# Hidden Oases: Florida's Deep-Sea Reefs

## Teacher's Guide

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Front cover: Close up of deep-sea reef habitat off Cape Canaveral (~730 meters) with living stony coral *Lophelia pertusa* (white branches), glass sponge (*Aphrocallistes*), gorgonian sea fans (*Plumarella pourtalesi*), orange solitary cup corals and two squat lobsters (*Eumunida picta*) on dead *Lophelia* branches. Photo: Sandra D. Brooke and John K. Reed.

Back cover: Cutthroat eel (*Synaphobranchus*) swimming over stony coral (*Enallopsammia profunda*) thicket off Fort Lauderdale. Photo: Charles Messing.

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## INTRODUCTION

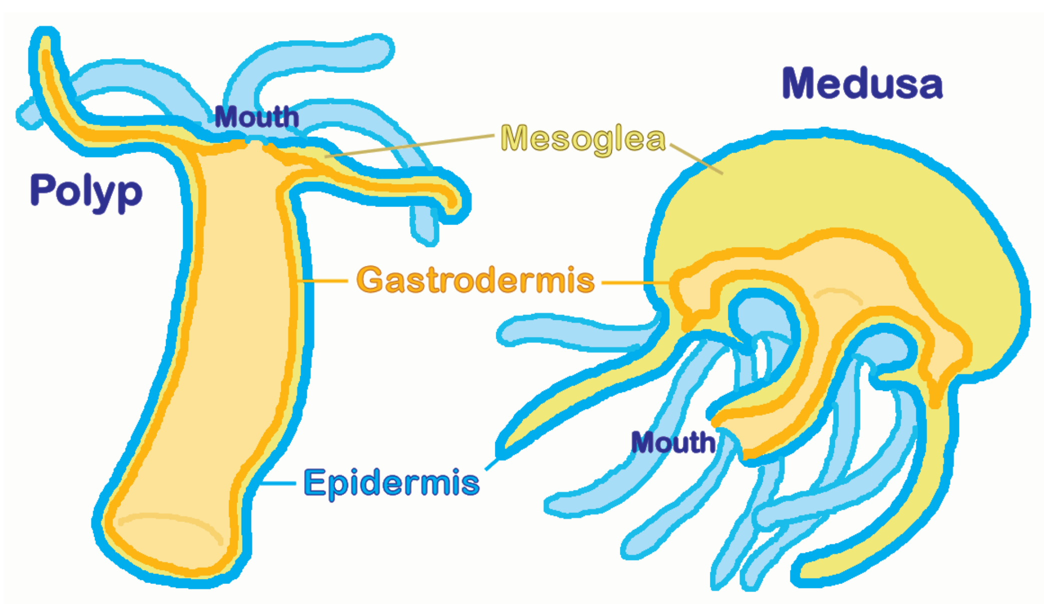
When we think of coral reefs, we think of gaily colored fishes schooling over a fantasy garden of animals that look like plants, populated by a menagerie of odd and sometimes comical residents. The water is always warm, clear and tropical. But, coral reefs also grow in the deep sea, hidden in perpetual darkness. This little-known environment remains full of mysteries.

As part of a project funded by the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration, two Florida science teachers were invited to participate in a research expedition that would attempt to solve some of those mysteries. The accompanying video describes their excursion, and this guide explains and elaborates many of the concepts introduced in the video.

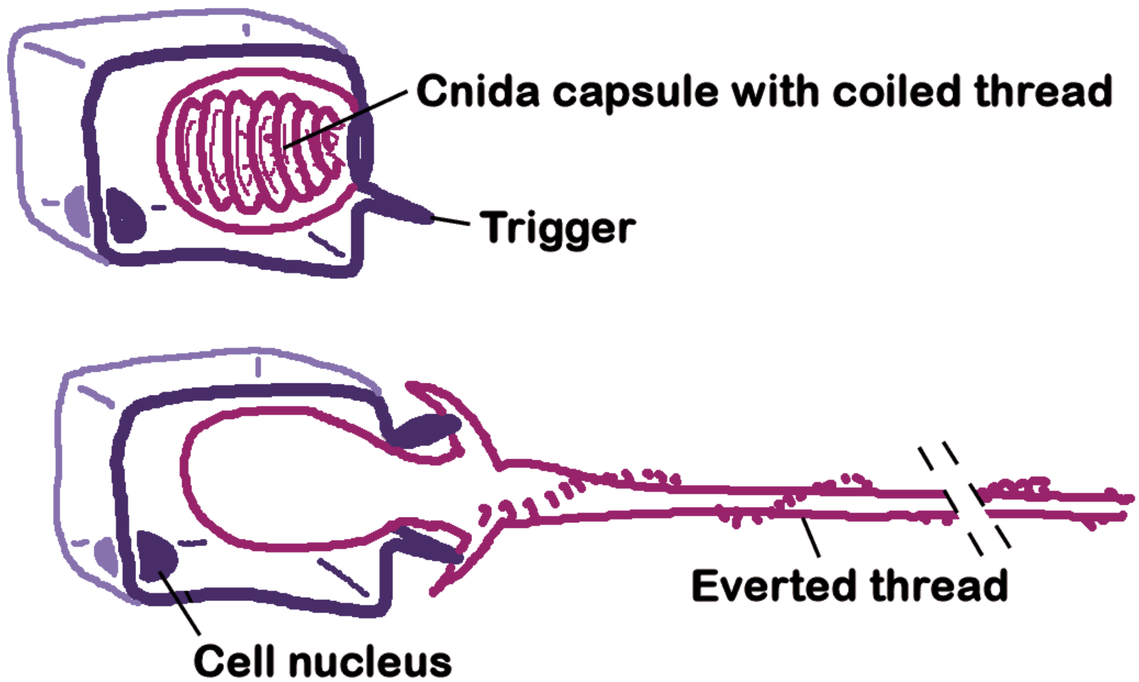
## WHAT IS A CORAL?

