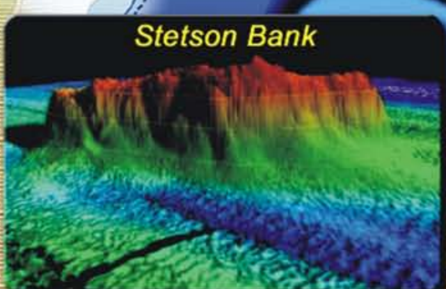
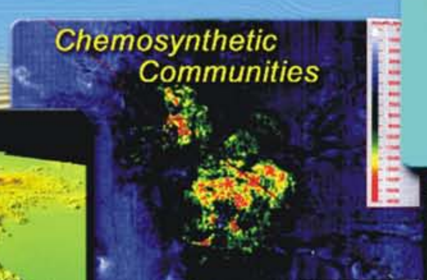
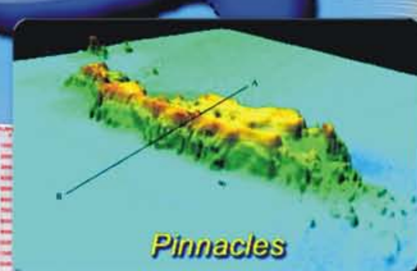
OCS Report
2006-017

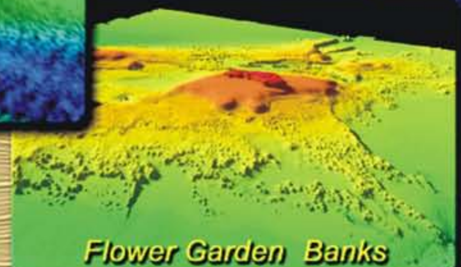
Gulf of Mexico Offshore Oases

A Teacher's Companion









MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

GULF OF MEXICO OFFSHORE OASES
A Teacher's Companion

Authors: Gregory S. Boland
James Sinclair
Susan A. Childs

Editors: Michael Dorner
Deborah Miller
Pat Adkins

Photo/Images: Susan A. Childs
Gregory S. Boland
Terry Rankin
Harley Moody
Douglas Weaver
J. Blair
LGL Ecological Research Associates

Class Exercises: Susan A. Childs
Gregory S. Boland
James Sinclair
SeaWorld

First Printing, December 2001
Revised Printing, March 2006

NOTE TO TEACHERS

Gulf of Mexico Offshore Oases is a teacher's instructional guide to accompany the poster of the same title. In this guide, you will find information that focuses on the various seafloor habitats and the geology that drives them, as well as the marine animals associated with these extraordinary systems. This guide will focus on three specific habitat features. The information and activities are intended for use in grades 6-12. Additional topics and resources are included at the end of the guide.

The Minerals Management Service (MMS) has funded numerous scientific studies to understand the oceanographic processes in the Gulf of Mexico. This Teacher's Companion contains information that was gathered during these studies. The MMS is the Federal agency that regulates oil and gas activities on the U.S. Outer Continental Shelf. To learn more about the MMS, please visit our website at **www.mms.gov**.

WHERE TO GET THE POSTER AND TEACHER'S COMPANION?

Copies of the poster and Teacher's Companion may be obtained from the Public Information Office at the following address:

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
Public Information Office (MS 5034)
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394
Telephone: (504) 736-2519 or
1-800-200-GULF

You can also access the Teacher's Companion online at:

http://www.mms.gov

Select:

- ⇨ Kid's Page from the left column
- ⇨ Gulf of Mexico Kid's Page from the left column

TABLE OF CONTENTS

ABOUT THIS LESSON

This lesson is designed to teach students at the middle and high school levels about Offshore Oases habitats of the Gulf of Mexico. Each topic covered within the lesson is followed directly by class exercises. The material presented follows the National Science Education Content Standards guidelines. You can also access this Teacher's Resource online at http://www.mms.gov.

WHERE IT FITS IN THE CURRICULUM

Topics: This lesson can be used to help students learn about factors that influence unique offshore habitats. It can also be used as part of a biology and geology curriculum.

Standards: The material meets the content standards for grades 6-12 as defined by the National Science Education Content Standards from the National Science Teachers Association. The following content standards apply:

Science as Inquiry

- Abilities Necessary to do Scientific Inquiry
  - Think critically and logically to understand the relationships between evidence and explanations.
  - Identify questions and concepts that guide scientific investigation.
- Understandings about Scientific Inquiry
  - Different kinds of questions require different kinds of scientific investigations, including observing and describing, collecting, experimentation, research, discovery, and developing models.
  - Scientists usually inquire about how physical, living, or designed systems function.

Life Science

- Structure and Function in Living Systems

Science in Personal and Social Perspectives

- Science and Technology in Local, National, and Global Challenge
  - Science and technology can indicate what can happen, not what should happen. The latter involves human decisions about the use of knowledge.

Objectives for Students

1) To learn the factors that influence Offshore Oases habitats.
2) To understand the importance of substrates in the Gulf of Mexico.
3) To gain knowledge about marine life associated with each Offshore Oasis.
4) To apply basic biology and geology concepts related to unique offshore features.

Materials for Students

The materials in the lesson can be printed, photocopied, and distributed to students.

SPECIAL SEAFLOOR HABITATS OF THE GULF OF MEXICO

INTRODUCTION

Whereas all of the different habitats associated with the Gulf of Mexico are important and play a vital role in the overall ecosystem health and sustainability of the Gulf's resources, this teacher's companion is dedicated to the special seafloor habitats. Special seafloor habitats include coral reefs, chemosynthetic communities, and pinnacle trends.

In various locations, geologic processes have "thrust up" or "pushed up" rocks to stand above the soft bottom. These comparatively small areas support a totally different community of organisms from the soft bottoms around them. The stability and complexity of these hard-bottom habitats provide a relatively unchanging home for a wide array of reef animals. As a result, a complex, thriving, and often densely packed community of organisms develops. The organisms inhabiting hard bottoms in the Gulf of Mexico are especially adapted to the ecosystems and habitats in which they are found.

The Gulf of Mexico encompasses approximately 580,000 mi^2 of area where most of the seafloor is made of soft sediments (sand and mud). Factors that influence offshore oases habitats include substrate and relief types, the nepheloid layer, habitat complexity, distance from shore, and temperature. Focusing on each of these influences will enhance understanding and sharpen the image of the offshore oases habitats of the Gulf of Mexico.

SUBSTRATE

Substrate is one of the major factors that determine what kind of community a habitat will support. The word substrate literally refers to the "layer below," or the bottom of the ocean underneath the water. The substrate forms the structure of the habitat. There are two basic types of substrate: soft and hard.

Soft substrate is composed of mud, sand, or gravel. Although individual pieces of gravel are hard, the substrate is considered soft because it is not "fixed" in place. It can be moved about by currents and wave action. Residents of soft bottoms usually live *in* the substrate and are adapted to their changing environment. Most of the floor of the Gulf is soft substrate.

Several types of hard substrate occur in the Gulf of Mexico and most are composed of rock. The Florida peninsula is carbonate (limestone) that was built up over millions of years, after which the peninsula was covered by a shallow sea harboring reef-building animals. West of Florida, sediments from river runoff accumulate in thick layers, eventually forming sedimentary rock.

Coral reefs developed on hard substrates thousands of years ago. In some cases, these are still living coral reefs, built up by reef animals to keep pace with the rise of sea level and the subsidence of the seafloor. In other cases, the reefs do not build as quickly as the relative rise in sea level and the reef is drowned. So, the substrate is coral reef, but not living coral reef.

Hard substrates in the Gulf of Mexico are sparse. Thriving communities can bloom in the few places where rocks are thrust up from the seafloor. These rocks nurture layer upon layer of organisms that could not survive on the soft bottoms. The rocks become covered with a layer of algae, sponge, bryozoans, and all manner of encrusting organisms. Hydroids, anemones, corals, and many other organisms that attach and grow upright form a complex, labyrinthine second layer of living habitat. In these layers live crabs, shrimp, worms, snails, bivalves, urchins, featherstars, fishes, and other animals. In the outermost layer are fish, which forage above the reef. Many fish are nomads that visit the hard-bottom habitats routinely for food and shelter. There is no doubt that these habitats are essential to many of the fisheries in the Gulf of Mexico.

