword Puzzle

Objective: Students will learn about life on the coral reef by finding words to complete the crossword puzzle.

Interdisciplinary Index: Language Arts, Science

Materials:

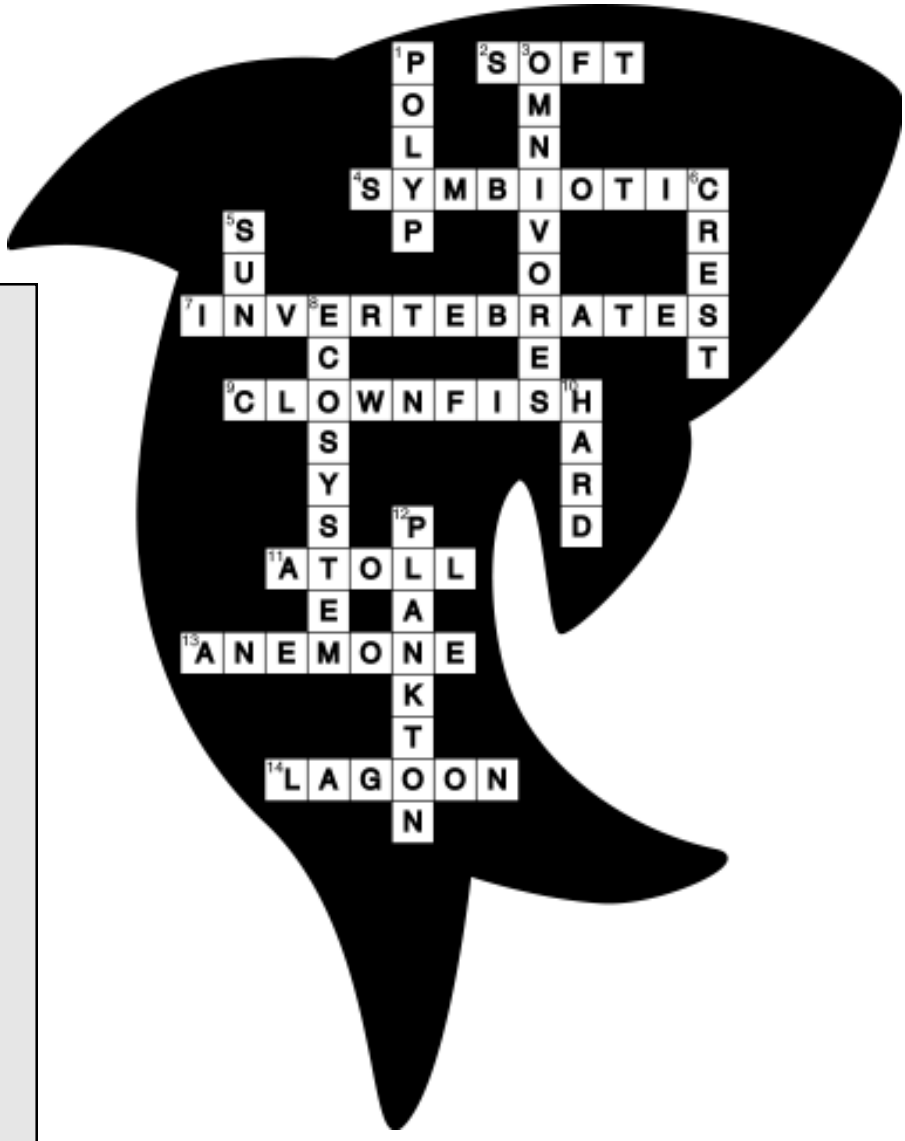
- a copy of the **Reef Links Crossword Puzzle**, one per student
- pencils

PRESENTATION:

1. Hand out one copy of the **Reef Links Crossword Puzzle** to each student.
2. Ask them to read the description and find the word that both answers the description and fits into the boxes.
3. When everyone is finished, discuss the answers with the students.

FOLLOW-UP/EXTENSION:

Have students create their own crossword puzzles for the class to answer.



ANSWER KEY:

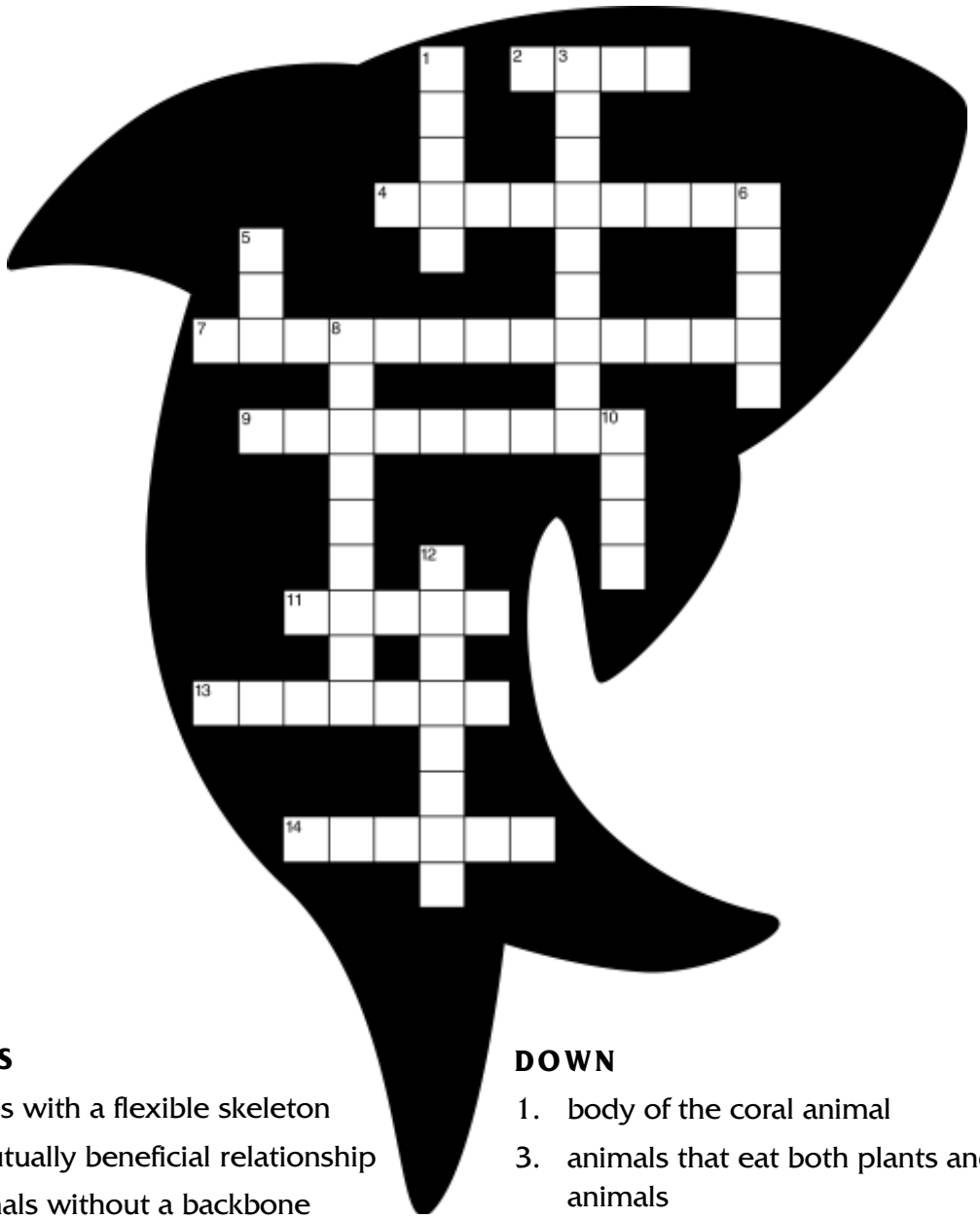
ACROSS

2. soft
4. symbiotic
7. invertebrates
9. clownfish
11. atoll
13. anemone
14. lagoon

DOWN

1. polyp
3. omnivores
5. sun
6. crest
8. ecosystem
10. hard
12. plankton

REEF LINKS CROSSWORD PUZZLE



ACROSS

2. corals with a flexible skeleton
4. a mutually beneficial relationship
7. animals without a backbone
9. a damselfish that has a symbiotic relationship with #13
11. ring-like coral formations surrounding a central lagoon
13. an invertebrate that has a symbiotic relationship with #9
14. the area between the beach and the reef crest

DOWN

1. body of the coral animal
3. animals that eat both plants and animals
5. without it's light, coral reefs could not exist
6. highest and shallowest part of the reef
8. a group of living things and their non-living environment
10. a type of coral that builds reef
12. creatures that move passively through the water

Positive Posters

Objective: Students create posters addressing a major coral reef threat and solution.

Interdisciplinary Index: Science, Art, Language Arts

Vocabulary: anthropogenic

Materials:

- copies of the human threats described in **Benefits, Threats, and Solutions**
- drawing paper
- pens/pencils
- crayons, markers, colored pencils, or paints

PRESENTATION:

1. Explain that coral reefs are damaged by natural as well as anthropogenic (human-made) events. We will concentrate on the anthropogenic threats, since these are the ones that we can prevent.
2. Assign each student one of the human threats described in **Benefits, Threats, and Solutions**. You may wish to read and discuss each of these threats before assigning them.
3. Have the students that were assigned to the same topic work together to brainstorm several solutions to the problem.
4. Individually, students should use crayons, markers, colored pencils, or paints to design a colorful, educational poster that briefly explains the problem and solution.
5. Have the students share the posters with the class by giving a brief oral presentation or displaying the posters in the classroom.

Advice Column

Objective: Students express an understanding of an anthropogenic (human-made) activity which threatens the coral reef by writing a letter to an imaginary advice columnist. This activity should be completed after the "Positive Posters" lesson.

Interdisciplinary Index: Science, Language Arts

Vocabulary: advice columnist

PRESENTATION:

1. Discuss the role of advice columnists and the types of letters they receive.
2. Have each student select a threat to the coral reefs that is of particular interest to him or her (other than the one he/she used for the **Positive Posters**).
3. Have the students write a letter to a fictitious advice columnist from the viewpoint of a coral reef creature. Express the specific concerns of that animal.
4. Students should exchange papers and answer each other's letters.

How You Can Help Reef Relief!

Objective: Students use their knowledge of anthropogenic threats to coral reefs to write effective direct action letters to elected officials.

Interdisciplinary Index: Science, Language Arts

Materials:

- a copy of **Effective Letter-Writing Guidelines**, one per student
- paper
- pens/pencils

PRESENTATION:

1. Choose one or more of the current threats to coral reefs and discuss with the students. Also, discuss the value of taking direct action as a way to protect the reefs. Review the **Effective Letter-Writing Guidelines**.
2. Based upon this information, ask the students to write a direct action letter about one of these threats. You can either assign a threat to each student or they can choose one of their own.
3. Have each student read his/her letter to the class and discuss its effectiveness. Were the guidelines followed? Is the letter persuasive? Did the student understand the issue?
4. Mail the finished letters to the elected officials, then wait and see if the elected official replies to them.

Here are some addresses to get you started:

Name
President of the United States
The White House
1600 Pennsylvania Ave. NW
Washington, DC 20500

Name
Vice-President of the United States
United States Senate
Washington, DC 20510

Your Senator _____
United States Senate
Washington, DC 20510

Your Representative _____
U.S. House of Representatives
Washington, DC 20515

Name
Administrator
Environmental Protection Agency
401 M Street, SW
Washington, DC 30460

For specific information about current coral reef threats and whom to write, contact REEF RELIEF at tel: (305) 294-3100, fax: (305) 293-9515, e-mail: reef@bellsouth.net, or go to our web site:
http://www.reefrelief.org

FOLLOW-UP/EXTENSION:

Ask students to research the countries worldwide that have coral reefs. Then, have them choose a country and ask that country's leader(s) to help preserve the coral reefs by creating marine parks and passing laws to protect coral reef ecosystems.

EFFECTIVE LETTER-WRITING GUIDELINES

Date

Legislator or other's name and address

Dear _____:

First Paragraph: Describe your request with a few adjectives to help them visualize. If possible, tell them what you would like them to protect and how. If there is a bill being considered, provide the name and/or number of the bill and if you want them to vote for or against it. (You can write to REEF RELIEF or look at the Action Alerts section of the REEF RELIEF Web Site to get current information on legislation and other actions to protect coral reefs. The URL is www.reefrelief.org.)

Second Paragraph: Explain what's important about what you want protected. What's special or unique about it? What is its function to humans and/or other species? Tell why it's important to you.

Third Paragraph: Describe what is threatening it. Provide suggestions about how to protect it. If there is a bill, explain how that bill will work for or against protection.