Coral is not an easy word to define. The word may refer to a group of animals, the skeletons they produce, or the deep pink color of one type that is not even a true coral. All corals are simple animals, but they do not form a single group of closely related species like, say, the mammals. All of them do belong to the great branch, or phylum, of the animal kingdom call the Cnidaria (nye-DA-ree-uh) (sometimes called Coelenterata). Members of this group also include sea anemones, jellyfish, sea fans, sea plumes and the Portuguese man-o-war. All cnidarians have the following features in common.

1) The body is basically a hollow bag or cylinder constructed of two layers of cells (outer ectoderm or epidermis, and inner endoderm or gastrodermis) with a mouth at one end surrounded by a ring of tentacles. There is no head, brain or distinct organs, and the body is radially symmetrical—with its structures arranged like wheel spokes. The polyp version of this body form usually attaches to the sea floor. The medusa form (commonly called a jellyfish) is basically an inverted bowl- or bell-shaped polyp thickened with gelatinous material (mesoglea) between its two cell layers. It usually swims.



2) Specialized cells produce cnidae (singular cnida; pronounced NYE-dee and NYE-da), which are microscopic capsules that contain a coiled thread. Mechanical or chemical stimulation causes the thread to evert, or uncoil out of the capsule at explosive speed, turning inside out as it goes, like pulling a sleeve out of a shirt. Cnidae are chiefly used for defense and food capture, and they may release mild to deadly toxins. The commonest kind of cnida is a nematocyst. (Nematocysts are often called stinging cells, but they are actually structures produced within cells.)




The Cnidaria is divided into three major groups. Most cnidarians that we call corals belong to the Anthozoa, which also includes the sea anemones. Anthozoans lack a medusa stage, and the polyp interior is divided by numerous radiating sheets of tissue (mesenteries). In the Scyphozoa, which includes sea nettles, moon jellies, and box jellies, the medusa stage dominates. The Hydrozoa includes simple polyps and medusae. In many species, both polyp and medusa stages occur during the life cycle, while others exhibit only one or the other. This group includes the tiny freshwater polyp called *Hydra* and the Portuguese man-o-war, as well as the fire corals and lace corals.

Another feature of cnidarians is that in many species a single polyp will produce additional polyps that remain attached to each other to form a colony.

So, what exactly is a coral? Corals are cnidarian polyps that secrete a calcareous skeleton. Calcareous means made of calcium carbonate ($CaCO_3$), the chemical that forms limestone, seashells (e.g., snails, clams) and the skeletons of sea urchins and sea stars, as well as corals. Many coral species are single polyps similar to sea anemones, while many others form colonies that may be branched, dome-like, leafy or irregular. Individual coral polyps range in size from almost microscopic to several inches across, while colonies range from smaller than a dime to big as a house. In the true, or stony corals, the base of the coral polyp secretes a cup-shaped calcareous skeleton into which the polyp can withdraw. In species that grow as colonies, the polyps form a thin sheet of living tissue that gradually deposits layer upon layer of calcareous skeleton beneath.

Many organisms that we call corals are variations on this theme, hence the difficulty with the definition. In soft corals, the skeleton is reduced to tiny sculptured bits of calcium carbonate (sclerites) imbedded in the polyps and the tissues between them. In blue coral, fire corals and lace corals, soft tissues fill canals throughout the skeleton. Black and golden corals have a branching skeleton composed of a protein similar to fingernail, while in gorgonians (sea fans, sea plumes and their relatives), sclerites surround a branching protein skeleton.

## WHAT IS A REEF?

Traditionally, a reef referred to any submerged hazard to navigation, whether rock, oyster bed or coral. Coral reefs are accumulations of the skeletons of coral animals and other organisms (such as calcareous algae), built up over long stretches of time. Reef-building corals are also called hermatypic corals. Typical coral reefs chiefly develop in the tropics between latitudes 30ºN and 30ºS. But even here, they do not occur everywhere. Because hermatypic corals require warm, clear, salty water, reefs do not develop where cool ocean currents run toward the equator (e.g., along the west coasts of North and South America and Africa), or where great rivers pour muddy fresh water into the ocean (e.g., the Amazon, Congo and Niger Rivers).