RELIEF

Relief of the substrate is a significant factor affecting the development of the community associated with that habitat. The term "relief" refers to the elevation of the substrate compared with the surrounding seafloor. If a hard bottom has low relief (less than 6 feet), the community will likely be of low diversity and density, that is, few organisms in small numbers. If a habitat has medium relief (up to 20 feet), diversity and density will increase. Habitats with high relief (over 20 feet) may have high diversity and density. The difference is largely caused by sedimentation near the bottom caused by the nepheloid layer.

NEPHELOID LAYER

The nepheloid layer is a bottom layer of water that carries a large amount of suspended sediment. Fine sediments enter the Gulf of Mexico from rivers and settle on the bottom. Often these clays and silts are stirred back into the water column by wind, waves, and currents. Nepheloid layers in the Gulf are variable and may frequently affect a habitat. Any habitat within the nepheloid layer is subject to heavy sedimentation and low light levels. Only animals tolerant of these conditions can survive within the nepheloid layer. This is why habitats with low relief have a low diversity and density of organisms. Substrates that have high enough relief to stand above the nepheloid layer can support a community at its pinnacle very different from that at its base.

HABITAT COMPLEXITY

The complexity of a habitat affects the complexity of the community that develops. A smooth pyramid could represent the least complex of habitats. It would have only one type of substrate for the attachment of organisms: smooth, steep sides. Habitats with flat tops that protrude above the nepheloid layer have much more complex communities. Many more animals are able to settle and live on the horizontal surface of the top. Below the nepheloid layer, animals survive better on the steep vertical surfaces because these shed sediment deposits. In between the top and the nepheloid layer, the more complex the surface, the more diversity and density of organisms it supports. If the surface is pockmarked with depressions, gullies, and pits with overhangs, and even holes and tunnels that make the substrate hollow, then many more types of animals will be able to colonize the habitat. Community diversity and density are related to the topography of the habitat and are also affected by the topography of the seafloor surrounding it. If the habitat is part of a trend or large area with similar habitats in the vicinity, it will have higher diversity and density because of its association with organisms in other habitats. The habitats in a large area support each other by supplying larvae for colonization. Larvae have a better chance to survive and grow because of an increased likelihood for them to find a suitable home.

Distance from Shore

The distance of a habitat from shore controls the community that develops on any hard substrate. Salinity, nutrient load, turbidity, and the depth of water are all related to distance from shore. Rain runoff and rivers transport freshwater into the nearshore waters of the Gulf of Mexico, diluting the salt content of nearshore waters, reducing salinity. Many animals do not tolerate reduced salinity and are therefore restricted from nearshore waters. Rain and rivers also wash nutrients into the Gulf of Mexico, often producing plankton blooms. Plankton blooms, along with sediments from rivers, cloud the water, making it turbid. These combine to restrict light penetration to organisms on the substrate. Add to this the fact that even clear water filters out light, and you have a dynamic combination of factors that greatly influence communities. Nearshore communities are more likely to be exposed to high turbidity and low light penetration. Communities farther from shore may have less turbid water but are deeper, with *more* water between the animals and sunlight. This is why most of the animals on the oases habitats in the Gulf of Mexico are filter feeders that do not require sunlight for their survival. These filter-feeding animals survive better if they are farther from shore and elevated above the bottom with less suspended sediment to cover them.

Temperature

Two major factors control the prevailing temperature on an oasis habitat: latitude and water movement. The distance of a habitat from the equator, latitude, greatly influences the temperature by changing the angle of the sun. The latitude of oases habitats in the northern Gulf of Mexico is from 26° to about 30° north of the equator and is far enough north that they are exposed to a temperate climate. At these latitudes, temperatures frequently fall below 16°C in winter on many of the offshore oases habitats. The 16°C isotherm is stressful for most coral and is considered the lower limit for coral growth; therefore, tropical reefs are rare in the northern Gulf of Mexico.

CORAL REEFS OF THE FLOWER GARDEN BANKS NATIONAL MARINE SANCTUARY, INCLUDING STETSON BANK

INTRODUCTION

The Flower Garden Banks National Marine Sanctuary, including Stetson Bank, is a distinct habitat on the Outer Continental Shelf of the Gulf of Mexico (Figures 1 and 2). It is located approximately 110 miles south of Galveston, Texas, and is the northernmost coral reef on the continental shelf of North America and one of the most pristine reefs in the world. The Minerals Management Service (MMS) has long been concerned with the protection and preservation of this Offshore Oasis habitat. The work of MMS, along with the National Oceanographic and Atmospheric Administration (NOAA), was instrumental in the establishment of the Flower Garden Banks as a National Marine Sanctuary in 1991. Three distinct levels can be seen in the habitat at the Flower Garden Banks National Marine Sanctuary. The banks are made up of living coral reef, partly drowned coral reef, and drowned coral reef. These components are the result of the varying amounts of light that reach the substrate at each depth. Each part of the reef harbors different groups of plants and animals.

*Figure 1. Photograph of reef-building hermatypic corals that are dominant at the Flower Gardens – this is large-grooved brain coral (*Copophelia natans*). (Photo by Moody)*

*Figure 2. Many marine organisms use the reef system of Stetson Bank as a nursery ground, for feeding, and for prey avoidance. Pictured among others are creole fish (*Paranthias furcifer*), spotfin butterfly fish (*Chaetodon ocellatus*), and reef squirrelfish (*Holocentrus coruscus*). (Photo by Boland)*

LIVING CORAL REEFS

The living coral reef (Figures 1 and 2) comprises the upper part of the reef or "cap" and is found in water depths of 60-170 feet. The reef is considered living because the "rock" of the reef is actually growing. Studies sponsored by MMS show that the stony corals and other organisms build or add approximately 0.2-0.3 inches of thickness each year to the surface of the reef. They accomplish this by extracting calcium from the water and building their own skeletons, forming deposits of calcium carbonate (limestone). As corals develop and other organisms die and new ones grow, the reef is built.

The living coral reef exhibits several distinct communities. The upper part of the living coral reef, above 120 feet, is an area of higher diversity. Although not as biologically diverse as most tropical reefs, the Flower Gardens are a regional reservoir of shallow-water Caribbean reef fishes and invertebrates in the Gulf of Mexico. There are more than 200 species of reef fishes, 253 species of invertebrates, and 18 species of reef-building corals (Figures 3 and 4). This part of the living coral reef is the most studied because it is accessible with scuba gear. The reef is a maze of coral structures riddled with small caverns, pockets, and overhangs, with occasional patches of sand or gravel. This makes for a complex habitat with a much more decidedly diverse community than other areas of the reef system. A myriad of animals make their homes in this complex structure, which provides them food to eat and refuge to avoid being eaten. Many fish that do not live in the reef routinely visit to feed on those fish and invertebrates that are a part of the reef community.

Figure 3. Christmas tree worms inhabit all areas of the reef with tubes typically encased in the massive reef-building corals. (Photo by Childs)

Perhaps the most significant of all organisms found on the reef are the coral animals themselves and the algae they harbor in their tissues. The term "essential flora and fauna" is used to describe the coral animal and leafy algae, or Zooxanthellae, which are of primary importance to the coral reef. The corals and Zooxanthellae have a distinctive symbiotic relationship that enhances creation of the corals' massive calcium carbonate skeletons. During this symbiosis, the Zooxanthellae absorb and use the nitrogen (Figure 5) produced by the coral animal, which in turn changes the pH of the water, allowing for greater deposition of calcium carbonate in the coral skeleton. Calcium carbonate produced in great quantities by many species of calcareous algae also bind these formations produced by the corals. Together, the reef corals and algae create a framework that becomes habitat to a highly diverse and productive marine community (Figures 1 and 2).