Summarize your ideas and add your personal feelings. Ask again for their support and action.

Sincerely,

Student's Name
Grade
Name of School
Address
City, State

Student Assessment

Tell and Show What You Know

Objective: Students will review what they have learned about the coral reef by illustrating their knowledge and sharing it with others.

Interdisciplinary Index: Science, Language Arts, Art

Materials:

- writing paper or butcher paper for each student
- colored pencils, pens, crayons, and felt pens

PRESENTATION:

1. Have students fold paper into 4, 8, or 16 equal parts.
2. Tell students that they are to think of the 4, 8, or 16 most interesting things that they have learned about the coral reefs.
3. Have students draw or write down their thoughts in the 4, 8, or 16 parts of the paper.
4. Have students share their thoughts/pictures in small groups or with the class.
5. The finished product can be used as a mural.

FOLLOW-UP/EXTENSION:

Ask students to repeat the activity based on one of the following formats:

What would happen if...

What would you do if...

How I can help...

The 4, 8, 16 most interesting coral reef creatures are...

THE CORAL REEF TEACHER'S GUIDE

LESSON PLANS FOR 9-12:

- **What and Where are the Coral Reefs?**
- **Life on the Coral Reef**
- **Benefits, Threats, and Solutions**

Moray eel. (Photo: Terry Brown)

Where in the World?

Objective: Students compare the political, social, and economic issues involved with the protection and use of coral reefs, and analyze the activities, roles and responsibilities of the various agencies or governments with dominion over the locales involved.

Vocabulary: coral reef, Great Barrier Reef, tropics, equator, tropic of Cancer, tropic of Capricorn

Interdisciplinary Index: Science, Social Studies, Geography, Civics, Economics

Materials:

- World map
- a copy of the coral reef map, Figure 1-6, on page 1-6 of the **Background Information**, one per student
- a copy of the **Coral Reef Map**, one per student
- colored pencils, pens, or markers

PRESENTATION:

1. Look at a world map. Discuss where in the world coral reefs form and the conditions necessary for their development.
2. Referring to Figure 1-6, have the students mark the location of coral reefs on their copy of the **Coral Reef Map**. Referring to the world map, have them mark the names of countries adjacent to the reefs. Review students' maps and note the distribution of reefs near the equator.
3. Discuss some of the native coastal people in these areas and their political, economic, and cultural aspects in preparation for the following projects.

   These projects are designed to be done by individuals or groups and presented to the class in a creative and interactive manner, using role-play, debate, discussion, illustrations, etc.

Projects

A. Choose a country with a coral reef and research the following questions: Who uses and lives near the reef? How does the reef impact their lives in terms of economics, geography, or politics? Do they view the reef as an asset, and if so, why? What is the country doing to protect the reef?

   Create a skit featuring several students representing the people involved with the reef.

B. Compare and contrast two different countries' programs to govern their coral reef ecosystems in terms of commerce, fishing, tourism, and ecological concerns.

C. Research the various international organizations involved with reef governance and/or protection and write to them for information on their programs. Discuss the differences/similarities and any conflicts/agreement among them.

D. Select a law which governs reefs and learn who enacted it, who is affected by the law, the effectiveness of the law, and how it might be improved.

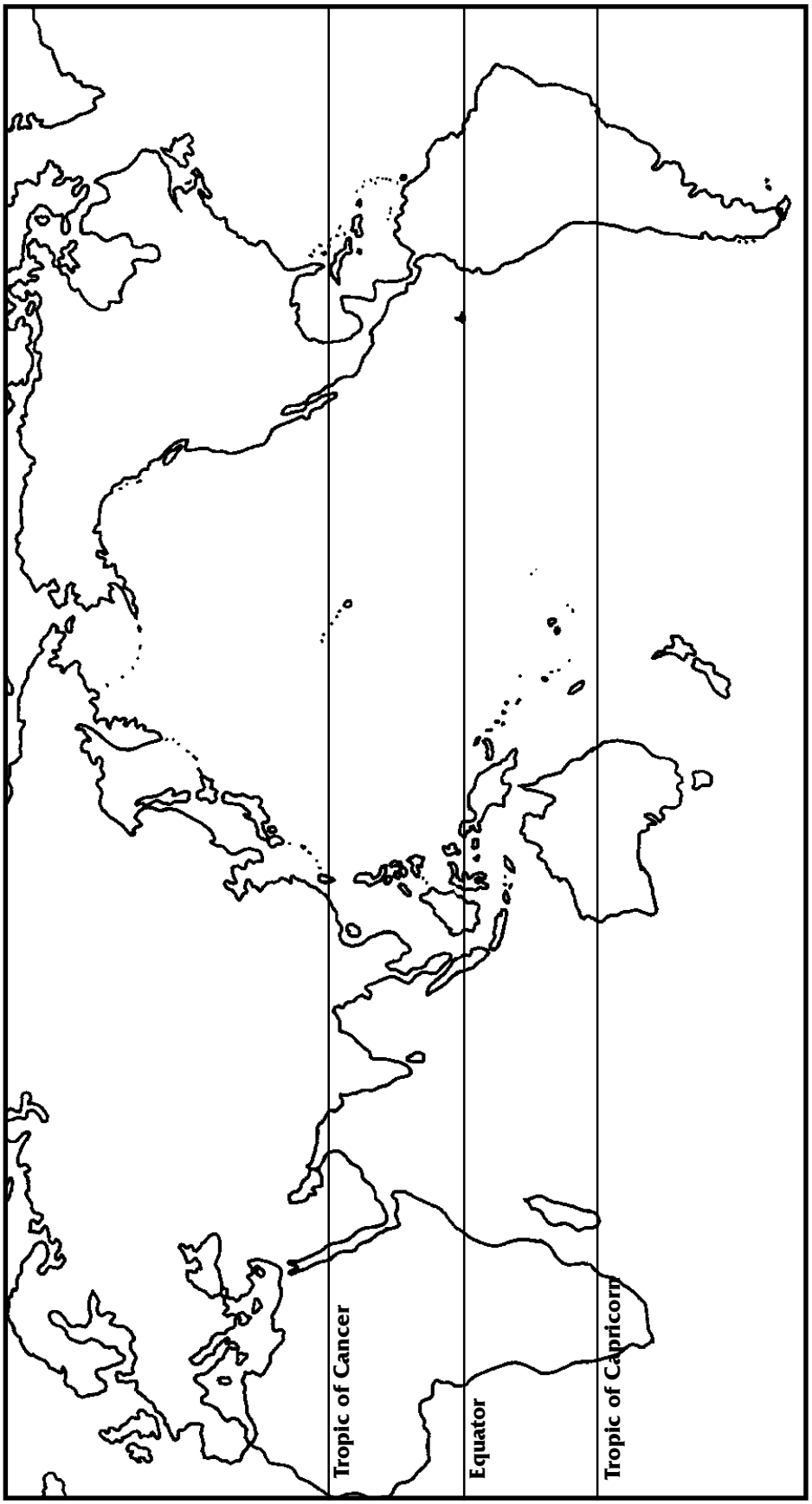
E. Find out who is responsible for governing the world's coral reef ecosystems (individual countries, international organizations, trade organizations, etc.) and where conflicts arise among the various groups. What are possible solutions?

FOLLOW-UP/EXTENSIONS:

If possible, use the Internet to connect with people and organizations involved with coral reef communities.

Write, as individuals or as a class, to express your opinions on various issues to national or international agencies with the power to affect reef ecosystems.

CORAL REEF MAP



Reef Formation Animation

Objective: Students describe the stages and conditions necessary for the formation of a reef, and how geographical locations impact reef formation.

Interdisciplinary Index: Science, Geography, Art, English

Vocabulary: fringing reef, barrier reef, atoll, lagoon, storyboard, animation, claymation

Materials:

Project A:

- **Storyboard**
- **Video Animation Project A**
- plain notebook paper or white drawing paper (8 1/2" x 11")
- markers, crayons, paints, etc. to color images
- video camera and videotape
- lights.

Project B:

- **Storyboard**
- **Video Animation Project B**
- Plastelina-type clay in colors
- painted background on cardboard or butcher paper
- video camera and videotape
- lights.

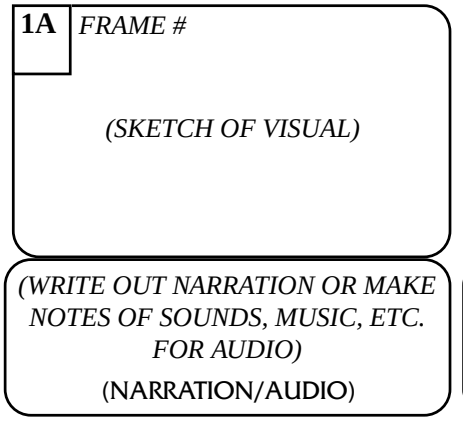
PRESENTATION:

Present to the class the conditions and stages of reef formation using the information found in the **What and Where are the Coral Reefs?** section in the **Background Information**, and use the enclosed form to create a storyboard to serve as a guide to animating the series of steps in this process. Introduce the class to the animation techniques below. Discuss how these techniques could be used to illustrate other scientific principles which are difficult to see in action because they occur over long periods of time or are hidden in some manner (i.e. microscopic or internal).

PROJECT A: 3-RING BINDER ANIMATION

1. Draw each step in the process of reef formation horizontally on a separate 8 1/2" x 11" plain paper, and arrange in proper order in a notebook.
2. Place notebook upright on an easel or other surface
3. Videotape each page in the sequence in order.
4. Add narration, sound effects, music, etc.

STORYBOARD FRAME



PROJECT B: CLAYMATION

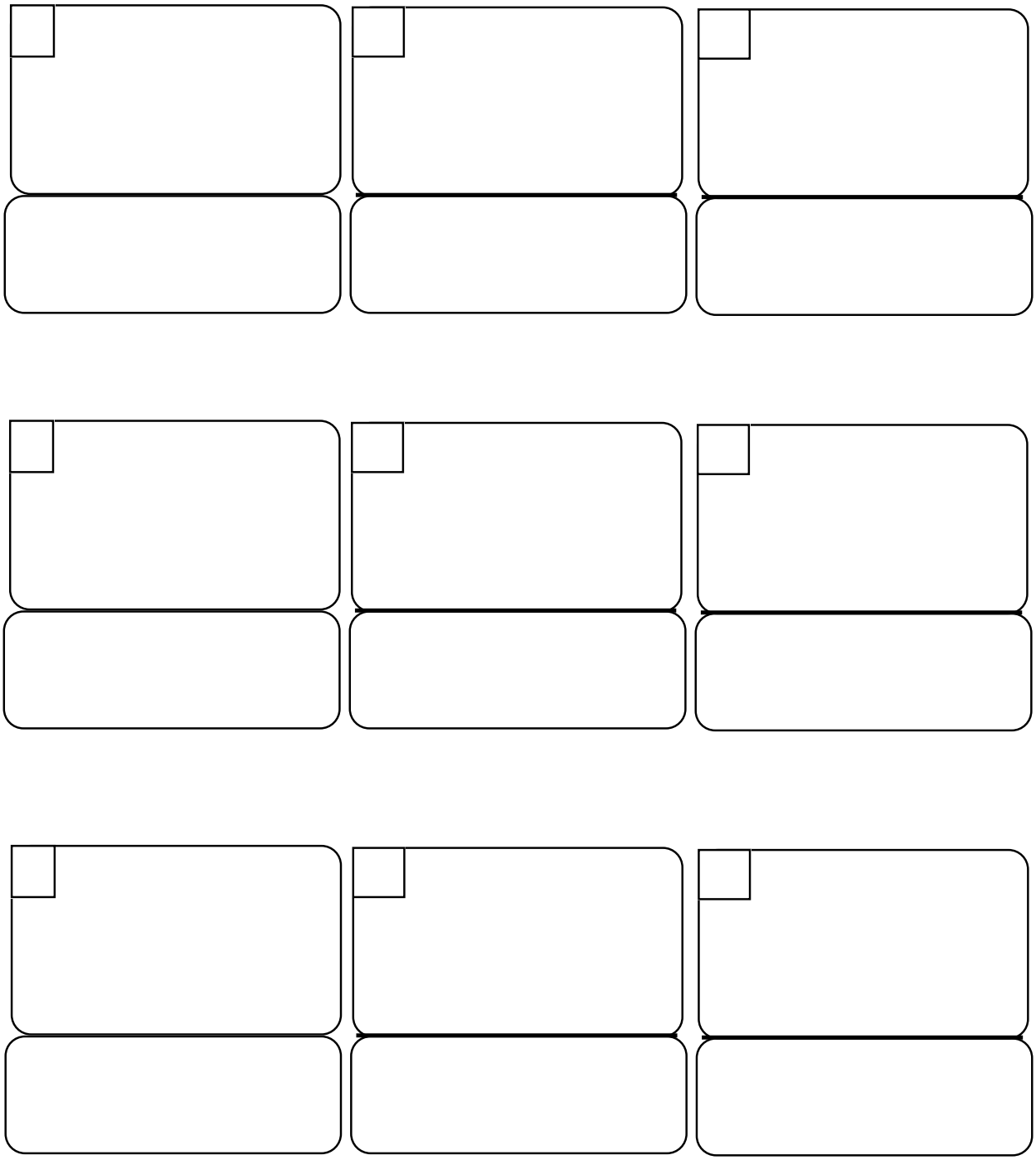
1. Create a clay model of the first stage of reef formation.
2. Videotape according to the above directions.
   (NARRATION/AUDIO)
3. Change the model, moving clay parts approximately 1/4" for each frame.
4. Videotape the next frame.
5. Change.
6. Video.
7. Proceed through the entire sequence of reef formation, following the storyboard.
8. Add narration, sound effects, music, etc.