## HOW DO REEFS SURVIVE IN CLEAR WATER?

The clearer ocean water is, the less food it contains. The transparent waters of the tropics are low in both the dissolved nutrients and small drifting organisms (plankton) that reef-building corals might use for food. Yet corals and other creatures associated with reefs can grow there in enormous numbers. The solution to this mystery lies within the corals themselves.

Shallow-water, tropical reef-building corals have huge numbers of microscopic algae called zooxanthellae (zo-zan-THEL-ee) living within their tissues. Zooxanthellae are dinoflagellates, a large group of single-celled organisms that includes important photosynthetic plankton (phytoplankton) as well as toxic species that cause harmful algal blooms (red tides). The coral tends these algae like its own internal farm. Like plants, zooxanthellae capture sunlight via photosynthesis, storing the energy from sunlight in sugars and other carbohydrate molecules built up from carbon dioxide and water. The word zooxanthellae means “little yellow animals”—yellow because their dominant photosynthetic pigment is golden brown (though they also contain green chlorophyll, like plants), and animals because most dinoflagellates swim and were previously included in the animal kingdom.

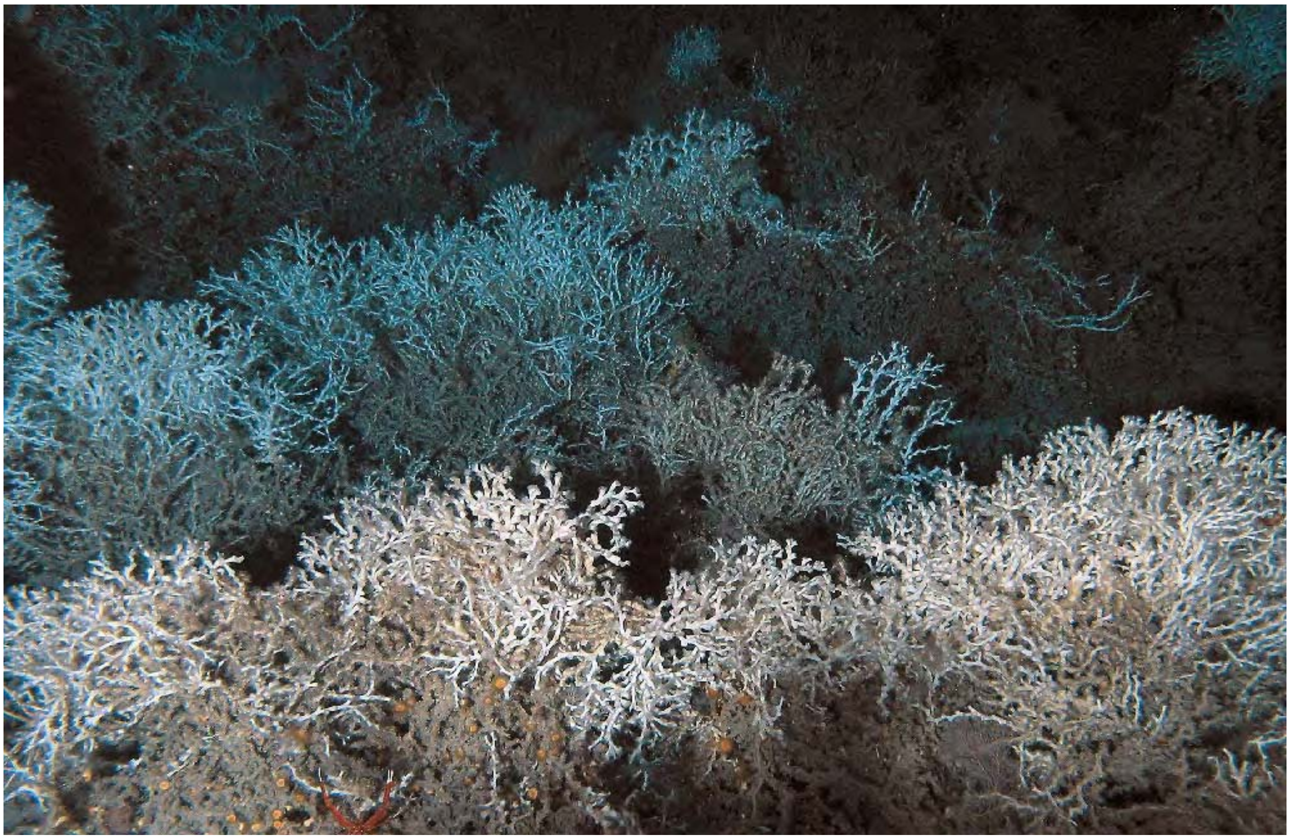
The algae give up some of their manufactured food molecules to feed the coral, which allows the coral to grow and build its skeleton faster. The coral in turn provides the algae a protective home. Such a close give-and-take relationship between two different species is called symbiosis, and when both partners benefit—the coral gets food and the algae get protection—the relationship is called mutualism. Different coral species augment their algae-derived diets to different degrees by capturing planktonic food with their cnidae.