*Figure 4. Polyps of a star coral (*Montastraea annularis*) and large grooved brain coral (*Colpophylia natans*), two of the most abundant large reef builders found at the Flower Gardens. (Photos by Moody)*

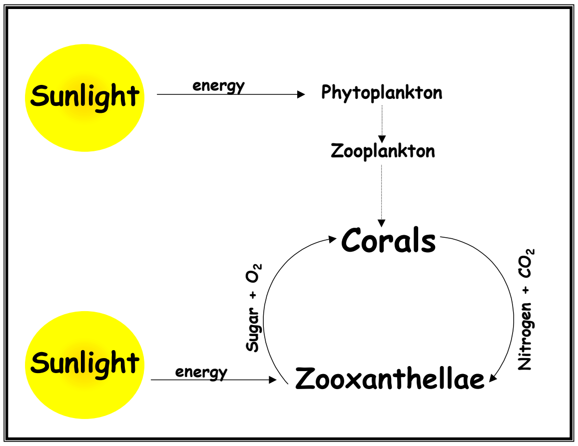


Figure 5. The symbiotic relationship between the coral animal and their interstitial algae, Zooxanthellae, is the building block of a coral reef.

Partially Drowned Reefs

Partly drowned reefs occur in water depths of approximately 150-290 feet. At these depths, light intensity is too low to support communities dominated by organisms that build coral reefs. Reef-building corals do live here but not in sufficient quantities to cover substantial portions of rock. Partly drowned reefs were once living coral reefs, but because of sea level rise over the past 2,000 years, they are no longer near the surface.

Coralline algae play a large role in the partly drowned reef zone. The algae produce encrusting growth over any solid surface, cementing coral and shell debris to form nodules. The algal nodules cover 50-80 percent of the bottom, creating a complex habitat of high diversity comparable to living coral reefs in more shallow waters.

In addition to the coralline algae, an abundance of sponges and leafy algae grow among the nodules and on the structure of partly drowned reefs. Also to be found are calcareous green algae, sea urchins, sea stars, basket stars, feather stars, anemones, snails, bivalves, and many species of fish.

Drowned Reefs

Drowned reefs at the Flower Garden Banks National Marine Sanctuary are in water depths below 290 feet with little light penetration. This area is typically turbid and covered with thin layers of sediment. No reef-building corals or coralline algae thrive at these depths; however, many animals do live on and around drowned reefs. The most conspicuous attached animals are crinoids, sea whips, sea fans, encrusting sponges, and solitary corals. Numerous fishes inhabit the drowned reefs as well, including snapper, grouper, butterflyfish, scorpionfish, and bass. Most of these fish are commonly found only on drowned reefs and deep, partly drowned reefs.

Geology

The physiographic provinces in the Gulf of Mexico—shelf, slope, rise, and abyssal plain—reflect the underlying geology. The erosion of land and deposition of sediments form

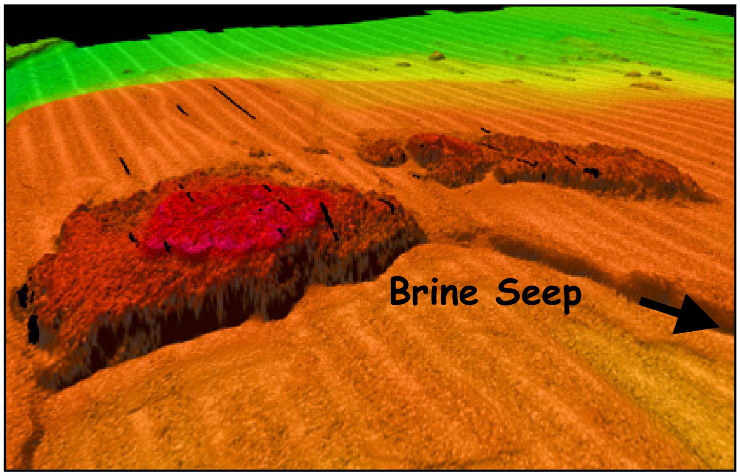


Figure 6. Multibeam bathymetry image of the East Flower Garden Bank illustrating some of the distinct geological formations (USGS 2000). The East Bank also features a unique underwater salt lake, fed by a brine seep 233 feet below the surface.

sedimentary features, such as deltas, fans, canyons, and sediment flow forms. The Flower Garden Banks (Figure 6) are the result of a geologic phenomenon, the formation of salt diapirs. Early in its formation, the Gulf of Mexico was a shallow sea that repeatedly dried out and refilled, leaving massive deposits of salt. Later, when the sea returned, sediments deposited by rivers into the Gulf of Mexico buried the salt deposits. The sediments continued to build, forming sedimentary rock over the salt. The weight of the rock and the sediments caused the salt to flow and squeeze up through faults in the rock. This action lifted some of the rock up through the overlying sediments, exposing it to the bottom of the seafloor. The sedimentary rock at the base of the Flower Garden Banks was lifted in this manner. The salt layers that gave rise to the salt dome beneath the Flower Gardens formed 160-170 million years ago. The living coral reefs one sees today probably began forming 10-15 thousand years ago.

The Flower Garden Banks are distinguished from other salt diapir formations by several characteristics. Their distance from shore, 110 miles, removes them from the direct influence of land runoff. Therefore, clear waters with good light penetration surround them. These banks also have a much higher profile than other banks. The East Flower Garden Bank rises 380 feet from the surrounding seabed. The West Flower Garden Bank rises 430 feet. In addition to their high relief, these banks are much larger than similar banks, with the East Bank covering approximately 26 mi^2 and the West Bank covering 53 mi^2. This makes the Flower Garden Banks one of the premier offshore oases habitats of the Gulf of Mexico.

Stetson Bank

Another premier Offshore Oasis is Stetson Bank—distinctly different from the Flower Garden Banks in its geological morphology. As seen in Figure 7, outcrops of vertically oriented claystone, siltstone, and sandstone of mid-Tertiary origin form Stetson Bank. Stetson is isolated from other banks by waters over 160 feet deep and is characterized by its exposed bedrock and colorful sponges and fire corals. Stetson

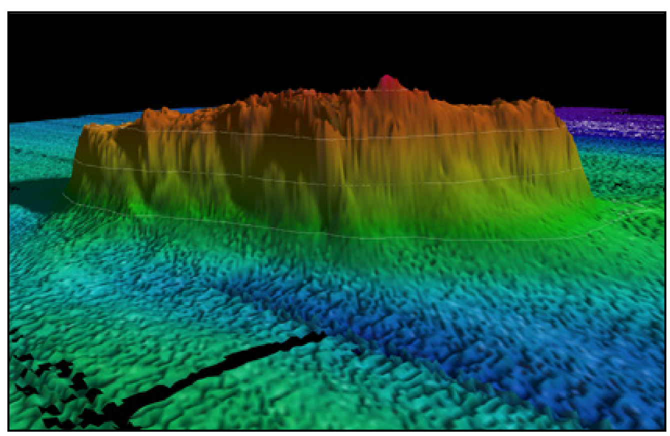


Figure 7. Multibeam bathymetry image of Stetson Bank showing the vertical orientation of the formation. (USGS 2000)

lies near the northern physiological limit for reef-building hermatypic corals, resulting in a species composition markedly different from that of tropical coral reefs. The reef is dominated by a variety of sponges and fire coral. There are also sparsely distributed coral species, like the ten-ray star coral, a leaf-like coral known as fragile saucer coral, and the symmetrical brain coral. Because the species of star coral is so susceptible to being covered up through sedimentation, it tends to grow on sharp ledges around the reef and has developed an extraordinary formation known as the "*Madracis* wall" (referring to the scientific name *Madracis decactus*). Even though Stetson is deeper than the Flower Garden Banks and is located near the northern limits for coral growth, there are several hermatypic corals that occur. However, these species are sparsely distributed across the bank and small in comparison to those found at the Flower Garden Banks. Blushing star coral and symmetrical brain coral are two of the more common species found. Stetson Bank is considerably smaller than either the East or West Flower Garden Bank, measuring approximately 0.6 miles long and 0.12 miles wide.

Because of its vertical expression, Stetson attracts a number of pelagic species that move back and forth across the continental shelf, using various banks, including the Flower Gardens, for seasonal feeding, mating, and as nursery ground. These large pelagic animals include species such as manta, eagle, and devil rays, and the filter-feeding whale shark (Figure 8). During winter months, December through March, large numbers of sharks and rays concentrate at Stetson and the Flower Garden Banks. Scalloped hammerheads, tiger sharks, sandbar sharks, and spotted devil and manta rays are among the largest groups found during this time.