FOLLOW-UP/EXTENSION:

Present the animations to other students.

Following the storyboard, use a software program such as KidPix SlideShow, or Multimedia Workshop to create a multimedia version for use on computers.

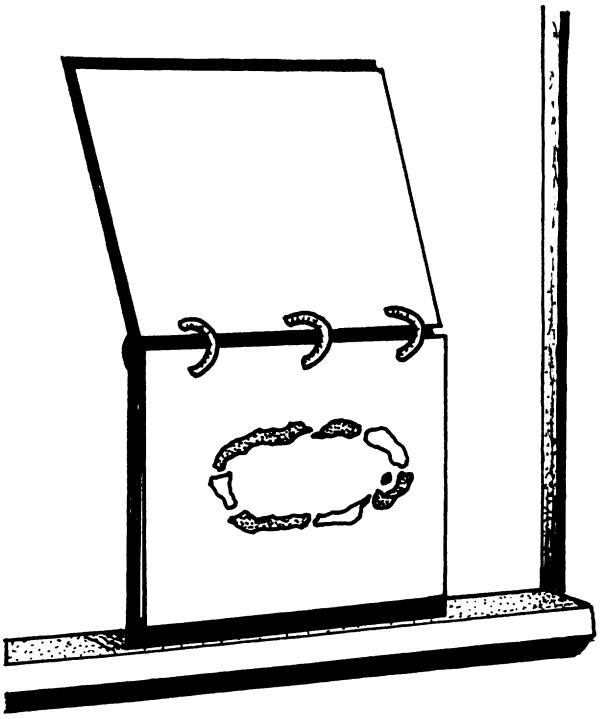
STORYBOARD

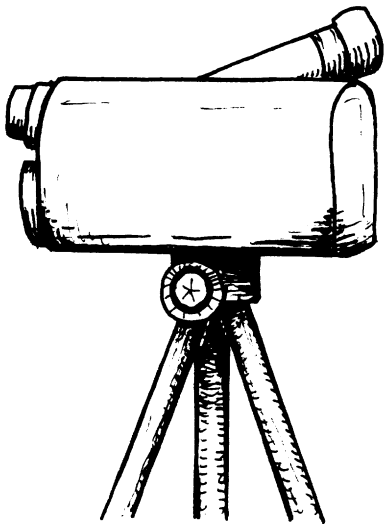


VIDEO ANIMATION PROJECT A

3-RING BINDER ANIMATION

1. Draw each step in the process of reef formation horizontally on a separate 8 1/2" x 11" plain paper and arrange in proper order in a notebook.
2. Place notebook upright on an easel or other surface.
3. Videotape each page in the sequence in order.
4. Add narration, sound effects, music, etc.



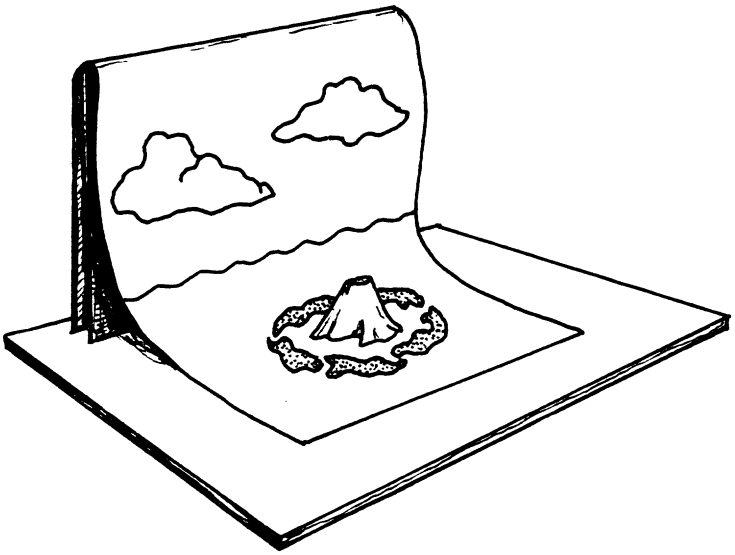


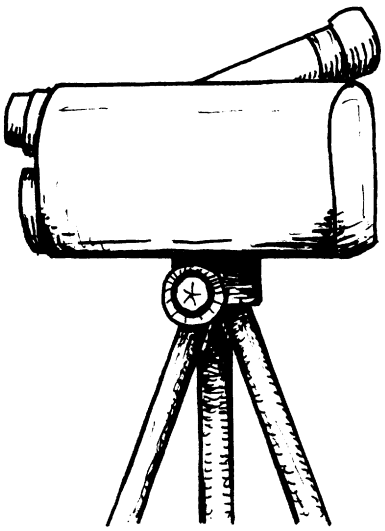
Use a 3-ring binder to hold animation sequences in order while videotaping.

VIDEO ANIMATION PROJECT B

CLAYMATION

1. Create a clay model of the first stage of reef formation.
2. Videotape.
3. Change the model, moving clay parts approximately 1/4" for each frame.
4. Videotape the next frame.
5. Change.
6. Videotape.
7. Proceed through the entire sequence of reef formation following the storyboard.
8. Add narration, sound effects, music, etc.





Butcher paper can make a painted backdrop for claymation scenes.

Who Am I?

Objective: Students present in-depth the characteristics of a species in the coral reef community, and analyze and classify information to name other species when they are described by characteristics.

Interdisciplinary Index: Science, English, Drama

Vocabulary: hard and soft corals, anemones, sharks, clownfish, nudibranchs, sea stars, squids and octopi, sponges, etc. See the **Life on the Coral Reef** section in the **Background Information** for more.

Materials:

- **Who Am I?** handout for each student
- paper, pencils, or computer/word processor

PRESENTATION:

1. Present information about the various species of life on the coral reef. Have the class list and classify the types of coral, sponges, fish, etc. and their characteristics. Brainstorm more statements to add to the list below which would give a clear picture of the plant or animal.
2. Assign groups to develop presentations on a particular type of marine plant or animal. For example, one group might represent the different types of coral. Each person in the group should be prepared to "be" the appropriate coral and complete the following types of statements.

I live _____(where).

I prefer _____(conditions).

I am made of _____(structure).

I have _____(physical adaptations).

I eat _____(diet).

I hunt/forage/feed _____(when/where).

I live _____(life span).

I reproduce _____(how, how often).

I am threatened by_____(predators, environmental hazards).

3. Each member of a group presents the statements above, in turn, with other students trying to guess "Who Am I?" The presenting group who can elicit the correct response quickest wins. This would necessitate ordering the statements with the most distinctive characteristics first.

FOLLOW-UP/EXTENSION:

Create a game using index cards with two or three of the statements on one side, the name of the animal on the other side. The object would be to draw a card, read the statements, and guess "Who Am I?"

WHO AM I?

To develop presentations on a particular type of coral reef animal, you will need to research its habits and environment. For example, one group might represent the different types of coral, another group the different types of fish. Each person in the group should be prepared to "be" the appropriate plant or animal and complete the following types of statements. As the class thinks of other statements, add them to the list.

Lionfish. (Photo: Terry Brown)

I live_____(where).

I prefer_____(conditions).

I am made of_____(structure).

I have_____(physical adaptations).

I eat_____(diet).

I hunt/forage/feed_____(when/where).

I live_____(life span).

I reproduce_____(how, how often).

I am threatened by_____(predators, environmental hazards).

3-D Mobile

Objective: Students identify individual members of the coral reef community and discuss their relationships with one another.

Interdisciplinary Index: Science, Art

Vocabulary: food chains, ecosystem, herbivores, omnivores, carnivores

Materials:

- butcher paper or drawing paper (white)
- crayons, paint or markers
- scissors
- glue and staples
- old newspaper for stuffing
- nylon fishing line or string

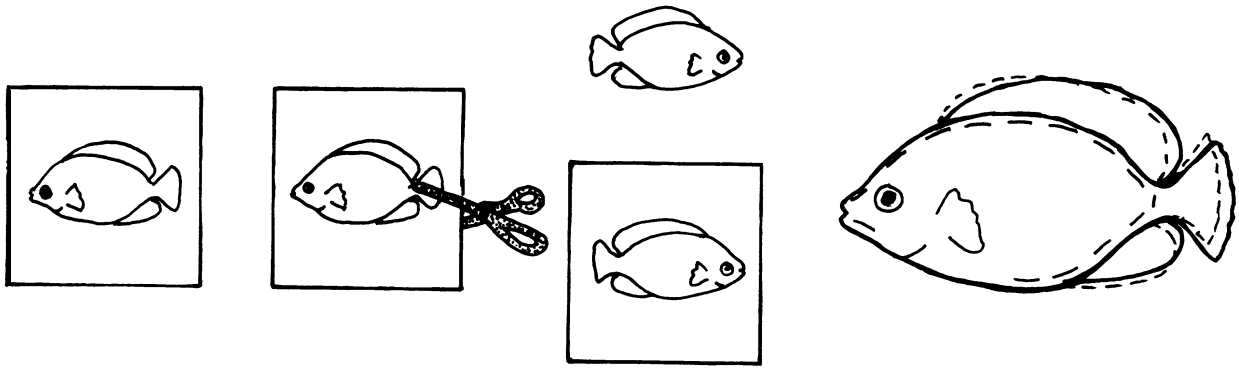
PRESENTATION:

1. Use the **Background Information** to introduce students to the variety of life on a coral reef. Discuss the interrelated nature of a reef ecosystem, food chains, etc. Create with the class a life-sized hanging mural/mobile of the coral reef community to depict the various life forms and the connections among them.
2. Draw the fish, coral etc. on paper.
3. Cut out and flip over to make a template to draw the other side, and cut it out.
4. Color both sides in accordance with the accurate depiction of the animal or plant.
5. Staple the two sides togther, leaving a space to stuff the newspaper inside.
6. Stuff bodies loosely and leave fins and tails free.
7. Staple fishing line to the top of the creature and hang all of them from a ceiling or in a display window.

FOLLOW-UP/EXTENSION:

Students in each group present their part of the project to the class.

Play a game in which students on one team give a description of an unnamed animal and the second team must choose the correct animal and then tell one fact about their animal or lose their turn. Go back and forth between group one and two. The group that has the most correct answers wins.



Coral Reef Comparisons

Objective: Students use compiled data to create a variety of graphs, and use these graphs to draw conclusions about coral reef populations.

Interdisciplinary Index: Math, Science

Vocabulary: data, species, population, herbivore, carnivore, omnivore

Materials:

- graph paper
- colored pencils or markers
- overhead projector and transparencies (optional)

PRESENTATION:

1. Tell students that they are going to compare the number of various coral reef species found on an Australian reef and a Caribbean reef.
2. Put the following data on an overhead or the chalkboard for everyone to see.

	% of Total Community	
Species	**Australia**	**Caribbean**
Damselfish (herbivore)	18%	20%
Parrotfish (herbivore)	8%	5%
Giant clam (herbivore)	7%	0%
Barracuda (carnivore)	3%	3%
Grouper (carnivore)	10%	15%
Shark (carnivore)	2%	3%
Angelfish (omnivore)	12%	9%
Hard coral (omnivore)	31%	35%
Sea star (omnivore)	9%	10%

(Note: The percentages given here are fictional, and are presented for the sake of comparison only.)

3. Discuss and describe the species listed.
4. Have students construct a bar graph comparing the percentage of herbivores, carnivores, and omnivores which dwell on the Australian reef.
5. Once the graphs are completed, discuss the following questions.
   - Which group accounts for the largest population in the Australian reef? Smallest?
   - What percentage of coral reef life eats plants? (include both herbivores and omnivores)
   - Predict what would happen to the number of carnivores if the number of herbivores decreased.
   - Predict what would happen to the number of herbivores if the number of carnivores decreased.
6. Repeat steps 4 and 5 using data from the Caribbean reef.
7. Have students construct a bar graph comparing the percentage of each species of herbivore in the Australian reef to the percentage of that species in the Caribbean reef.
8. Repeat this process for the carnivores and omnivores, and discuss any similarities or differences that may occur.