## CORALS WITHOUT ALGAE

Many coral species lack symbiotic zooxanthellae. Among the stony corals, most are solitary cups that do not form either colonies or reefs. Some live on reefs in the shadows under ledges and in crevices and caves, like little anemones. Among the other coral groups, shallow-water tropical gorgonians and fire corals have zooxanthellae, while black, golden, lace and most soft corals do not. And, all corals that live in the deep sea lack zooxanthellae simply because little or no sunlight penetrates to where they live. All of these corals use their cnidae to capture planktonic food.

## DEEP-SEA REEFS

There are about 1200 species of true, or stony corals. About half are solitary cup corals, and half are colonial reef-builders in shallow tropical waters. But, there is also a handful of species that are colonial, lack zooxanthellae, and build reef-like structures in deep and cold waters. Unlike the wide variations in colony form among shallow-water corals, all of the deep-sea reef-builders develop branching colonies. Also unlike shallow tropical reefs, deep-sea reefs are usually not solid rocky structures. Instead, most are accumulations of dead coral and fine muddy sediment. They begin when a coral larva settles on a small hard substrate, perhaps a shell or rock. As the colony grows, water passing among the branches slows down, allowing fine particles of mud to settle to the sea floor. Eventually, the accumulating mud may kill some or all of the coral, which gradually falls to pieces. Some branches survive, or new corals grow on the dead rubble, and more sediment accumulates. The cycle continues and the mud and dead coral form a larger and larger mound. Although individual colonies only reach a meter or so high, their accumulated skeletons and sediment may form reefs reaching hundreds of feet high and more than half a mile across. Other organisms, including sponges, other corals, anemones, crustaceans, mollusks, worms, echinoderms, microorganisms and fishes, find homes on, among and over the coral branches.



*Lophelia pertusa* reef thickets off the east coast of Florida in ~700 meters depth. Photo: Sandra D. Brooke & John K. Reed.

## WHERE DO DEEP-SEA REEFS OCCUR?

Deep-sea reefs occur in all oceans. In fact, they may cover more area of the sea floor than shallow-water reefs. Some deep-reef-building coral species occur only in limited areas of the world's oceans, e.g., *Oculina varicosa* off the east coast of Florida and *Goniocorella dumosa* off New Zealand. Others, such as *Madrepora oculata* and *Solenosmilia variabilis* are almost cosmopolitan. Among the most widespread, and certainly the best known, is *Lophelia pertusa*. This species occurs throughout most of the Atlantic Ocean and is also known from the Indian and eastern Pacific Oceans. It also grows over a wide range of depths, from ~40 meters off Norway (where the water is cold near the surface) to 3300 meters on the Mid-Atlantic Ridge. Reefs dominated by *Lophelia* reach their greatest development in the northeastern Atlantic Ocean where they form an almost continuous band along the edges of the continental shelf from northern Scandinavia to northwest Africa.

## DEEP-SEA REEFS OF THE UNITED STATES

Deep-sea reefs in U.S. waters are found along the southeastern continental margin from North Carolina southward through the Strait of Florida and into the eastern and northern Gulf of Mexico. Many occur on a great wedge-shaped underwater platform called the Blake Plateau that runs from Cape Hatteras to the Bahamas. In one area called the Stetson Bank, which lies in 640-869 meters of water southeast of Charleston, SC, numerous coral mounds up to 146 meters high are spread over a 6174-$km^2$ area. Throughout the deep reefs of the southeastern U.S., the dominant framework-builders deeper than 200 meters are *Lophelia pertusa* and *Enallopsammia profunda*, with lesser contributions by *Madrepora oculata* and *Solenosmilia variabilis*.