Figure 8. The whale shark, an occasional visitor at Stetson and the Flower Gardens, is easily recognized by its large size and spotted appearance. The whale shark is the largest fish known, with recorded specimens greater than 35 feet in length. (Photo by Boland)

Stetson's exceptional characteristics have resulted in its use by divers, boaters, and commercial and sport fishermen, as well as by professional photographers, and its being mentioned in national publications in connection with the Flower Gardens National Marine Sanctuary. Stetson Bank became part of the Flower Garden Banks National Marine Sanctuary in 1996.

PROTECTION

The MMS is charged with managing mineral resources on the OCS in an environmentally sound and safe manner. This means managing mineral exploration, production, and transport in a manner that protects and preserves the environment while providing for the economic recovery and processing of natural resources. The MMS has sponsored studies of the Flower Garden Banks for years and requires continued monitoring of the effects of oil and gas activities in the marine environment. The MMS is one of the primary agents in the protection of this matchless offshore oases habitat.

Class Exercises

Class Exercise 1—Tackling Taxonomy

We share the earth with approximately 1.4 million other kinds or species of organisms (that we know of). To study these organisms, scientists have developed a classification system called taxonomy. Taxonomy is the science of classifying animals and plants on the basis of their natural relationships. Using this system, scientists name individual species and can relate the species to each other. You can use a variety of publications on fish and corals to find scientific names of these animals.

Number the scientific name to match the number of its correct common name.

Common Name

1. Fire Coral
2. Devil Ray
3. Vermilion Snapper
4. Barbfish
5. Red Snapper
6. Blushing Star Coral
7. Common Octopus
8. Scalloped Hammerhead Shark
9. Large Grooved Brain Coral
10. Creole Fish
11. Manta Ray
12. Gray Snapper
13. Ruby Brittle Star
14. Yellowtail Snapper
15. Ten Ray Star Coral
16. Spotfin Butterfly Fish
17. Red Stinging Sponge
18. Slate Pencil Urchin
19. Fragile Saucer Coral
20. Smooth Trunk Fish
21. Symmetrical Brain Coral
22. Yellow Pencil Coral
23. Whale Shark
24. Spotted Scorpion Fish
25. Star Coral
26. Banded Coral Shrimp
27. Mutton Snapper
28. Long-spined Sea Urchin
29. Rockboring Sea Urchin
30. Sandbar Shark
31. Tiger Shark
32. Atlantic Thorny Oyster
33. Christmas Tree Worm

Number	Scientific Name
	Colpophylia natans
	Paranthias furcifer
	Lactophyrys triqueter
	Madracis mirabilis
	Scorparena plumieri
	Diadema antillarum
	Agaricia fragilis
	Neofibularia nolitangere
	Sphyrna lewini
	Diploria strigosa
	Eucidaris tribuloides
	Lutjanus analis
	Montastraea annularis
	Rhincodon typus
	Mobula hypostoma
	Millipora alcicornis
	Madracis decactis
	Scorpaena brasiliensis
	Lutjanus griseus
	Ocyurus chrysurus
	Stephanocoenia michilini
	Manta birostris
	Echinometra lucunter
	Carcharhinus plumbeus
	Spondylus americanus
	Galeocerdo cuvieri
	Chaetodon ocellatus
	Lutjanus campechanus
	Rhomboplites aurorubens
	Octopus vulgaris
	Ophioderma rubicundum
	Stenopus hispidus
	Spirobranchus giganteus

Class Exercise 2—Phylogenetic Order

Place each animal listed in Exercise 1 in the correct phylogenetic order to include:

PHYLUM
CLASS
ORDER
FAMILY
GENUS
SPECIES

Class Exercise 3—Optional Field Study

Materials

5"x 7" index cards
11 tables
pencils
paper

Animal specimens (Use slides, mounts, taxidermy specimens, or photos of species representing each of the phyla listed below):

4 species of Porifera
4 species of Cnidaria
4 species of Ctenophore
4 species of Platyhelminthes
4 species of Nematoda
4 species of Bryozoa
4 species of Echinodermata
4 species of Annelida
4 species of Mollusca
4 species of Anthropoda
4 species of Chordata

1. Collect specimens for student observations.
2. Create cards listing the predominant characteristics of each phylum. For example, the Cnidaria card may read: "Invertebrate animal that is radially symmetrical, has a central mouth surrounded by tentacles, and has nematocysts." Omit the phylum name from each card. Students will determine the phylum from the information given and the specimens they observe.
3. Set up 11 tables; clearly number each. Place three specimens of the same phylum on each table. Include the correct card for the phylum represented. Place one remaining specimen on each table so that each table has one incorrect specimen. The specimen will not meet the requirements of the phylum represented.

4. Divide the class into cooperative learning groups. Groups have five minutes at each table to determine which phylum the specimens represent. Groups must also determine which specimen does not belong. Each group chooses one student (in its group) to record findings. This student will write the table number, the phylum represented at that table, which specimen does not belong on that table, and the phylum the group thinks this "misplaced specimen" belongs to.
5. After students have visited each table, groups report their findings to the class. For each table, students discuss the phylum and explain why the incorrect specimen does not belong.

Which of these animals does not belong? Answer: The crab is an arthropod. The octopus, abalone, and snail are all molluscs.

From Diversity of Life|Missing Links

CHEMOSYNTHETIC COMMUNITIES

It is not widely known that the Gulf of Mexico, a relatively small body of water in comparison with the Atlantic or Pacific Oceans, is home to some remarkable deep-sea animals usually associated with geological features in the major oceans' great basins. The animals in these habitats, known as chemosynthetic communities, literally eat gas. In more specific terms, chemosynthetic communities are defined as persistent, largely sessile assemblages of marine organisms dependent upon chemosynthetic bacteria as their primary food source. These communities consist of clams, mussels, and tube worms (Figures 9 and 10), and have been discovered in association with hydrocarbon seeps in the northern Gulf of Mexico, hence the statement "literally eating gas." To clarify, "literally eating gas" refers to the consumption of the gas symbiotic bacteria, not the animals that inhabit these communities.

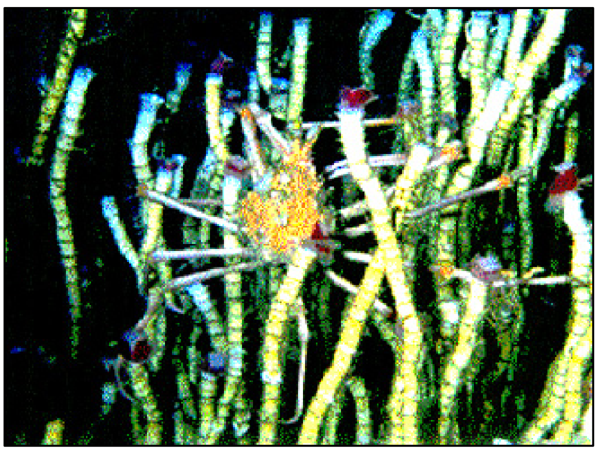


Figure 9. "Tube worm forests" harbor numerous attached as well as motile species like the spider crab. (Photo J. Blair, National Geographic Society)

Figure 10. Chemosynthetic mussels use methane gas as their energy source and form high-density mats. They are also a significant part of deepwater chemosynthetic communities, providing food and shelter for many other organisms. (Photo by LGL/MMS)

In the mid-1980's, a team of scientists from Texas A&M University under contract to the Minerals Management Service (MMS) and the oil and gas industry discovered chemosynthetic life forms on the floor of the Gulf of Mexico thousands of feet below the surface. The discovery was surprising and their presence unsuspected. In fact, that scientific investigation was one of many sponsored by MMS on the Gulf's Outer Continental Shelf since the passage of the National Environmental Policy Act of 1969.

CHEMOSYNTHETIC COMMUNITIES: A NEW WAY OF LIVING

For the most part, deep-sea animals live under conditions of total darkness, low temperature, nearly featureless mud, and sparse food resources. Plants cannot grow at this depth, and the source of food for most benthic (bottom-dwelling) fish and invertebrate life is the energy-poor remains of organic material that rain slowly down from surface waters. As a result, deep-sea animals tend to be generally small and fragile and display low densities and overall biomass (Figures 11 and 12).