FOLLOW-UP/EXTENSION:

Have students average the two percentage figures for each species. Once students have calculated the average, have them graph it on a large piece of paper. Students can then draw pictures of each species represented and arrange pictures and graphs on a bulletin board.

Coral Reef Word Find

Objective: Students will review and become familiar with words related to the coral reefs in the **Life on the Coral Reef** section of the **Background Information**.

Interdisciplinary Index: Language Arts, Science

Vocabulary: phytoplankton, damselfish, trunkfish, barracuda, clam, clownfish, polyp, shark, juvenile, zooplankton, parrotfish, anemone, lobster, triton, nudibranch, zooxanthellae, octopus, mollusk, crab, crepuscular, lagoon, coral, seagrass, triggerfish, sponge, mangrove, omnivore, herbivore, carnivore

Materials:

- A blank **Coral Reef Word Find**, one for each student
- pencils

PRESENTATION:

1. Review the vocabulary.
2. Tell students they are going to make their own **Word Find**.
3. Have students place the review words (one letter in each square) randomly across, down, or diagonally on the grid.
4. When all of the words have been placed on the grid, students will fill in the empty squares with letters.
5. Have students exchange **Word Finds** and solve.

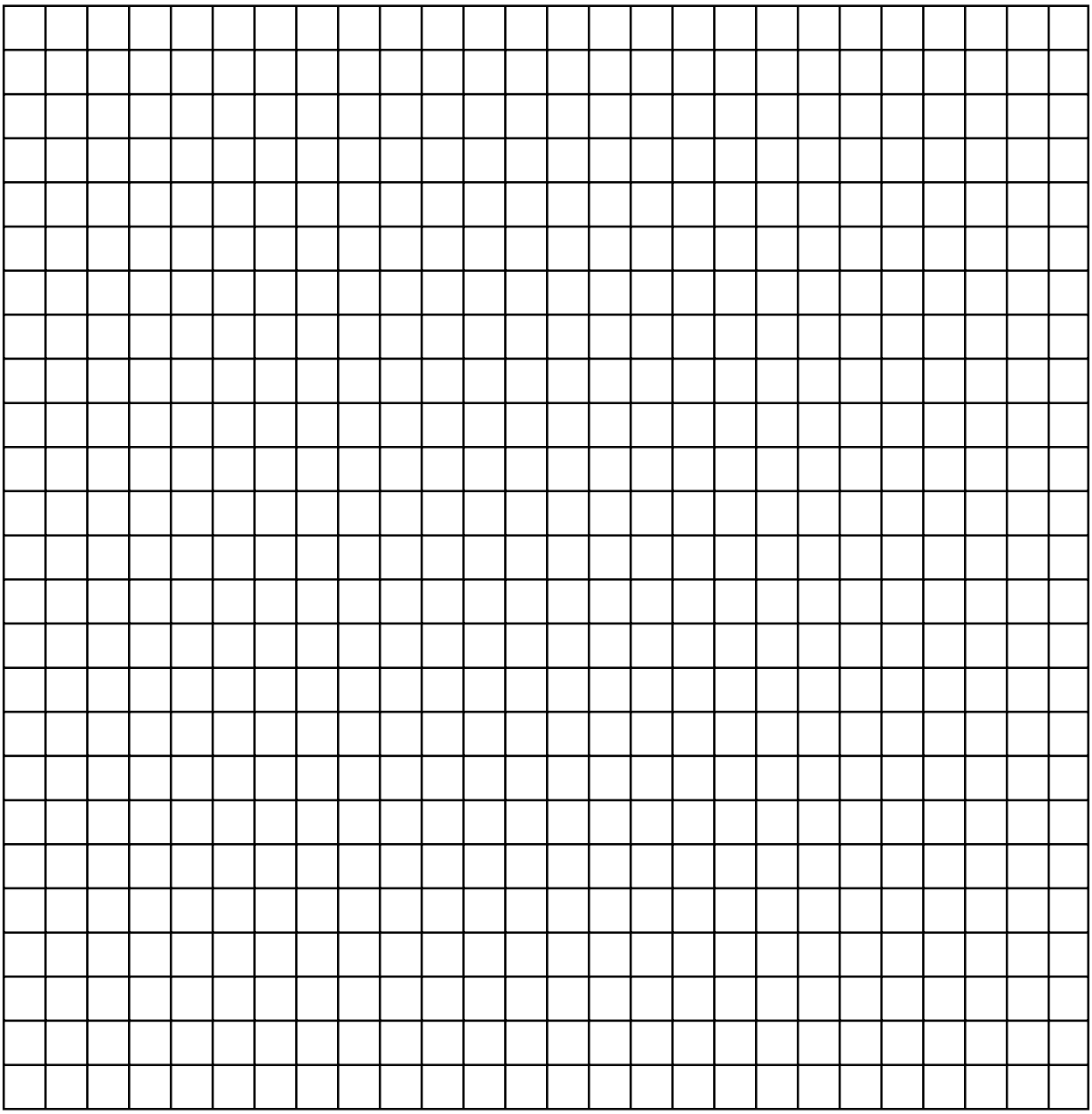
FOLLOW-UP/EXTENSION:

Give each student another **Word Find** sheet as homework. The student can make a word find for a friend or relative to solve. Encourage students to add their own coral reef words.

CORAL REEF WORD FIND

Use the words related to life on the coral reef to make a word search. See if someone else can solve your puzzle. Do they know what these words mean?

phytoplankton	polyp	lobster	crab	sponge
damselfish	shark	triton	crepuscular	mangrove
trunkfish	juvenile	nudibranch	lagoon	omnivore
barracuda	zooplankton	zooxanthellae	coral	herbivore
clam	parrotfish	octopus	seagrass	carnivore
clownfish	anemone	mollusk	triggerfish	



Living Together in a Coral Reef Community

Objective: Students will become familiar with the many diverse and intimate relationships in coral reef ecology. Topics to be discussed and developed for roll-playing presentations are from the **Life on the Coral Reef** section of the **Background Information**.

Interdisciplinary Index: Science, Art

Vocabulary: the marine food chain, predation, protection, symbiosis

Materials:

- transparency of page 2-7, "The Food Chain"
- copy of the **Coral Reef Color Page** on page M-21 for each student in the class

PRESENTATION:

The Marine Food Chain

1. Using a transparency of the marine food chain, discuss how the sun's energy is utilized and transferred between the different participants in the food chain. Introduce the terms primary producers, primary consumers (herbivores), secondary consumers (carnivores and omnivores), and decomposers. Handout copies of the **Coral Reef Color Page** and have students identify and label each of the organisms by common name and role in the marine food web. Refer to the "Marine Food Chain Answer Key" at the end of this lesson plan. Consider having the groups divide up the work and present their results to the class.
2. Have students diagram their own marine food chain using a representative organism from the color page. They can refer to "The Food Chain" transparency while doing this.

EXAMPLE:

Sun

- primary producers: plants, i.e. seagrass, phytoplankton, algae, zooxanthallae
- primary consumers: herbivores, i.e. sea urchin, parrotfish, damselfish, giant clam, conch
- secondary consumers: omnivores, i.e. feather stars, sponges, angelfish; and carnivores, i.e. sharks, moray eel, trumpet fish
- decomposers, i.e. bacteria and algae (recycle nutrients)

3. Discuss the possible effects of removing one of the players from the marine food chain and its effect on the entire ecosystem. For example, discuss the possible impact of the removal of sharks from the food chain. How about herbivorous fish?

EXPLANATION:

Sharks are a crucial secondary consumer at the top of the marine food chain that have lived in the ocean for over 300 million years. They are an integral factor in controlling the size of many coral reef fish populations and their removal can cause some fish populations to increase drastically resulting in the concurrent loss or crowding out of other species. These effects can be felt at all levels of the marine food chain, resulting in unforeseen damage to the marine environment. The coral reef food chain is a finely balanced system and human disturbances can have devastating effects.

If herbivorous fish, such as damselfish, are overfished or removed from coral reefs, algae can quickly overgrow the corals and block them from receiving the sunlight that they need for photosynthesis. This algal overgrowth can cause reefs to die out. In the late 1980's overfishing in Jamaica contributed to the overgrowth and loss of several major reefs.

Predation and Protection

4. Discuss the importance of predation and protection on survival in the coral reef ecosystem. Describe different protective strategies used by organisms on the reefs and their adaptive importance. Using the **Coral Reef Color Page**, have students form small groups and discuss the protective strategies utilized by as many of the organism as they can. Have each group pick their favorite relationship or adaptive strategy and have them present a short role playing skit to the class.

EXAMPLES OF PROTECTIVE STRATEGIES:

Blue Dash Butterflyfish: The blue dash butterflyfish is shaped like a thin pancake so that it can hide easily among the coral and be safe from predators. It is bright yellow with a blue streak on its body and a "fake eye" on its tail to confuse any predators that try to attack. The predator thinks that it is aiming for the head when in reality it is aiming for the tail, enabling the butterflyfish to dart forward and escape.

Clown Triggerfish: The clown triggerfish is marked with large white polka dots which help to break up its outline and camouflage it against the reef. It is also very poisonous so predators do not try to eat it. The clown triggerfish attacks small reef animals, such as fish that hide in the sand and sea urchins, by blowing streams of water out its mouth to uncover or overturn its prey.

Hard Coral: Hard corals build reefs by secreting a hard external limestone skeleton. During the daytime, the coral polyp retracts into its limestone base for protection from hungry fish but at night it comes out to feed on floating plankton.

Nudibranch: The nudibranch feeds on the tentacles of sea anemones but does not trigger their stinging cells (called nematocysts). Instead, the stinging cells migrate to the nudibranch's exposed gill where they serve as a defense against predators. Nudibranchs come in a wide variety of shapes and bright colors. Their bright colors warn predators of their deadly poison.

Pufferfish: 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 called *tetraodontoxin* which discourages predators from eating them.

Stonefish: 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 to be the most deadly venomous fish in the Indo-Pacific region.

Symbiosis

5. Discuss the importance of symbiotic relationships for life on the coral reef. Pick one of the following symbiotic relationships: coral - zooxanthellae, sea anemone - clownfish, or cleaner wrasse - fish being cleaned, and discuss the energetic, ecological, and survival benefits for each of the organisms involved. Have the class break up into small groups and prepare a short poem, role playing presentation, or artistic representation about the importance of symbiosis on the coral reef. As an extension have each student prepare a research essay describing a symbiotic relationship and its evolutionary and ecological importance to the organisms involved.

EXAMPLES OF SYMBIOSIS:

Corals and zooxanthallae: Within the tissue of the coral polyp live many microscopic algae called zooxanthallae. These algal cells provide the coral with food through the process of photosynthesis in which zooxanthallae cells use sunlight to convert the carbon dioxide and water in the polyp tissue into oxygen and carbohydrates. The oxygen is used by the polyp for respiration and the carbohydrates are used for energy to build its limestone skeleton. In return, the polyp provides the zooxanthallae with nutrients, protection, a place to live, and carbon dioxide, a by-product of respiration which is vital for photosynthesis.

Sea anemone and clownfish: The clownfish has a symbiotic relationship with its partner, the sea anemone. The clownfish 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. In return, the clownfish, being extremely territorial, drives off any fish that try to prey on the anemone. The clownfish also drops bits of food among the tentacles which the anemone can eat.

Cleaner wrasse and fish being cleaned: The cleaner wrasse cleans debris and parasites off of larger fish which keeps the larger fish healthy and gives the cleaner wrasse nourishment and protection. The fish being cleaned will allow it to move freely about its gills and mouth without trying to eat it. In some places fish actually line up for this service, forming cleaning stations along the reef. Cleaner fish are very important in keeping fish, and therefore the reef, healthy and strong.