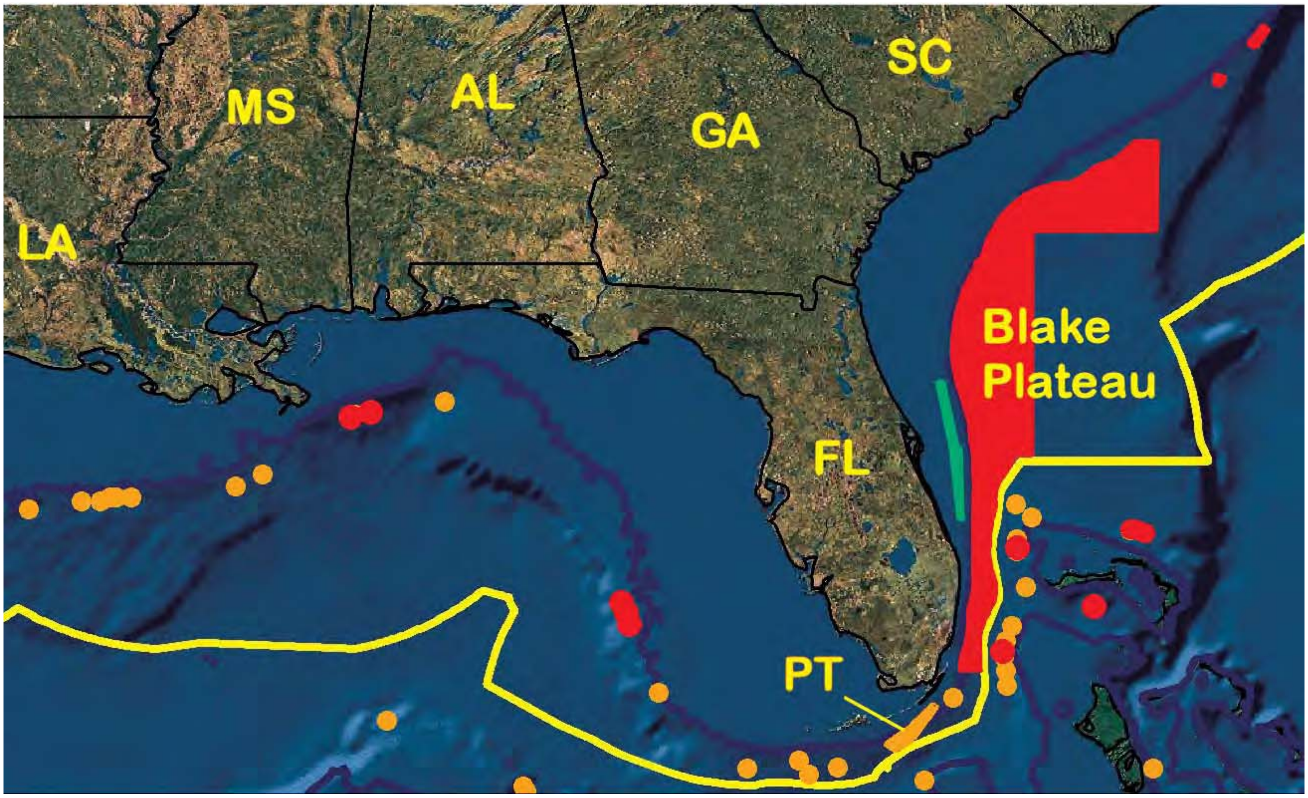
## DEEP-SEA REEFS OF FLORIDA

A nearly continuous band of hundreds of mounds and pinnacles up to 168 meters high runs from southern Georgia to about Jupiter, FL, at depths of 400-866 meters. So far, marine scientists using submersibles or remotely operated vehicles (ROVs) have observed nearly ten percent of these features, confirming the presence of *L. pertusa* or *E. profunda* or both. Unlike many other deep-sea reefs, the mounds off southern Georgia and Jacksonville are rocky, with limestone terraces and pavements capped with coral and coral rubble. South of St. Augustine, the reefs are more typical—sediment and dead coral capped with dense 1-meter-tall thickets of *L. pertusa*, *E. profunda* and some *M. oculata*. Further south and all the way to northern Key Largo, deep-sea reefs built chiefly by *E. profunda* lie about halfway between Florida and the Bahamas. These are low mounds and ridges of coral rubble and muddy sand at most about 4.5 meters high. Many appear to be dead. There are no living corals on them, only dead colonies and branches, though there are other animals such as sponges. On others, living corals cover only up to about ten percent of the bottom. We do not yet know why there are so few living colonies.

Another coral, *Oculina varicosa*, has built hundreds of pinnacles, mounds and ridges up to 35 meters high and 300 meters long along the edge of the shelf from about Fort Pierce to north of Daytona Beach. These lie in only 60-100 meters, shallower than other deep reef corals. *O. varicosa* is an unusual species. Small stubby colonies can grow in as little as a few meters depth and contain zooxanthellae. However, the colonies that build the reefs lack zooxanthellae and can reach 2 meters across and 2 meters high. Like most of the deeper-water reefs, these appear to consist of sand, mud and coral skeletons capped by living coral colonies. In 1984, NOAA designated a portion of this region as the first deep-sea coral marine protected area in the world and prohibited bottom trawling, dredging, bottom longlines and anchoring. The protected area was expanded in 2000, but many of the reefs had already been destroyed.

Off southeastern Florida, the Miami Terrace is a long narrow limestone shelf that runs from Boca Raton to northern Key Largo. It is widest off Miami, where its eastern edge lies about 22 kilometers offshore at a depth of about 350-400 meters. Here, dense colonies of *L. pertusa* and some *M. oculata* grow in great bouquets along the rugged terrace rim above steep slopes and cliffs. However, although they form reef-like habitats, they do not appear to build up mounds of their own.

Finally, scientists have recently investigated an area of rocky, coral-covered mounds 5-15 meters tall at depths of 428-466 meters at the edge of the continental shelf in the Gulf of Mexico west of Naples, FL. *L. pertusa* is the dominant species. This region of mounds extends along the shelf edge for at least 20 kilometers, but may be more extensive.