Figure 11. Photograph of a member of the Chimaeridae family of ratfish, Hydrolagus alberti*. This is a deep-sea/benthopelagic species that ranges from 1,100- to 2,700-foot depth in the Gulf of Mexico. (Photo by Boland)*

Figure 12. Deepsea crab, Chaceon quinquedens, *photographed at approximately 2,600-foot depth in the Gulf of Mexico. (Photo by LGL/MMS)*

Until about 30 years ago, it was thought that all living things, plants and animals, were dependent upon the process of photosynthesis. But in 1977, other remarkable forms of life known as "chemosynthetic animals" were discovered. These animals were later found to be able to extract their energetic needs from dissolved gasses in their environment in the presence of dissolved oxygen. The first discoveries of chemosynthetic animals, huge tube worms (known as vestimentiferans) and large clams, were in the Pacific Ocean. Living near hydrothermal vents in the spreading seafloor at the mid-ocean ridge, these remarkable animals were obtaining their energy from dissolved hydrogen sulfide issuing from the vents.

During the MMS-funded Northern Gulf of Mexico Continental Slope Study by LGL and Texas A&M University, well-developed chemosynthetic communities were discovered near natural petroleum seeps in the Gulf of Mexico. The community known as "Bush Hill" for its "bushes" of giant tubeworms was investigated by using a manned submersible. These Gulf communities were shown to be similar to those of other discoveries around the world. In all cases, chemosynthetic forms were shown to harbor huge numbers of bacteria in their bodies and to possess various anatomical and physiological adaptations and intricate biochemical pathways that allow the use of chemical compounds produced by the symbiotic chemosynthetic bacteria. Aside from the fact that some of the chemicals used are ultimately the products of ancient photosynthesis laid deep into sedimentary rocks over geologic time, these chemosynthetic animals had successfully broken their dependence upon photosynthesis and conventional eating (called heterotrophy).

The ecological significance of the chemosynthetic process in the deep ocean continues to be resolved through interdisciplinary studies. However, the evolutionary relationships among these communities are still an open question. Through research and continued investigative procedures, we will be able to understand the complex interactions among chemical, biological, and geological processes in these unusual environments.

Information on the deep Gulf is needed now as the oil and gas industry moves well onto the slope and into deeper water in its continuing search for producible oil and gas. Only a few years ago, technical and engineering considerations limited the depths in which oil and gas operators could explore for oil and produce it if they found it. Now, thanks to remarkable technological advances, the limiting factors are chiefly the costs involved; given the right market prices and a reservoir of sufficient size, however, the investment is economically justifiable. Under these circumstances, it becomes necessary to know more about life in the deep sea.

CLASS EXERCISES

Class Exercise 1—Deepwater Projects

Assignment

Assign students projects relative to these deepwater topics: general information, research tools, fauna, geology, significance, ethics, and unsolved mysteries.

Discuss the following subjects:

(1) What is the basis of the chemosynthetic community food chain?

(2) How do tubeworms survive without sunlight or a mouth?

(3) How many creatures are associated with chemosynthetic communities and the deepwater of the Gulf?

Related Activity

Make a model of the fauna around a chemosynthetic community, or deep Gulf seep.

Resources

You may find images of creatures of the deep sea, including chemosynthetic communities associated with cold seeps and hydrothermal vents, on these and other web sites:

"Deep-sea Bestiary" from NOVA Online/Into the Abyss at

http://www.pbs.org/wgbh/nova/abyss/life/bestiary.html

Pennsylvania State University

http://www.bio.psu.edu//cold_seeps/index.html

MMS Chemosynthetic Communities Webpage

http://www.gomr.mms.gov/homepg/regulate/environ/chemo/chemo.html

Class Exercise 2—You're the Chief Scientist!

You are the Chief Scientist of an upcoming cruise to investigate chemosynthetic communities and associated deepwater organisms. You will be in charge of many scientists who are specialists in several different fields. You will also have a small group of school science teachers on board to assist the researchers. They know a lot about science, but little about cold seeps. They have many questions.

Your job as Chief Scientist is to coordinate the research work. You also must coordinate teaching the teachers about these areas.

Assignment

If this is a class project, assign classmates to become experts in these deepwater topics: general information, research tools, fauna, geology, significance, ethics, and unsolved mysteries.

Discuss the following subjects:

(1) What is the basis of the chemosynthetic community food chain?

(2) How do tubeworms survive without sunlight or a mouth?

(3) Are there just a few creatures associated with chemosynthetic communities and the deepwater of the Gulf?

Related Activity

How could I make a model of the fauna around a hydrothermal vent, chemosynthetic community, or deep Gulf seep?

PINNACLE TRENDS

The "Pinnacle Trend" is a band of submarine features off the Mississippi-Alabama coast and a significant component of the Gulf of Mexico Offshore Oases habitats (Figure 13). Commercial fishermen historically have known the value of these banks as important fishing grounds. The features lie in water depths ranging from about 220 to 360 feet and are mostly relict carbonate structures. The average height of the pinnacles is about 30 feet, with some exceeding 50 feet. Ahermatypic corals, octocorals, crinoids, hydroids, and sponges (Figure 14) dominate the communities. Other organisms living in these areas include a variety of antipatharians, crabs, seastars, and brittlestars. One of the most important contributions of these features is to provide habitat for numerous fishes commonly associated with hard-bottom habitats in the Gulf, as well as a variety of pelagic fishes.

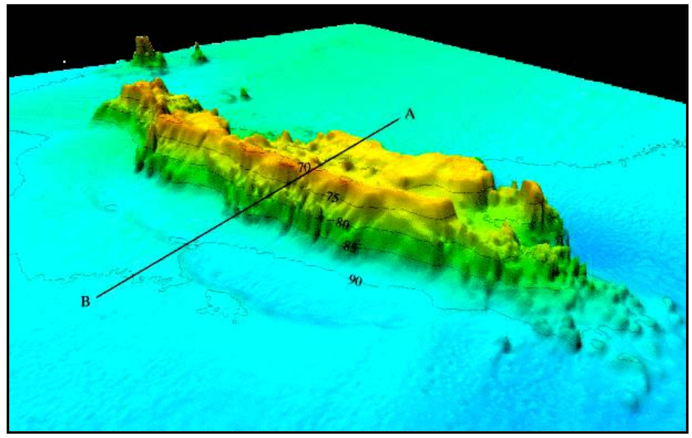


Figure 13. Multibeam bathymetry image of pinnacle reefs off the coast of Alabama/Mississippi. (USGS 2000)

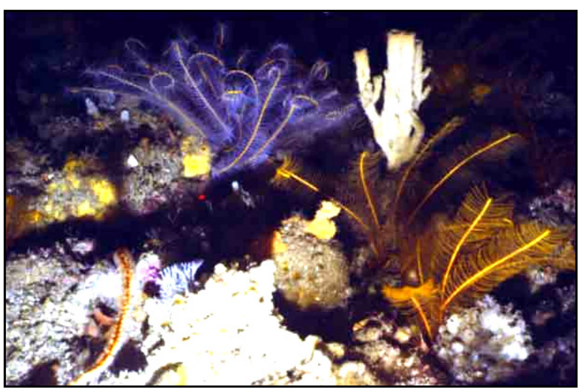


Figure 14. The Minerals Management Service has studied and protects the Pinnacle Trend, a grouping of rocks and ridges that provides a hard-bottom oasis for animals like these sea fans, octocorals, feather stars, and basket stars. (Photo by CSA/MMS)

The Pinnacle Trend exhibits a range of community diversity and density governed by local conditions. Two major factors affecting a community are elevation above the seafloor and the nature of the substrate itself. Organisms near the bottom of a feature, close to the surrounding soft substrate, are frequently enveloped in the nepheloid layer. As a result, light is blocked and sediments settle on the surfaces of the organisms. These conditions allow the existence of a community of only low diversity and low density. Only animals that need little to no light and can grow tall or settle on vertical surfaces are able to survive. On pinnacles with low relief (less than 6 feet), the nepheloid layer dominates.