MARINE FOOD CHAIN ANSWER KEY

1. **White tip reef shark**
   secondary consumer - carnivore (page 2-9)
2. **Lettuce coral**
   primary producer (zooxanthallae), and secondary consumer - omnivore (polyps) (page 1-2)
3. **Butterfly cod (lionfish)**
   secondary consumer - carnivore (page 2-10)
4. **Parrotfish**
   primary consumer - herbivore (page 2-8)
5. **Soft coral**
   secondary consumer - omnivore; soft corals lack zooxanthallae and feed entirely on passing plankton (page 1-5)
6. **Sea whips**
   secondary consumer - omnivore; a gorgonian soft coral (page 1-5)
7. **Brain coral**
   primary producer (zooxanthallae), and secondary consumer; omnivore (polyps) (page 1-2)
8. **Olive sea snake**
   secondary consumer- carnivore
9. **Soft Coral**
   secondary consumer - omnivore (page 1-5)
10. **Feather star**
    secondary consumer - omnivore
11. **Damselfish**
    primary consumer - herbivore; damselfish are a reef "farmer" that actively guard and grow small patches of algae as a food source (page 2-8)
12. **Plate coral**
    primary producer (zooxanthallae), and secondary consumer - omnivore (polyps) (page 1-2)
13. **Vasiform sponge**
    secondary consumer - omnivores (plankton)
14. **Cuttlefish**
    secondary consumer - carnivore (page 2-13)
15. **Needle coral**
    primary producer (zooxanthallae), and secondary consumer - omnivore (polyps) (page 1-2)
16. **Batfish (juvenile)**
    secondary consumer - carnivore
17. **Moorish Idol**
    secondary consumer - omnivore; a bottom feeder
18. **Gorgonian fan coral**
    secondary consumer - omnivore; a soft coral (page 1-5)
19. **Sea anemone**
    secondary consumer - carnivore
20. **Mushroom coral**
    primary producer (zooxanthallae), and secondary consumer - omnivore (polyps) (page 1-2)
21. **Giant clam**
    primary consumer - herbivore, and primary producer (zooxanthallae) (page 2-8)
22. **Six-banded trevally**
    secondary consumer - carnivore also known as jacks
23. **Trumpetfish**
    secondary consumer - carnivore
24. **Coral cod**
    secondary consumer - carnivore; a grouper
25. **Yellow margin moray eel**
    secondary consumer - carnivore
26. **Spotted seahorse**
    secondary consumer - carnivore
27. **Sponge**
    secondary consumer - omnivore (plankton)
28. **Blue sea star**
    secondary consumer - carnivore (page 2-11)
29. **Flowery flounder**
    secondary consumer - carnivore
30. **Branching coral**
    primary producer (zooxanthallae), and secondary consumer - omnivore (polyps) (page 1-2)
31. **Emperor angelfish (juvenile)**
    secondary consumer - omnivore
32. **Banded coral shrimp**
    secondary consumer - carnivore; cleans parasites from anemones, corals and other hosts

Fishy Problems

Objective: Students gain a greater understanding of the problems facing coral reefs and native coastal people by calculating the answers to the questions on the following page.

Interdisciplinary Index: Math

Materials:

TABLE OF EQUIVALENTS

1 kilogram = 2.205 pounds

1 metric ton = 2,204.623 pounds

1 kilometer = .621 miles

1 mile = 5,280 feet

- one **Fishy Problems** handout per student

PRESENTATION:

1. Discuss the various anthropogenic threats affecting coral reefs and the native coastal people dependent upon them for survival.
2. Distribute a copy of the **Fishy Problems** handout to each student and have them answer the questions.
3. Discuss the answers with the students and their feelings about the impact these situations are having on the environment, people, local and global economies, etc. What solutions might they recommend? Emphasize that all of the questions are based upon actual scientific information.

ANSWERS TO FISHY PROBLEMS:

1. a) 3 million
   b) 4
   c) 50
2. 22,500
3. 12,000
4. a) 48
   b) 37.5 kg.
   c) 3969 lbs.
   d) 496 lbs.
5. a) 3279 ft.
   b) $3,660/ft.
6. $62 million
7. a) between 20 to 35 metric tons
   b) 44,092.5 to 77,161.8 lbs.
8. a) 429,730 metric tons
   b) 3 million people eat 0 lbs. of fish
   6 million people eat 58.42 lbs./person

FISHY PROBLEMS

QUESTIONS:

1. The world's oceans are fished by over one million large fishing ships and two million smaller ones. Around the world, 12.5 million people make their living catching fish, and another 150 million people are employed in on-shore operations or the processing of fish.
   a) How many ships fish the world's oceans?
   b) For every single fishing boat, how many people are needed, on the average, to catch fish?
   c) For every single fishing boat, how many people are needed, on the average, to handle on-shore fishing operations and processing?
2. "Almost all tuna stocks worldwide are in peril from overfishing, with the Atlantic bluefin tuna declining 90 percent in the last two decades, from 225,000 in 1970 to only _____ in 1990."

   Calculate the number of bluefin tuna remaining in the ocean in 1990.
3. Shrimpers off the southern coast of the United States catch approximately 48,000 endangered sea turtles a year. It is estimated that one quarter of these are killed in the shrimp nets. How many turtles are killed each year?
4. In a coral reef area near Santiago Island in the Philippines, observers recorded 6 dynamite fishing explosions per hour, with an estimated catch of 1800 kg of fish per day.
   a) Assuming there are eight hours in the fishing day, how many dynamite explosions occured in one day?
   b) How many kg of fish on the average would have been caught after each explosion?
   c) How many pounds of fish would have been caught in a day?
   d) How many pounds caught in one hour?

   Surveys indicated that more than half of the corals in that area had been killed by the dynamite blasting.
5. In the Maldives, a coral reef was destroyed which caused increased erosion of the beach and loss of sand. This could have the disastrous effect of increasing the loss of life and property during storms, decreasing income from tourism, and harming habitat. As a result, the government spent $12 million for 1 km of seawall to replace the destroyed reef.
   a) How many feet long was the seawall?
   b) What was the cost per foot to build?
6. It is important to consider the economic value, both short term and long term, of environmental conservation. However, often this is not done. For example, in the Philippines a logging concession was expected to yield $13 million from cutting down the rainforest over a 10-year period. The resulting environmental problems, such as erosion and siltation, would have severely damaged the adjacent coral reefs where fishing was done. If this had happened, it was estimated that up to $75 million in fishing revenue would have been lost. If this logging concession had been granted, what would have been the net loss of revenue?
7. In the Philippines, it is estimated that 1 square kilometer of coral reef in poor condition produces only 5 metric tons of fish per year, just enough to feed 100 people. A healthy reef, however, can feed between 400 to 700 people per year.
   a) How many metric tons of fish would be produced by a healthy reef?
   b) How many pounds of fish would this equal?
8. At a conservative estimate, coral reef destruction in the Philippines has meant a loss of 37% in fish production each year, or 159,000 metric tons.
   a) If the coral reefs were healthy and fish production was at 100%, how many metric tons of fish would be produced?

   This 37% loss means that 3 million people now get no seafood protein, or 6 million people get only half the protein they need.
   b) How many pounds of fish does each of these people now eat in a year?

Don't Teach Your Trash to Swim!

Objective: Students describe marine debris and its effect on coral reef ecosystems. They then propose some possible solutions to the problem.

Interdisciplinary Index: Science, English, Journalism

Vocabulary: marine debris, reduce, reuse, recycle, journalistic style, inverted pyramid

Materials:

- **Stop Trashing the Reef!** and **Journalistic Writing Style** handouts to each student
- paper, pencil, or computer

PRESENTATION:

Trash found in the ocean is directly affecting the health of the world's coral reefs. The accompanying handout for students and the information in the **Benefits, Threats, and Solutions** section will provide more background on this threat and point to solutions.

1. Present the background information on the threat posed by trash, and offer recycling as a possible solution. Read the **Stop Trashing the Reef!** handout and discuss the recycling concepts of reduce, reuse, recycle.
2. Read the **Journalistic Writing Style** handout. Introduce the suggestions for journalistic writing style and the inverted pyramid.
3. Have students write a newspaper article using journalistic writing style and an inverted pyramid explaining why reef systems are important to people in your community and what makes trash such a threat to reefs. Link local recycling efforts to global effects on the reefs. Cite resources for information. Include photos, artwork, or clip art to illustrate the articles.
4. Allow students to edit each other's articles and display the finished products.

FOLLOW-UP/EXTENSION:

Submit the best articles to the local newspaper for possible publication.

Research other newspapers or magazines which might publish the articles.

DON'T TEACH YOUR TRASH TO SWIM

Trash in the water or along the shore is called marine debris. Ocean sources of garbage include recreational vessels, merchant, military, and commercial fishing boats, and oil platforms. People on the beaches who allow trash to blow or wash into the water, illegal dumping and waste disposal, and plastics are major land-based contributors to the problem.

We must all realize that the products we use in our homes, even if far away from the oceans and coral reefs, can ultimately reach the sea. The planet is indeed linked, and each system affects the others. Therefore, recycling efforts in our communities can have a direct effect on the health of a coral reef in another part of the world. If at home and at school we can reduce, reuse, and recycle, the positive impact will be tremendous.

Brainstorm ideas to add to the lists below.

California sea lion entangled in fishing net, Sea of Cortez, Mexico. (Photo: Hal Beral)

REDUCE: Use a plate or glass instead of paper plates or cups; use fewer paper towels; buy products in bulk or in less packaging, or buy products in recycled packaging.

REUSE: Use reusable containers for lunch; use a reusable lunch bag; use margarine tubs, shoeboxes, etc. for other things.

RECYCLE: Newspaper, glass, plastic, aluminum; oil and other auto fluids, paint, solvents and thinners can also be recycled.

JOURNALISTIC WRITING STYLE

Writing a newspaper or magazine article requires a different style than you would use to write an essay, a short story, or a biography. The reporter must keep in mind the purpose of the article and the readers' needs. The purpose of the article might be to convey information, to expose corruption, or to portray all sides of an issue. Entertainment would probably not be the primary purpose of the article, unless it were part of the entertainment section of the newspaper. The article can be humorous, as long as that serves the main purpose of the article.

The readers need to have answers to their questions. There are five questions which traditionally form the basis for the journalistic style of writing. They are: Who?, What?, Where?, When?, and Why? Answering these questions in your article will allow you to be thorough, precise, and concise. The writer must decide in which order to answer these questions, whether the topic is about who is involved, or what is happening, or one of the other "5 W's." Following are the "5 W's" and some examples of other questions you might ask to clarify your writing. Apply these questions, or others you may think of, to the topic of your article.

"5 W's"

Who? – Who is involved? Who did it? Who is affected?

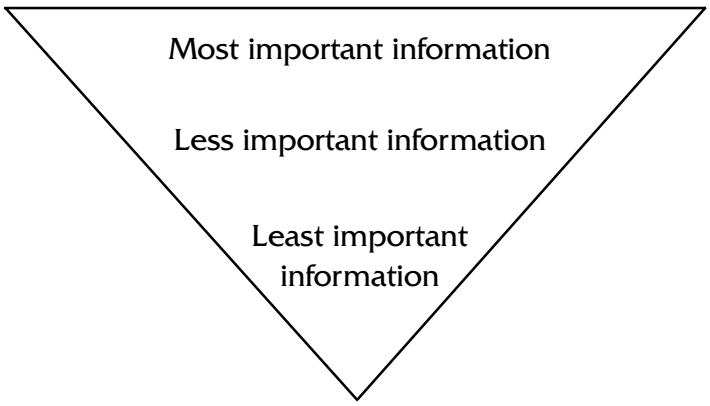
What? – What happened? What was the outcome? What is it?

Where? – Is the location important?

When? – Is this story about the past, present, future, or all three?

Why? – Why did the people act the way they did? Why did it happen here? Why is this happening here? Why is this a problem? Why should we care about this?

Another characteristic of journalistic writing involves writing in an inverted pyramid style. Think of it in terms of putting the most important information first, the second most important information next, and so on. This is a good idea for two reasons: 1) the reader gets hooked into the story right away and is more likely to keep reading, 2) the editor is often forced to cut articles because of space, and this allows cuts to be made from the bottom up without deleting the important information.



Destructo Diver

Objective: Students discuss the dangers of human activities to reefs, particularly diving, and encourage proper techniques which will lessen human damage to reefs.

Interdisciplinary Index: Science, English, Writing, Drama

Vocabulary: anthropogenic, sedimentation, weight and buoyancy control

Materials:

- **Destructo Diver Vs. Dependable Diver** and **Destructo/Dependable Diver Behaviors** handouts to each student
- painted backdrops
- props such as masks, fins, and other diving equipment

PRESENTATION:

1. Discuss the nature of threats to the coral reef and brainstorm possible solutions. Discuss the problem that people, such as divers, who enjoy and are interested in the reefs can still have a negative impact on the fragile coral community.
2. Have the students call local dive shops or dive clubs and interview some divers in preparation for writing a series of short skits in which they role-play the actions of **Destructo Diver vs. Dependable Diver**.
3. As a class, discuss the behaviors associated with **Destructo Diver** and with **Dependable Diver**. Cover such topics as boat diving, collecting, spearfishing, etc. using the **Destructo/Dependable Diver Behaviors** handout.
4. Assign specific behaviors for each group to portray.
5. In groups, students write a short skit illustrating the behavior.
6. Assign roles, practice.
7. Produce the skits for the class, including props and backgrounds if possible.
8. Critique the skits in class, discussing which was most effective and why.