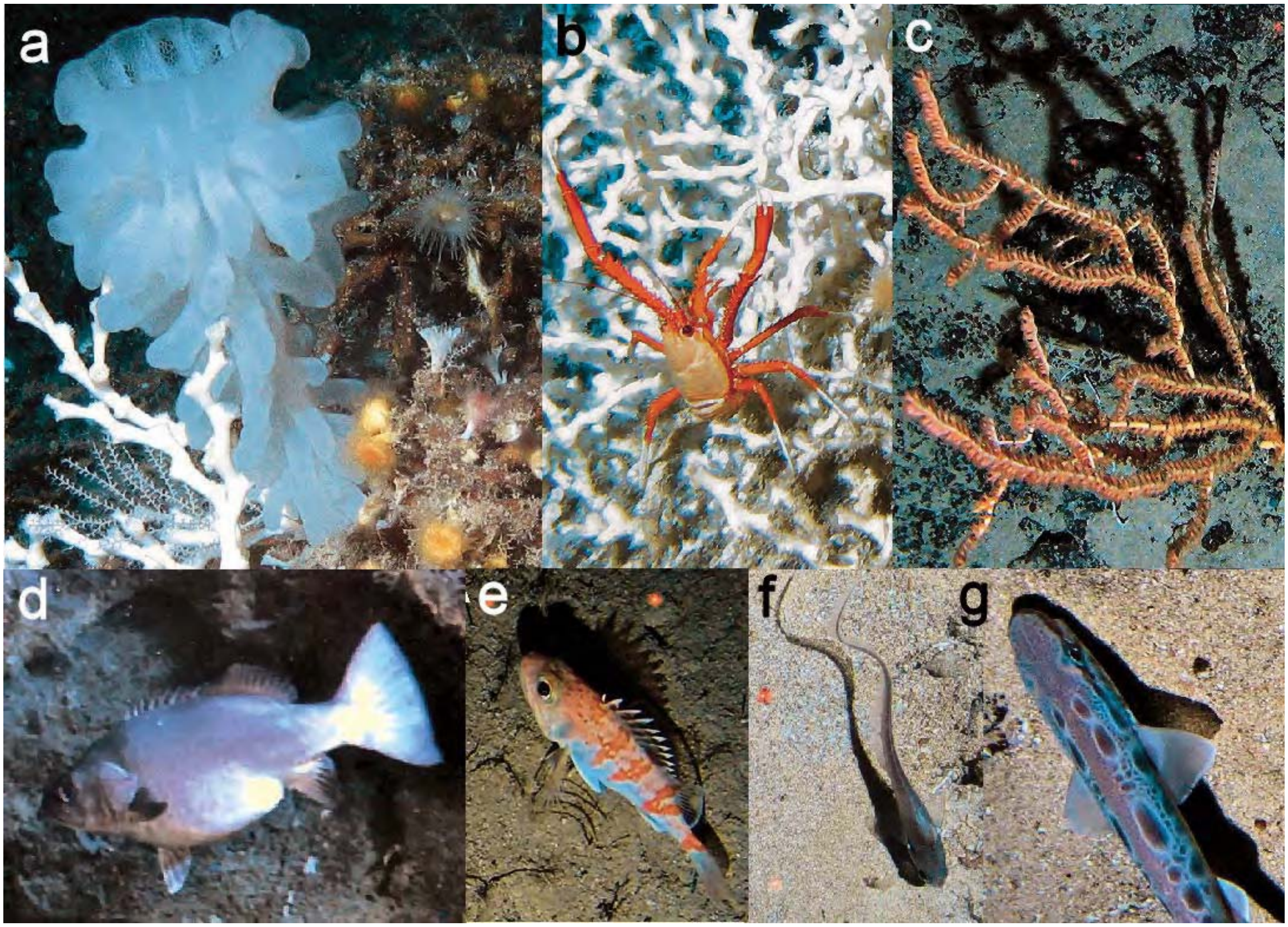

Distribution of deep-water colonial corals in the southeastern United States and adjacent waters. The large red polygon and the two small polygons at upper right indicate Habitats of Particular Concern (HAPC) proposed by the South Atlantic Fishery Management Council for protecting deep-water corals. The orange polygon represents the Pourtalès Terrace (PT) HAPC south of the Florida Keys, which is dominated by lace corals, not stony corals. The green polygon represents the distribution of the coral *Oculina varicosa*. Red dots indicate other deep-sea reefs sites. Orange dots are non-reef locations where deep-sea colonial corals (*Lophelia, Enallopsammia, Madrepora and Solenosmilia*) have been collected. Map by Brian Walker and Charles Messing.

## OTHER CREATURES

Deep-sea coral reefs harbor a great variety of other creatures in addition to corals. No plants, of course, because there is no light. Instead, there are many species of the different major groups of invertebrates—animals without backbones—and fishes. Three major invertebrate groups—the sponges, octocorals and lace corals—contribute to the three-dimensional complexity of the reef's structure by forming additional habitats for other creatures to shelter among or cling to. Sponges may look like fancy vases, cups, fans, boulders, brackets, irregular masses, or thin encrusting sheets. Some are massive and solid, while others are delicate and lacy like spun glass. The chambers within the sponges' glassy skeletons also offer shelter to many small animals, such as crustaceans, worms and brittle stars.