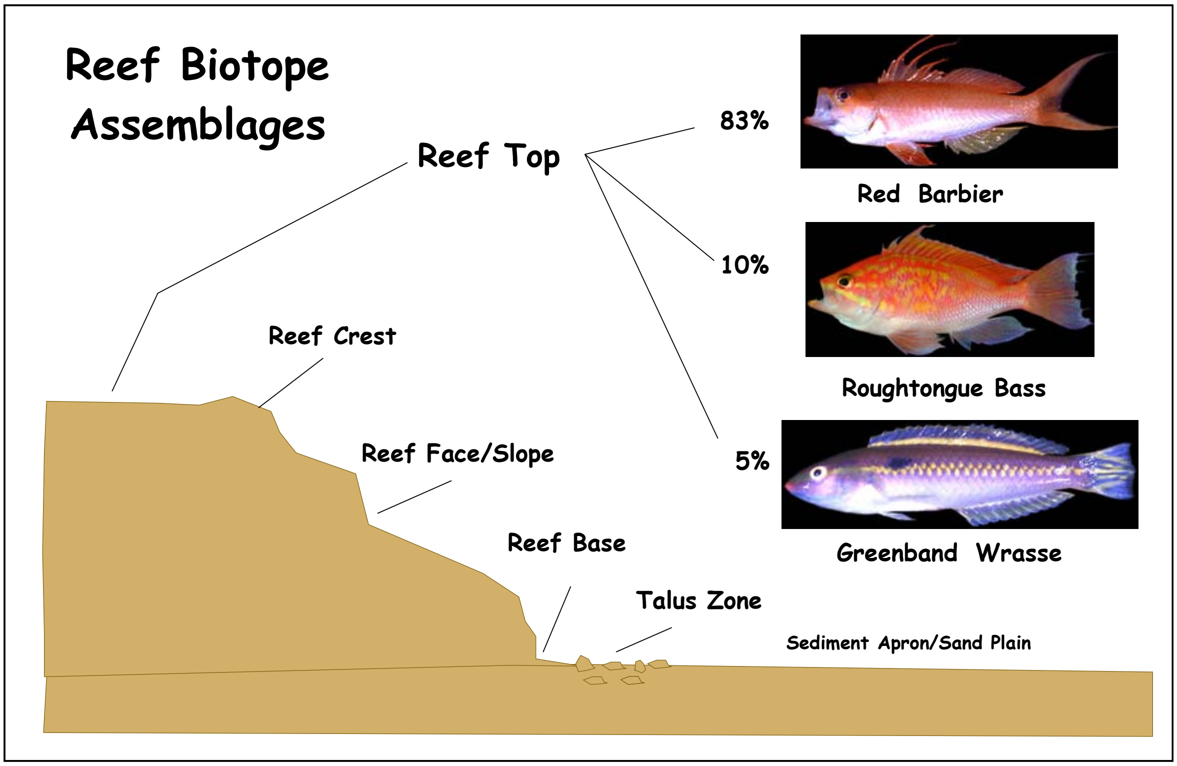
Above the nepheloid layer, on taller pinnacles, the nature of the substrate gains more influence. Little light penetrates these depths (170-360 feet), supporting only sparse coralline algae and rare corals. But this does not mean that few animals live here. A wide range of animals that do not require light for growth are able to flourish on these offshore oases habitats. The pinnacles are drowned coral reefs with variable surfaces. Vertical sides have low colonization, but horizontal flats are much more densely populated. Some pinnacles even have large flat tops produced by erosion in a past age. Pinnacles with flat tops have a dense population of ahermatypic corals, sea whips, sea fans, sponges, and other invertebrates and fish. The tallest pinnacles typically have the richest communities because these substrates are farthest above the nepheloid layer and closest to the surface, giving them sunlight and cleaner water. Some pinnacles have complex surfaces honeycombed by overhangs and openings supporting a large diversity and density of organisms. Others are smooth and featureless with correspondingly fewer animals.

STUDYING THE PINNACLES

*Figure 15. Photograph of a roughtongue bass (*Pronotogrammus martinicensis*). This small pelagic bass is generally found in depths of 100 to 200 meters, but schools have been reported associated with coral reefs and topographic features such as the Pinnacles. (Photo by Weaver)*

Researchers have led programs that accomplished bathymetric and habitat reconnaissance; sidescan mapping; and oceanographic, physical, and biological characterization and monitoring of pinnacle features and their hard-bottom communities. These investigations have provided the site locations, bathymetric charts, physical background, and macrofauna framework for the study of pinnacle reef demersal fish communities. Specific studies focused on the feeding habits and food web structure of the pinnacles' deep reef fishes (Figure 15). Methods for collecting data included the use of a remote operating vehicle (ROV) (Figure 16), videography, and still photography. During these investigations, scientists were able to document 146 species of fish either from collected specimens or videotape. Sixty-seven of the species documented are considered to be among the reef fishes of the Caribbean reef-fish faunal type. Thirty-two species are "facultative" reef fish, which have a broad distribution on the continental shelf, 47 species are bottom dwellers and shelf dwellers, some of which are pelagic and deep midwater animals. The reef fish were organized into assemblages and characterized on the basis of their "biotope" preference. Through videotape analyses of the fish community composition, scientists were able to determine the different biotope types associated with the pinnacle reefs: reef flat top, reef crest, reef face, reef base, talus zone, and circum-reef sediment apron. The species composition or numerical abundances were different for each biotope and are illustrated in Figures 17 and 18.

Figure 16. Remote operating vehicles (ROV) are often used to collect biological data in deepwater, where SCUBA cannot be used because of the deep depths. (Photo by Weaver)



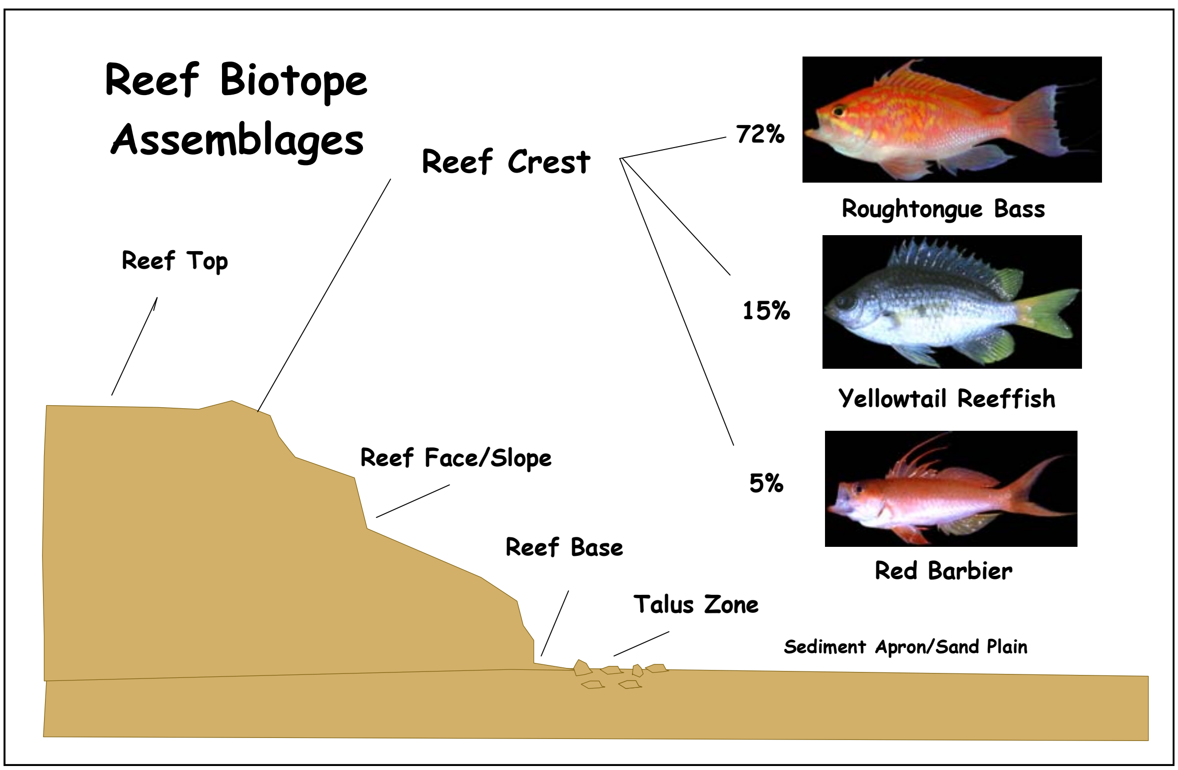


Figure 17. Comparative pinnacle reef fish composition by biotype: Reef top and reef crest. (illustration by Weaver, USGS, 2000)