FOLLOW-UP/EXTENSION:

Perform the skits for other audiences such as dive clubs.

Videotape the skits and distribute to others.

Create a series of posters based on the skits and send them to dive shops in your community.

Create a comic book or coloring book illustrating the lesson(s).

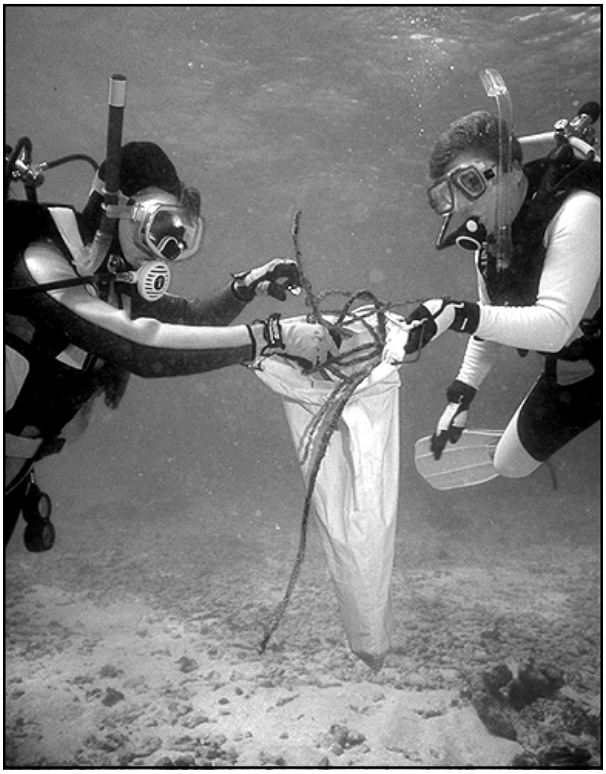
DESTRUCTO DIVER VS. DEPENDABLE DIVER

DESTRUCTO DIVER VS. DEPENDABLE DIVER

Living coral reefs attract people who want to experience their beauty first-hand. Unfortunately, many of these same people are damaging the very environment which they love. It is estimated that the average scuba diver has negative contact with a coral reef approximately seven times for every 30 minutes underwater. Multiply this by the millions of divers from the U.S. alone making multiple dives every year, and the impact is clear. Coral reefs are being carelessly and needlessly damaged.

Read the following information on the proper and improper behaviors of divers, then write a short skit portraying several of the behaviors. Present your skit to the class.

Make notes here about your skit:



Dependable Diver: coral reef sweepers do underwater reef clean-up. (Photo: Larry Benvenuti)

DESTRUCTO DIVER BEHAVIORS

Bad Boating: Careless diving off the dive boat can run the boat aground a coral reef, shearing off corals and stirring up sediments. Dropping anchor onto the reef damages the coral below.

Trashing the Reef: Dumping trash, emptying toilets, and spilling or leaking fuel and oil pollutes the water and can ultimately damage the reef ecosystem.

Careless Entries: Divers who jump into the water without looking can smash into corals and kill them.

Poor Buoyancy Control: Being overweighted and grabbing at live coral for balance or dragging fins over corals and kicking wildly to keep in balance can stir up the bottom silt and cloud the water with sediment which settles on the coral. Large amounts of silt smothers the coral, interfering with the coral's natural filtration system.

Standing on Corals: Sitting, kneeling, or standing on coral damages the living animal, creating wounds and dead areas which can become infected and spread to the entire coral colony. The stress of battling infection can be fatal to an organism already in delicate balance.

Trailing Equipment: Regulators, dive computers, net bags, bulky photography equipment, and other dangling articles can hit or become entangled in coral, ripping it off in chunks.

Interacting with Marine Life: Feeding the reef fish disrupts their natural patterns, making them more vulnerable to predators, both other marine animals and fishermen. Using bangsticks or spearguns to kill reef fish results in serious overfishing, diminishing an important part of the live coral reef. Collecting live specimens of coral, sponges, and fish as souvenirs or for resale is carelessly destroying life on the reefs. Chasing and grabbing onto fish or pulling animals out of their hiding places weakens and stresses them needlessly, often causing injury or death.

DEPENDABLE DIVER BEHAVIORS

Good Boating: Careful boat handling includes operating at a safe speed, and anchoring either at a buoy or far enough away from the reef that anchor and chain will not tear off coral as the boat drifts or sways.

Caring for the Reef: Carrying out trash and waste, and keeping boat engines in good repair to minimize fuel and oil leaks will help stop pollution.

Careful Entries: Gently dropping into open water and orienting yourself, once underwater, will allow you to approach the reef carefully.

Buoyancy Control: Practice buoyancy control in a pool or other quiet body of water where there is no surge from waves. Being able to hover over the reef without touching it with hands or feet protects the reef, reducing the chance of silt being churned up in the water. The feeling of flying is one of the real thrills of diving.

Floating Over Corals: Proper weighting allows the diver to float comfortably without having to stand on the coral.

Controlling Equipment: Keep all equipment tucked into belts or close to the body. Use a compact camera with an attached strobe.

Observing Marine Life: Enjoy the sights of dazzlingly beautiful sea creatures in their natural environment. Do not disturb or feed wild fish or collect specimens. "Take only pictures, leave only bubbles."

Benefits, Threats, and Solutions Crossword Puzzle

Objective: Students will learn about the benefits derived from coral reefs, the threats to them, and possible solutions by finding words to complete the crossword puzzle.

Interdisciplinary Index: Language Arts, Science

Materials:

- a copy of the **Benefits, Threats, and Solutions Crossword Puzzle** and **Puzzle Clues**, one per student
- pencils

PRESENTATION:

1. Review the **Benefits, Threats, and Solutions** section in the **Background Information**.
2. Hand out a copy of the crossword puzzle and clues to each student.
3. Ask them to read the description and find the word that both answers the description and fits into the boxes.
4. When everyone is finished, discuss the answers with the students.

FOLLOW-UP/ EXTENSION:

Have students create their own crossword puzzles for the class to answer.

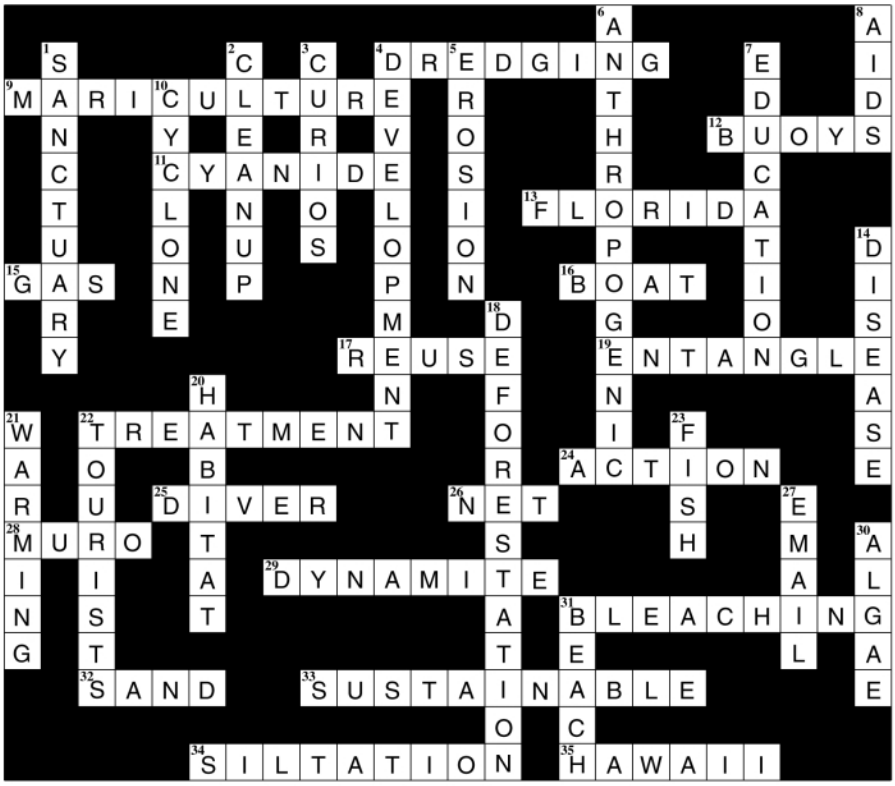
ANSWER KEY

ACROSS:

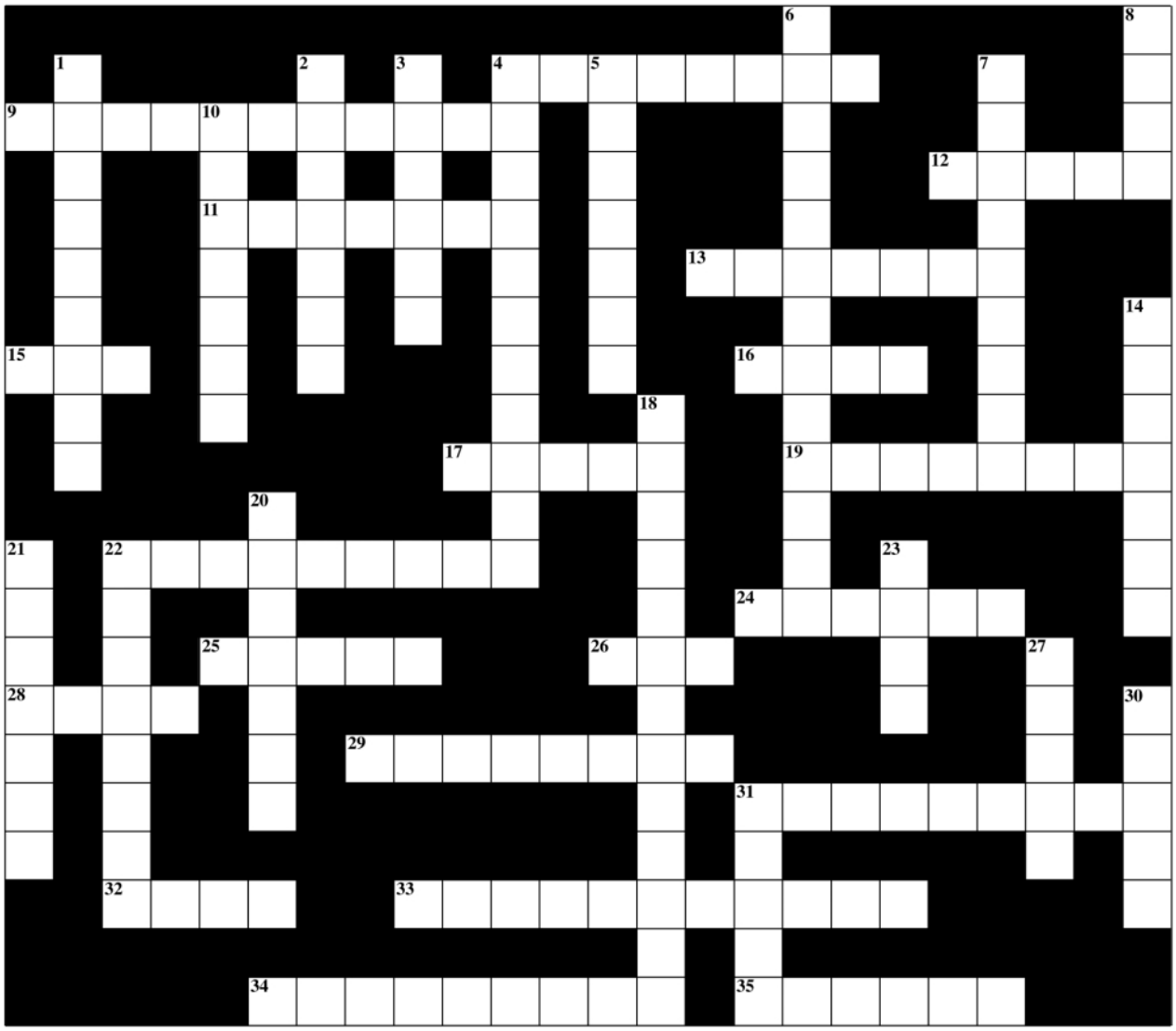
4. **dredging**
9. **mariculture**
11. **cyanide**
12. **buoys**
13. **Florida**
15. **gas**
16. **boat**
17. **reuse**
19. **entangle**
22. **treatment**
24. **action**
25. **diver**
26. **net**
28. **muro**
29. **dynamite**
31. **bleaching**
32. **sand**
33. **sustainable**
34. **siltation**
35. **Hawaii**