Octocorals, including the soft corals and gorgonians, are those anthozoan cnidarians in which the polyps always have eight tentacles (unlike the stony corals such as *Lophelia* that have tentacles in multiples of six). Species on deep reefs typically form branching colonies that look like small trees, bushes or fans. In one group, the bamboo corals, the supporting skeleton consists of cylinders of white calcium carbonate connected by short segments of tough black protein; this segmented structure appears similar to bamboo. The polyps generate an enormous amount of mucus—probably for protection—and, when irritated, produce a blue bioluminescence.

The commonest large crustaceans are the squat lobsters, or galatheids. With a short tucked-under tail and only three pairs of walking legs (instead of four as in crabs and true lobsters), galatheids typically perch on the corals, with their long red claws stretching upward in anticipation of their next meal. Echinoderms, particularly, brittle stars and feather stars, may occur in great abundance.



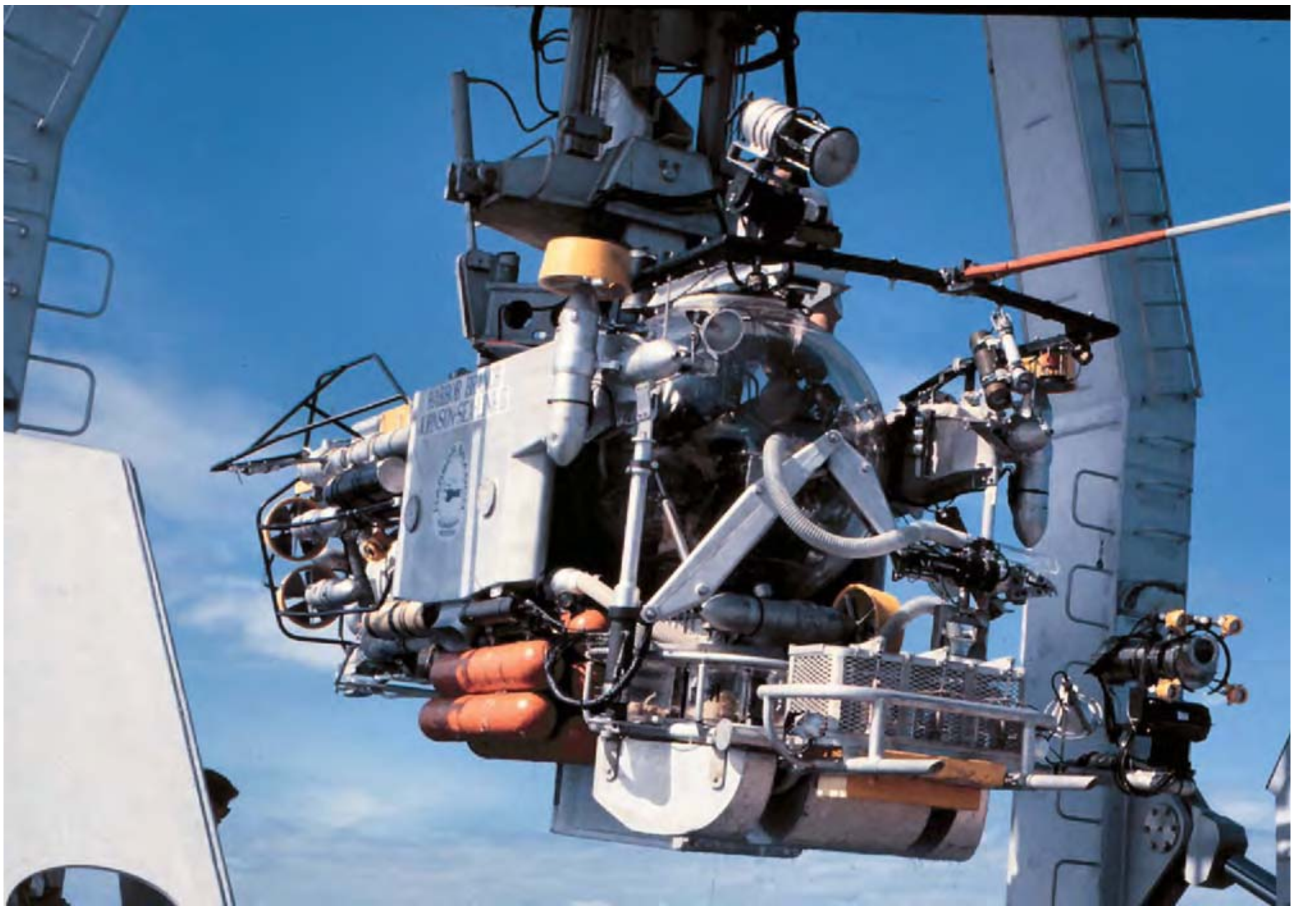

Deep-sea reef animals. **a.** Glass sponge (*Aphrocallistes*) with *Lophelia* (white branches), orange cup corals and small grey sea anemone. **b.** Squat lobster (*Eumunida picta*) on *Lophelia*. **c.** Bamboo coral (*Keratoisis*). **d.** Wreckfish (*Polyprion americanus*). **e.** blackbelly rosefish (*Helicolenus dactylopterus*). **f.** Rattail (*Nezumia*). **g.** rough catshark (*Galeus arae*). Photos: Sandra D. Brooke and John K. Reed (a, b, d); Charles Messing (c, e, f, g).