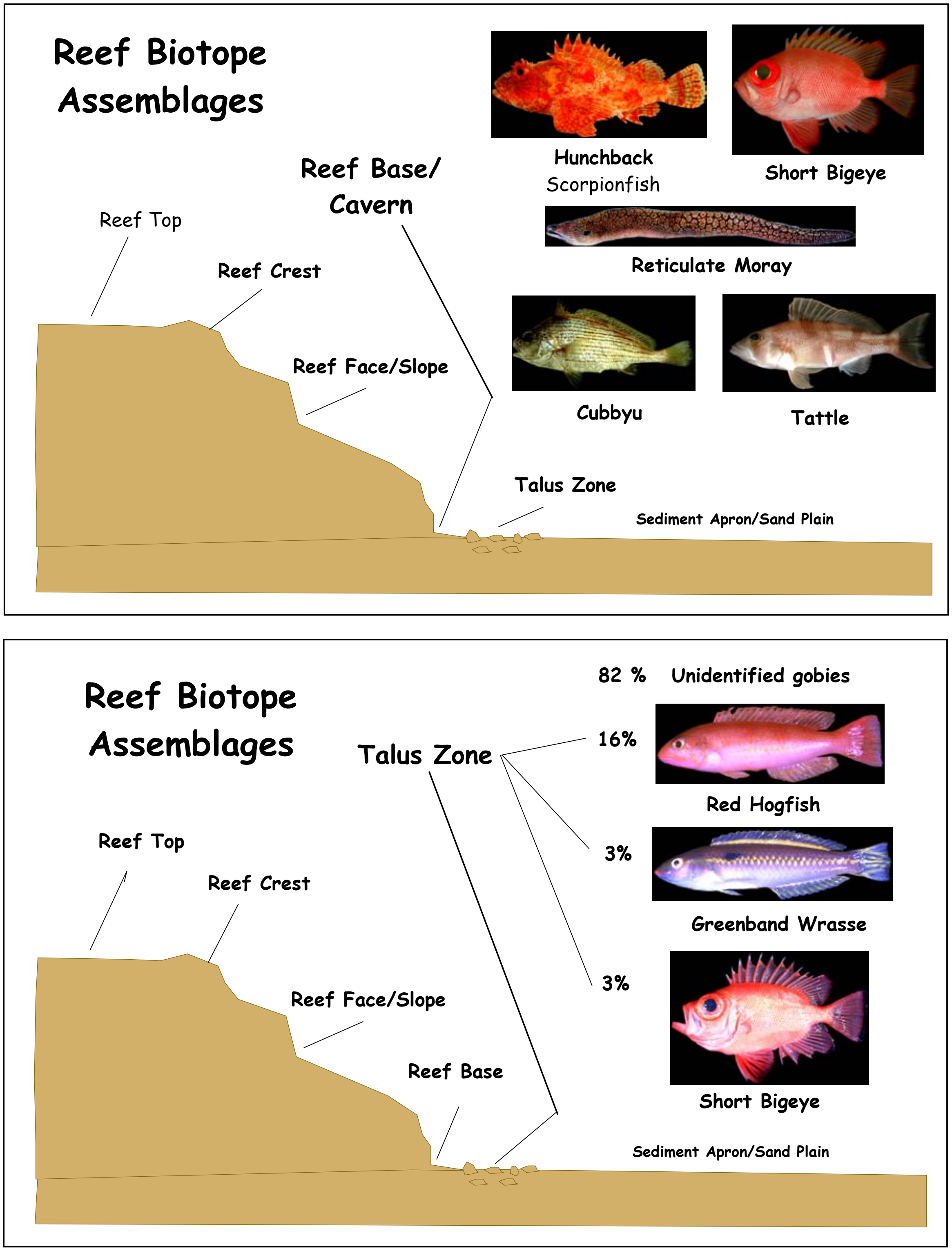


Figure 18. Comparative pinnacle reef fish faunal composition by biotype: Reef base/cavern and talus zone. (illustration by Weaver USGS, 2000)

Class Exercise—Life in the Food Chain

Charting Marine Food Chains

Materials

- Poster boards or butcher paper
- Yardsticks
- Markers
- Construction paper
- Scissors
- Illustrated references on marine life

Procedures

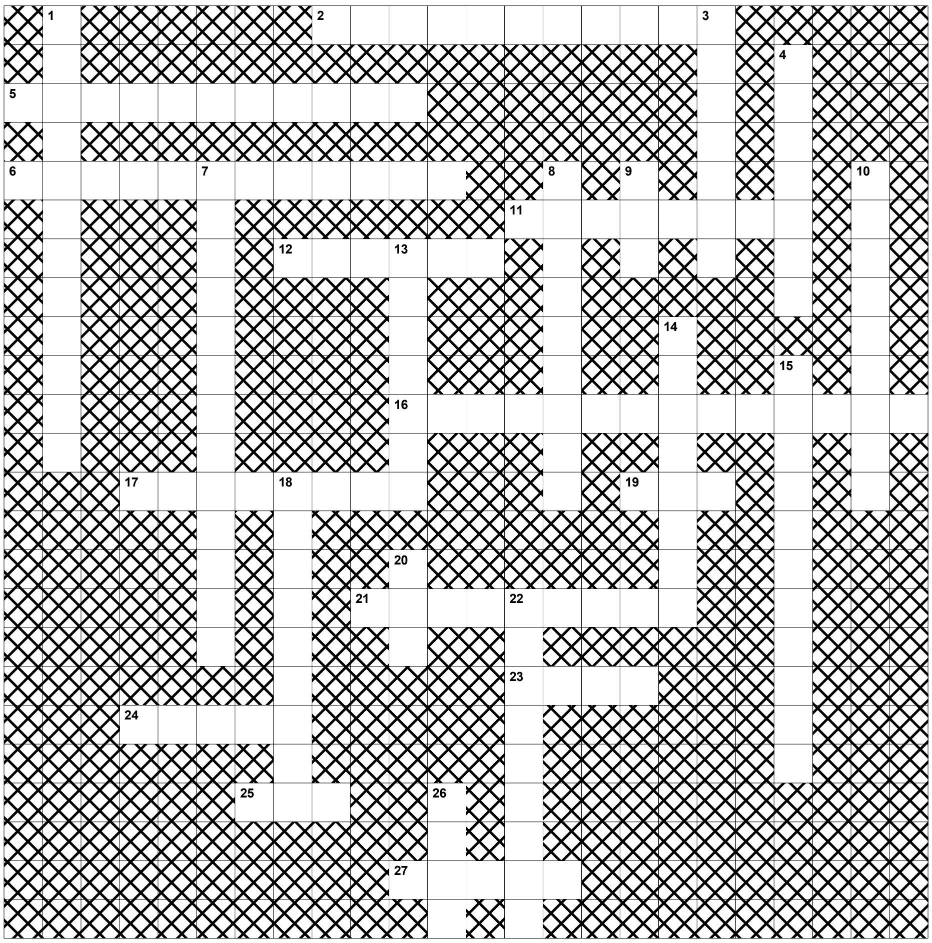
1. Divide students into groups and have each group develop a chart by using poster boards or large sheets of paper.
2. Have students divide charts into four vertical columns and five horizontal spaces by using yardsticks and markers. Each chart should have the following four column headings written in large, bold letters across the top:

Production/ Consumption	**Trophic Level Number**	**Herbivore or Carnivore**	**Example**
Producers			
Primary Consumer			
Secondary Consumer			
Tertiary Consumer			
Quaternary Consumers			

3. Beneath the first column head, label each of the five production/ consumption roles, running down the left margin.
4. Draw and cut out illustrations of animals identified in this workbook. Add additional organisms by using other references in order to fill out the chart. Consider the placement and role of humans.
5. Place the various animals' cutouts in the appropriate "Example" box on the chart. Identify primary producers, primary consumers, secondary consumers, etc.