DOWN:

1. **sanctuary**
2. **cleanup**
3. **curios**
4. **development**
5. **erosion**
6. **anthropogenic**
7. **education**
8. **AIDS**
10. **cyclone**
14. **disease**
18. **deforestation**
20. **habitat**
21. **warming**
22. **tourists**
23. **fish**
27. **email**
30. **algae**
31. **beach**



BENEFITS, THREATS, AND SOLUTIONS CROSSWORD PUZZLE



BENEFITS, THREATS, AND SOLUTIONS CROSSWORD PUZZLE CLUES

ACROSS:

4. the clearing of channels
9. the farming of marine plants and animals
11. a type of poison used to catch fish
12. moorings used by boats
13. a southeastern state with coral reefs
15. riding a bike saves this type of fuel
16. a vehicle that causes damage by grounding and anchoring
17. to use over and over again
19. to get caught in nets, fishing lines, garbage
22. medical care
24. to do something to protect the environment; take _____
25. someone who wears SCUBA gear underwater
26. a nylon or fiber mesh used in fishing
28. _____-ami, a type of net used in fishing
29. an explosive used to kill fish
31. the expelling of zooxanthellae from coral polyps due to stress
32. fine grains of limestone, rock and shells
33. non-exploitative use of natural resources
34. the covering of coral with sediment
35. the western island state with coral reefs

DOWN:

1. a marine protected area
2. picking up trash
3. gifts made from coral and shells
4. building and construction
5. the washing away of soil
6. human-caused
7. learning
8. a deadly virus, a treatment for which might be found in coral reefs
10. a fierce storm in the southern hemisphere
14. illness
18. clear-cutting of trees
20. the place where a plant or animal naturally lives
21. global _____, increase in water temperature
22. a source of income that wears tacky shorts and carries cameras
23. a source of protein that lives in the sea
27. a way to communicate electronically with others using the computer
30. a green marine plant that thrives on excess nutrients
31. sandy shore

Student Assessment

Tell and Show What You Know

Objective: Students will review what they have learned about the coral reef by illustrating their knowledge and sharing it with others.

Interdisciplinary Index: Science, Language Arts, Art

Materials:

- writing paper or butcher paper for each student
- colored pencils, pens, crayons, and felt pens

PRESENTATION:

1. Have students fold paper into 4, 8, or 16 equal parts.
2. Tell students that they are to think of the 4, 8, or 16 most interesting things that they have learned about the coral reefs.
3. Have students draw or write down their thoughts in the 4, 8, or 16 parts of the paper.
4. Have students share their thoughts/pictures in small groups or with the class.
5. The finished product can be used as a mural.

FOLLOW-UP/EXTENSION:

Ask students to repeat the activity based on one of the following formats:

What would happen if...

What would you do if...

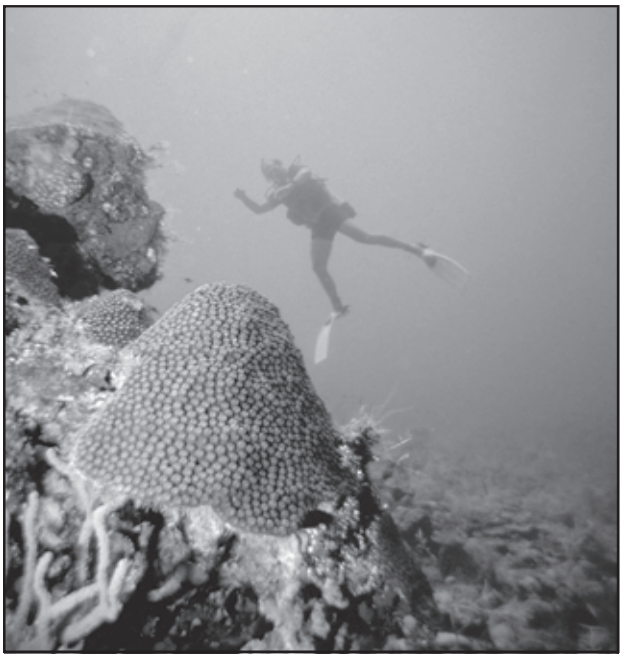
How I can help...

The 4, 8, 16 most interesting coral reef creatures are...

THE CORAL REEF TEACHER'S GUIDE

RESOURCES

- **Glossary**
- **Bibliography**
- **References for Students**
- **Educational Merchandise**
- **Coral Reef-Related Organizations**
- **Action Programs**



Scuba diver on Cuban reef. (Photo: Larry Benvenuti)

Glossary

ahermatype – soft corals and a few hard corals that do not build reefs.

algae – simple, chiefly aquatic plants, such as seaweed and kelp.

anemone – a marine invertebrate related to corals and jellyfish.

anthropogenic – human-caused changes.

atoll – a ring-shaped series of small coral islands that enclose a central lagoon.

barrier reef – a long narrow ridge of coral parallel to the coastline but separated from it by a lagoon.

budding – a form of asexual reproduction where a new cell is formed from the parent cell.

calcium carbonate – a white chemical compound which occurs naturally as chalk and limestone. This is the material which forms coral skeletons.

camouflage – the act or means of disguising something to deceive a predator.

carnivore – an animal that eats other animals.

cnidarian – members of the phyla Cnidaria which are characterized by a body that only opens at one end, such as corals, jellyfish, and anemones.

colony – a connected, interrelated group of hard coral polyps.

conservation – preservation from loss.

coral – colonial marine animals characterized by limestone skeletons, often forming reefs or islands.

coralline algae – type of red seaweed that encrusts itself with lime which helps to cement the dead coral rock together.

coral bleaching – loss of color by corals which occurs when the corals are stressed and expel their endosymbionts.

coral reef – a stony marine structure formed from joined skeletons of corals cemented together by algae and other organisms.

crepuscular – term used to describe animals that become active at dawn and/or dusk.

crustacean – usually a marine animal that has a hard shell.

decomposition – the process of breaking down into smaller elements; decaying.

diurnal – term used to describe animals that become active during the day.

ecosystem – all of the plants and animals in a community along with the non-living environment.

ecology – the study of the interactions of plants and animals with their environment.

endangered species – a species in danger of extinction.

endosymbionts – refer to zooxanthellae.

environment – everything surrounding an organism.

equator – an imaginary line circumscribing the Earth's surface, dividing the Earth into Northern and Southern hemispheres.

extinct – no longer in existence.

fringing reef – a coral reef that forms adjacent to the shoreline that does not have a lagoon.

food chain – a linear pattern of nutrient and energy transfer among organisms in an ecosystem.

Great Barrier Reef – the largest living organism in the world, stretching over 1,240 miles off the eastern coast of Australia and visible from outer space.

hard corals – reef-building corals that secrete external limestone skeletons and typically have tentacles in multiples of six.

herbivore – an animal that eats plants.

hermaphroditic – containing both male and female sex cells.

hermatype – hard corals that build reefs.

invertebrate – animal without a backbone.

lagoon – a body of shallow water separated from the open sea by a barrier, such as a reef.

mangroves – tropical trees that grow in the transitional zone between land and sea; some mangroves have roots that grow above the ground.

mariculture – the farming of marine plants and animals.

mesenterial filaments – long tubular structures which the coral polyp extends to defend itself from attack.

nematocyst – stinging organ found in corals, jelly-

fish, anemones, and other related organisms, which, when stimulated, ejects a harpoon-like structure that chemically paralyzes the victim.

nocturnal – term used to describe animals that become active during the night.

nudibranch – a marine organism also called a sea slug or marine snail.

octocorals – coral polyps that typically have eight tentacles and secrete flexible skeletons; also called soft corals.

omnivore – an animal that eats both plants and animals.

patch reef – an island of coral usually found growing on the floor of a lagoon.

photosynthesis – process by which the zooxanthellae use sunlight to convert the carbon dioxide and water in the polyp tissue into oxygen and carbohydrates.

phytoplankton – tiny floating or drifting aquatic plants.

plankton – tiny floating or drifting aquatic plants or animals.

planula – free-swimming coral larva.

pollution – that which makes something foul or unclean.

polyp – the tiny cylindrical body of a coral animal which has a mouth opening surrounded by tentacles.

population – all the members of a species that live in the same area and make up a breeding group.

predation – a relation between animals in which one captures and feeds on others.

primary consumer – organisms that get their nutrients from primary producers; typically herbivores that get their nutrients by eating plants.

primary producer -- organisms capable of producing their own food, typically through photosynthesis, using light as an energy source.

propagules – specialized seed pods that grow on the end of mangrove roots which drop down from the canopy of the tree.

protection – the act of defending or guarding from attack.

reef crest – the highest and shallowest part of the reef.

reef face – the seaward facing slope of the reef.

seagrass – simple aquatic plants that grow on the sandy floor of the lagoon.

secondary consumer – organisms that typically obtain their nutrients by eating primary consumers; typically carnivores that get their nutrients by eating herbivores.

sediment – fine particles of solid matter suspended in water or settling to the bottom of it.

soft coral – coral polyps that secrete flexible skeletons; also called octocorals.

spawning – a form of sexual reproduction where eggs and sperm are released, usually in water.

species – a group of organisms that look alike and are capable of producing fertile offspring.

sustainable – use that minimizes negative impacts on the ecosystem or environment while maintaining its contribution to society.

symbiotic – mutually beneficial relationship between two different species.

synergistic – working together.

tentacles – flexible, unsegmented feelers used for feeding, touching, and smelling.

tetraodontoxin – a powerful poison in some fish which can cause serious illness and even death if ingested.

tropics – region of the Earth's surface lying between the tropic of Cancer and the tropic of Capricorn (23 degrees, 27 minutes north and south of the equator).

vertebrate – an animal with a backbone.

zooxanthellae – one-celled algae that live inside the tissue of various animals, such as hard coral polyps, and produce photosynthetic products that the host can use.

zooplankton – tiny floating or drifting aquatic animals.

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References for Students

BOOKS

The publications listed below provide excellent resource material on coral reef ecosystems. See the following section for educational materials that are available through the REEF RELIEF mail order service.

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PUZZLES AND STAMPS

Life In the Coral Reefs. New York: Judy/Instructo, Simon & Shuster. 50 piece floor puzzle.

Life On a Coral Reef. National Geographic Society, (800-647-5463, Product no. 81154) 1994. 33 rubber stamps depicting marine life on a coral reef, sticker labels, and a washable blue ink pad.

Ocean World Puzzle. Hope, Arkansas: Fink & Co./ EDUCA. 100 large size pieces with an illustrated guide to identify marine life.

VIDEOS, SLIDES AND CD-ROMS

Cities of Coral. Stamford, Connecticut: NOVA Video Library, 1975. Video footage of Caribbean coral reefs, available for rental at Blockbuster Videos.

Coral Sea Dreaming–An Evolving Balance on Australia's Great Barrier Reef. Nashville, Tennessee: Small World Music (800-757-2277), 1993. 55 mins. Excellent video footage of the Great Barrier Reef without narrative. Outstanding for bilingual/multilingual classrooms.

Cousteau's World: Cities Under the Sea, Coral Reefs. CD-ROM, Volume 1. Jean-Michel Cousteau. New York: Enteractive, Inc., 1995.

Life on the Reef. Nashville, Tennessee: Small World Music (800-757-2277), 1994. 53 mins. Excellent narrated video footage of life on the Great Barrier Reef, with incredible coverage of coral spawning.

Educational Merchandise

The following lists books, childrens books, videos, cassettes, CD-ROMs and other educational merchandise that is available through Reef Relief. To order, please see the order form at the end of this section.