Because the deep-water reefs of Florida span a wide range of depths, from about 400 to over 800 meters (not including the *Oculina* reefs, which are not truly deep sea), they harbor a great diversity of fishes. Some look like typical shallow-water fishes. The wreckfish (*Polyprion americanus*) reaches almost 2 meters in length and may occur in large schools. It looks like a grouper but actually belongs in its own family. Others are more obviously modified for deeper environments. Alfonsino (*Beryx decadactylus*) and blackbelly rosefish (*Helicolenus dactylopterus*) have large eyes and are bright red. Only the dimmest blue light penetrates to where they live. Their red pigments absorb the blue light, so they appear black and blend in with their surroundings in the dark. Many fishes associated with the deeper reefs are long and slender, a body type typical of many truly deep-water fishes that live on or near the seafloor. The commonest ones include grenadiers or rattails (*Nezumia*), the shortbeard codling (*Laemonema barbatulum*) and cutthroat eels (*Synaphobranchus*).

Sharks on Florida's deep reefs range from the tiny mottled rough catshark (*Galeus arae*), which grows no more than about a foot in length (30 centimeters), to the very impressive smalltooth sandtiger (*Odontaspis ferox*), which may exceed 3 meters in length. The catshark usually occurs at the foot of the reef where it feeds on shrimps. Perhaps its dark brown blotches and spots help it blend in with the sand and broken coral. The sandtiger cruises over the reef and feeds on other fishes, squids and crustaceans. Other large fishes that sometimes visit the deep reefs include the giant ocean sunfish (*Mola mola*) and broadbill swordfish (*Xiphias gladius*), which has been known to attack submersibles.

## STUDYING FLORIDA’S DEEP-SEA REEFS

Scientists have used many instruments and equipment to study Florida’s deep-sea reefs. Early investigators relied on nets and dredges to bring samples up from deep water, but these might also destroy the coral habitat as they dragged along the bottom. More modern approaches include mapping the seafloor using instruments that bounce sound waves off the bottom. The latest versions can produce amazingly detailed maps, although photographs, film or video are still needed to determine what lives where. The expedition that generated this video used the manned submersible *Johnson Sea Link I,* owned and operated by the Harbor Branch Oceanographic Institution, Fort Pierce, FL.



*Johnson Sea Link I* submersible aboard the research vessel *Seward Johnson.*

For more information on the Florida’s Deep-Sea Corals Expedition, go to:
http://oceanexplorer.noaa.gov/explorations/05deepcorals/welcome.html

## SITE SUMMARY (November 2005, *Johnson Sea Link I*)

| Date | Latitude | Longitude | Location | Dive | Depth (ft) |
|---|---|---|---|---|---|
| 8 | 28°17.1'N | 79°36.9'W | Cape Canaveral, Peak 151 | 4909 | 2481-2380 |
| 8 | 28°17.1'N | 79°36.8'W | Cape Canaveral, Peak 151 | 4910 | 2519-2350 |
| 9 | 29°50.9'N | 79°38.0'W | St. Augustine, Peak 160 | 4911 | 2716-2435 |
| 9 | 29°51.0'N | 79°37.6'W | St. Augustine, Peak 160 | 4912 | 2857-2448 |
| 10 | 28°19.4'N | 79°45.1'W | Cocoa Beach, Peak 294 | 4913 | 1515-1291 |
| 10 | 28°19.3'N | 79°45.1'W | Cocoa Beach, Peak 294 | 4914 | 1530-1311 |
| 11 | 26°39.1'N | 79°32.5'W | West Palm Beach, Peak 295 | 4915 | 2545-2491 |
| 11 | 26°45.9'N | 79°33.2'W | Fort Lauderdale, Peak 297 | 4916 | 2482-2418 |
| 16 | 25°51.6'N | 80°02.0'W | Miami Terrace | 4917 | 875-805 |
| 16 | 25°45.4'N | 79°47.2'W | Strait of Florida, Peak 299 | 4918 | 2847-2440 |
| 17 | 26°05.7'N | 79°50.4'W | Miami Terrace | 4919 | 1236-926 |
| 17 | 25°41.92N | 79°52.0W | Miami Terrace | 4920 | 1251-1057 |
| 18 | 24°30.0'N | 80°40.1'W | Pourtalès Terrace | 4921 | 977-576 |
| 18 | 24°16.4'N | 81°02.2'W | Pourtalès Terrace | 4922 | 1740-1081 |

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