BOOKS

A Guide to Angelfishes & Butterflyfishes. Text and Photgraphes by Gerald R. Allen, Roger Steen and Mark Allen. Hardcover. $29.95

A Guide to Underwater Florida. Ned DeLoach. Maps and directions for 600 of Florida's best ocean and spring dives. 352 pp. $18.95

Anemone Fishes and their Host sea Anemones. Photos and text by Daphne G. Fautin & Gerald R. Allen 159 pp. $29.95

Blue Frontier, Saving America's Living Seas. A comprehensive look at ocean politics in America. David Helvarg. Paperback 299 pp. $15.00. Hardcover $25.95

Cetacea. Theresa Foley. An Eco-Thriller based in the Florida Keys. Paperback 220 pp. $11.95

Collaborative and Community-based management of Coral Reefs. Edited by White, Hale, Renard and Cortesi. Case studies of how various worldwide communities have worked to protect their coral reefs. Includes a chapter on REEF RELIEF. Paperback. 130 pp. $22.00

Deep Cuba, the Inside Story of an American Oceanographic Expedition. Bill Bellville A captivating look at what an expedition involves. 272 pp. $27.95

Diving and Snorkeling in the Florida Keys. John Halas, Judy Halas, and Don Kincaid. A handy photo-packed reference of more than 36 diving and snorkeling areas along the Florida Keys. Paperback. $12.95

Eye Of the Albatross, Visions of Hope and Survival. Carl Safina. A stunning epic about seabirds. Hardcover. 376 pp.$27.50

Everglades. Edited by Susan Cerulan. Hardcover. 256 pp. $18.95

Fire in the Turtle House. Osha Grey Davidson. A beautifully written book on coral reefs of the world. Hardcover. 258 pp. $26.00

Fort Jefferson and the Dry Tortugas National Park. L. Wayne Landrum Produced by the former park manager. Images and text. Hardcover. 71 pp. $19.95

Kayaking in the Keys. Kathleen Patton. Well written by a local resident. Hardcover. 190 pp. $199.95

Manatees and Dugongs of the World. Jeff Ripple. Photographs Doug Perrine. 131 pp. $19.95

Marine Conservation in the 21st Century. Hillary Viders. An essential guide for citizens, legislators, environmental professionals and aquatic sportfans. Paperback.$12.95

Marine Plants of the Caribbean. Mark and Diane Littler, Bucher, and Norris. A field guide from Florida to Brazil–the best book to identify algae on the reef . Paperback with 225 color plates, 263 pp. $25.00.

Marine Reserves, a Guide to Science, Design, and Use. Jack Sobel and Craig Dahlgren 369 pp. $70.00

Peterson's Guide to Coral Reefs. Eugene Kaplan. Paperback, 256 pp. $17.00

Peterson's Guide to Atlantic Coast Fishes. Robins/ Bay/Douglas. Paperback, 354 pp. $17.95 Paperback, 256 pp.

Peterson's Guide to Atlantic Sea Shores. Kenneth L. Gosner. Paperback with 329 pp. $16.95

Pisces Guide to Caribbean Reef Ecology. William Alevizon, PhD and REEF RELIEF Scientific Advisor. Paperback, 116 pp. with color throughout. $14.95

Protecting Paradise. Peggy Cavanaugh and Marget Spontak. Features 300 ways to protect Florida's encironment. Paperbak with 475 color plates, pp. $39.95

Reef Creature Identification. Paul Humann and Ned DeLoach. The definitive reference on marinelife. Paperback with 475 color plates, 344 pp. $35.00

Reef Creature. Paul Humann and Ned Deloach. In-A-Pocket waterproof companion to Reef Creature and Coral Identification for Divers and Snorkelers. 4 3/4" X 6" 23 pp. $11.92

Reef Coral Identification. Paul Humann and Ned DeLoach. The definitive reference on corals. Paperback with 354 color plates, 288 pp. $30.00

Reef Fish Identification. Paul Humann and Ned DeLoach. The definitive reference on reef fish. Paperback with with 345 color plates, 288 pp. $30.00

Reef Fish. Paul Humann and Ned DeLoach. In-A-Pocket waterproof companion to Reef Creature and Coral Identification for Divers and Snorkelers. 4 3/4" X 6" 23 pp. $11.92

Reef Set. Paul Humann and Ned DeLoach. Set of three hard cover books and a shelf case featuring the three definitive resources to identify reef life: Reef Coral Identification of Florida, Caribbean, Bahamas; Reef Creature Identification of Florida, Caribbean, Bahamas; and Reef Fish Identification of Florida, Caribbean, Bahamas. $120.00

River of Lakes, a Journey on the St. Johns River. Bill Bellville. A captivating journey that reveals as much about life in Florida as the natural setting it describes. 220 pp. $17.95

Seashore Life of Florida and the Caribbean. Gilbert L. Voss. With 19 full-color illustrations and 400 identification drawings. Paperback. 299 pp. $6.95

Sea Stars, Sea Urchins, and Allies. Hendler/Miller/Pawson/Kier. Hardcover. 339 pp. $39.95

Sea Turtles of the World. Text and photographs by Doug Perrine. 144 pp. $29.95

Sharks and Rays of the World. Text and photographs by Doug Perrine 128 pp. $19.95

Snorkeling Guide To Marine Life. Paul Humann and Ned Deloach. Paperback with 250 color plates, 80 pp. $13.00

The Florida Keys: The Natural Wonders of an Island Paradise. Jeff Ripple with photos by Bill Keogh and Jeff Ripple. Explore the islands from their formation to the impact of humans on the Keys today. Paperback. 128 pp. $19.95

The Everglades, Florida Bay, and Coral Reefs, an Ecosystem Sourcebook. Edited by James Porter and Karen Porter. A comprehensive college level resource with papers by leading researchers, managers and ecologists. 1,000 pp. $125.00

To the Deep and Beyond. Charles Messing. A great introduction to the coral reef. Paperback, 30 pp. $1.00

Wildlife of the Florida Keys. James Lazell, Jr. Details of the different species of animals living in the unique ecosystem of the Florida Keys. Paperback, 250 pp. $19.95

CHILDREN'S BOOKS

Angel Fish. Lian Smith. A pull and lift book. Hardcover. $10.95

Alligator Crossing – Marjory Stoneman Douglas. Hardcover. 199 pp. $16.95

At Home in the Coral Reef. Katy Muzik. Illustrations, Katherine Brown-Wing. Travel on an amazing journey through the sea, an early reader with wonderful illustrations. 32 pp. $6.95

Baru Bay: Australia. Bob Weir and Wendy Weir. A beautifully illustrated tale for children about a young girl on her first visit to a coral reef in Australia and her encounter with Aboriginal people, dolphins, and many sea creatures. An audio cassette features Bob Weir of the Grateful dead narrating the story, with original music inspired by aboriginal musicians. Hardcover. 40 pp. with cassette tape $20.00

Danny and Daisy. Suzanne Tate. A tale of a Dolphin Duo. Illustrations, James Melvin. 28 pp. $4.95

Dover Books series of Stickers, Etc.:
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Families of the Deep Blue Sea. Kenneth Mallory. Illustrations, Marshall Peck III. 22 pp $7.95

Fish Counting. Arthur David Zoller. 10 pp. $6.95

Hello Ocean. Pam Munoz Ryan. 32 pp. $7.95

I Wonder Why The Sea Is Salty and Other Questions about the Oceans. Text and illustrations by Anita Ganepri. Hardcover. 32 pp. $11.98

Mary Manatee. Suzanne Tate. Tales of sea cows. Illustrations, James Melvin 20 pp. $4.99

Old Turtle. Douglas Wood. Award Winning fable for children. Hardcover. $17.95

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Oozy Octopus. Susan Tate. Illustrations, James Melvin. A tale of a clever critter. 26 pp. $4.94

Peterson's Field Guide Coloring Book: Fishes. Sarah Landry. With descriptions of each fish and small color illustrations to serve as a guide for color. Paperback. 64 pp. $5.95

Rosie Ray. Suzanne Tate. Illustrations James Melvin. A tale of watery wings. 12 pp. $4.95

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VIDEOS

Canary of the Ocean: America's Troubled Reef. Miranda Smith Productions. 56 minute video that portrays the stunning beauty of America's fragile undersea kingdom, investigates the serious threats to its health, and profiles some of the concerned people, including REEF RELIEF representatives, working to preserve it for future generations. $35.00

Coral Reefs: Rainforests of the Sea. Oceanic Research Group in association with The Video Project. 20 minute video with study guide, 1996. Created especially for middle and high school age, it provides an excellent introduction to the science, ecology, and importance of coral reefs, as well as an overview of the serious environmental problems confronting them. Utilizing underwater footage shot on reefs worldwide, the video describes how reefs are formed, where they can be found, their importance to oceans and the human community, and the major natural and human-caused threats they face. $35.00

Seascapes III: The Incredible Coral Reef. Tom Jackson (former REEF RELIEF Board Member), narrated by Fisher Stevens. A 30 minute video describing hard and soft corals, fish and other sealife found at the coral reefs of the Florida Keys and Bahamas. $20.00

The Amazing Coral Reef. Oceanic Research Group in association with The Video Project. 20 minute video

with study guide. Created especially for elementary age children, it provides an introduction to coral reefs. Using extensive underwater footage and age appropriate narration, the program covers: how coral reefs are formed, basic ecological concepts, the importance of reefs to the oceans and humans, and the environmental dangers they face. $35.00

CD-ROM

Fish With Names Like. . . . . P&B Productions, Inc. Bilingual English/Spanish version 2.0. An interactive multimedia program that relates commonly known sealife to the objects that sound like their names. Geared to children 6-14, but a great experience for the entire family! $34.95

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San Francisco, CA 94132

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Culebra, Puerto Rico 00775

EarthEcho International–Phillippe Cousteau
1050 Connecticut Avenue, NW, Suite 1000
Washington, D.C. 20036

Greenpeace USA
1436 U Street, NW
Washington, DC 20009

Ocean Watch
8925 Leesburg Pike
P.O. Box 1618
Vienna, VA 22183-1618

Diving, Coral Reefs:
Coral Reef Alliance (CORAL)
64 Shattuck Square, Ste. 220
Berkeley, CA 94704

R.E.E.F. (Reef Environmental Education Foundation)
P.O. Box 246
Key Largo, FL 33037

Reef Ball Foundation
7085 Chappell Circle
Doraville, GA 30360

Education, Coral Reefs:
Smithsonian Institute
Washington, DC 20560

Expeditions:
Earthwatch
680 Mt. Auburn Street
P.O. Box 403
Watertown, MA 02272

General Ocean, Beaches, Sewage:
Blue Frontier
4007 Connecticut Avenue NW Suite 312
Washington, D.C. 20037-1311

Coast Alliance
1536 16th Street, NW
Washington, DC 20036

Izaak Walton League of America
1401 Wilson Blvd, Level B
Arlington, VA 22209

National Resources Defense Council
4 West 20th Street
New York, NY 10011

Oceana
2501 M Street NW Sutie 300
Washington, D.C. 20037-1311

Surfrider USA
122 S. El Camino Real, Ste. 67
San Clemente, CA 92672

The Ocean Conservancy
1725 DeSales Street, NW
Washington, DC 20036

The Wilderness Society
900 17th Street, NW
Washington, DC 20006

General Ocean, Coastal Peoples, Aquarium Fish:
Ocean Voice International
Box 37026
3332 McCarthy Road
Ottawa, Ontario K1B 7B2
Canada

General Ocean, Dolphins, Whales, Turtles:
Cousteau Society
2104 Pickwick Lane
Alexandria, VA 22307

Conservation International
2501 M Street, NW
Washington, DC 20037

Defenders of Wildlife
1244 19th Street, NW
Washington, DC 20036

Earth Island Institute
300 Broadway, Ste. 28
San Francisco, CA 94133-3312

Jean-Michel Cousteau Institute
1933 Cliff Drive
Santa Barbara, CA 93109

Marine Conservation Biology Institute
Suite 210
600 Pennsylvania Ave SE
Washington DC 20003004344

National Wildlife Federation
1400 16th Street, NW
Washington, DC 20009

General Ocean, Fisheries:
Environmental Defense Fund
257 Park Avenue South
New York, NY 10010

General Oceans, Government:
Florida Keys National Marine Sanctuary
P.O. Box 500368
Marathon, Florida 33050

National Oceanic and Atmospheric Administration (NOAA)
National Ocean Service
Public Affairs Department
1305 East-West Hwy.
Station 13519
Silver Spring, MD 20910

South Florida Ecosystem Restoration Task Force
United States Department of the Interior
FIU. OE 165 University Park
Miami, Florida 33199

South Florida Water Management District
3301 Gun Club Road
West Palm Beach, Florida 33406

United States Geological Survey
12201 Sunrise Valley Drive
Reston, VA 22092

U.S. Environmental Protection Agency
Public Information Center
PM-211B
401 M Street, SW
Washington, DC 20460

World Conservation Union (IUCN)
Rue Mauverney 28
CH 1196 Gland, Switzerland

Fisheries, Pollution:
ReefKeeper International
289 Bird Avenue, Ste. 162
Miami, FL 33133

World Wildlife Fund
1250 24th Street, NW
Washington, DC 20037

Mangroves:
Mangrove Action Project
4649 Sunnyside Avenue, N
Ste. 321
Seattle, WA 98103

Marine Activities, Resources, and Education:
MARE Program
Lawrence Hall of Science
University of California
Berkeley, CA 94720

Pollution, Pharmaceuticals:
Coral Reef Research Foundation
270 N. Canon Drive, Ste.1524
Beverly Hills, CA 90210

Rainforests, Forests, Coastal People:
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221 Pine Street, 5th Floor
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Research, Education:
Harbor Branch Oceanographic Institution
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University of Miami
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4600 Rickenbacker Causeway
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