REVIEW EXERCISE

CROSSWORD PUZZLE



- chemosynthetic
- community
- complex
- currents
- depth
- ecosystem
- Flower Gardens
- gas
- Gulf of Mexico
- habitat
- impacts
- light
- live bottoms
- MMS
- mud
- nepheloid
- oil
- pinnacle
- reef
- relief
- rock
- sediment
- stipulations
- substrate
- temperature
- topographic
- turbidity

ACROSS

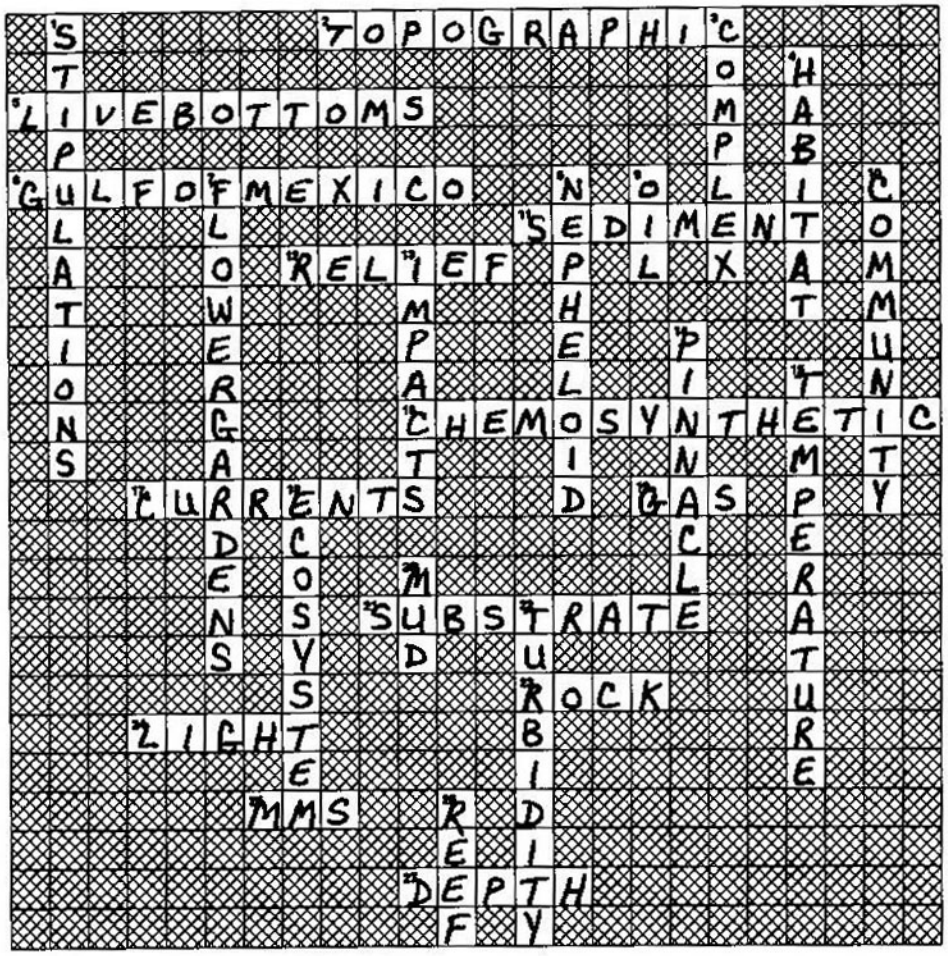
2. "Offshore Oases" features in the western Gulf of Mexico.
5. Low-relief areas in the east-central Gulf of Mexico with hard substrates and reef communities.
6. U.S. Mediterranean Sea.
11. Matter deposited by water.

12. The changes in elevation of a surface.
16. Organisms that use sulfur dioxide or methane gas for their metabolism.
17. Water movement that transports larvae and resuspends bottom sediments.
19. One of the major products regulated by the MMS from the Gulf of Mexico.
21. Bottom of the sea.
23. Sparse substrate in the Gulf of Mexico that harbors complex, thriving communities.
24. The depth of penetration by this limits the growth of many organisms.
25. Minerals Management Service.
27. Distance below the surface of the water.

DOWN

1. Mechanism for the protection of habitats by the Minerals Management Service.
3. Adjective for a habitat with overhangs, caverns, and rough surfaces.
4. The physical surroundings where organisms live.
7. Location of high-diversity, living coral reefs in the Gulf of Mexico.
8. Bottom-water layer of suspended sediment.
9. One of the major products regulated by the MMS from the Gulf of Mexico.
10. A group of organisms living in a single habitat.
13. Effects on habitats in the Gulf of Mexico.
14. A point or ridge of rock that is thrust up higher than the surrounding substrate.
15. Physical factor that limits the northward colonization of tropical marine organisms.
18. All living organisms in a community, their habitat, and physical factors that affect them.
20. Soft sediment that covers most of the Gulf of Mexico.
22. Low visibility caused by suspended matter in the water.
26. A hard substrate that stands above the seafloor and usually has organisms growing on it.

Crossword Puzzle Solution



GLOSSARY

Ahermatypic: Organisms that do not contribute significantly to the building of coral reefs.

Anemones: Solitary polyps akin to corals but with no skeletal structure; catch prey with stinging tentacles surrounding the mouth.

Antipatharians: "Black coral" and other corals with slender, branching colonies and horny skeletons.

Bathymetry: Measurements of water depth; can be depicted on a map.

Benthic: Refers to those plants and animals that live on the bottom of a lake or sea.

Biomass: The weight of living organisms per unit of area or volume of habitat.

Biotope: An ecological niche, or restricted area, or the environmental conditions that are suitable for certain plants and animals.

Bivalves: Molluscs such as oysters, clams, and scallops that typically have two shells encasing the body.

Brittlestars: Echinoderms akin to basketstars with a flattened central disc and five highly flexible arms used for locomotion and, in some, suspension feeding.

Bryozoans: Tiny, polyp-like, colonial animals individually called zooids; usually forming minute, rigid, adjoining calcium carbonate compartments with an opening in the surface of one end for feeding.

Calcium carbonate: The chalky material that makes up bone and structural elements of many animals (for example, shells of molluscs and the skeletons of hard corals).

Chemosynthetic: Refers to organisms that use hydrogen sulfide or methane gas, rather than photosynthesis, as their primary energy source.

Coralline algae: An encrusting red algae that incorporates calcium carbonate into its cell walls.

Crinoids: Echinoderms superficially resembling ferns. Arms branch to form a crown with 10-200 suspension feeding limbs. A central calyx is supported by a stalk with cirri (e.g., sea lilies) or simply bears cirri (e.g., featherstars). Cirri are wiry, prehensile tentacles for grasping and locomotion.

Density: In biology, the number of organisms per unit of area of a habitat.

Diapir: A geologic formation in which a mobile underlying layer, such as salt, has pushed up through a brittle overlying layer, such as sedimentary rock, forming a crest of rock that may be exposed on the surface.

Diversity: An expression of the number of different species present in a habitat.

Drowned reefs: Natural rock structures composed of the remains of reef-building organisms but no longer harboring reef-building organisms because of deep submergence and inadequate light penetration to the structure.

Echinoderms: A group of marine invertebrates characterized by bodies with penta-symmetry, flexible tube feet operated by water pressure, and calcified plates internally, in the skin, or both. This group includes featherstars, brittlestars, sea stars, sea urchins, and sea cucumbers.

Encrusting organisms: Plants and animals that grow in a layer tightly adhering to, and conforming to, the shape of the substrate or another organism.

Facultative: Not restrictive or capable of existing in more than one medium; bacteria that can exist aerobically (with oxygen) or anaerobically (without oxygen) are an example.

Featherstars: Crinoid echinoderms without a central stalk. (See crinoids).

Filter feeders: Animals that consume plankton and bacteria by straining water through some part of their body.

Gorgonians: Octocorals that typically exhibit an upright, flexible growth with a horny, axial skeleton (of gorgonon) and polyps with eight tentacles. Include sea whips, sea fans, and red coral.

Habitat: The specific places or type of environment in which an organism or biological population normally lives.

Habitat complexity: Variation of the physical structure of an environment ranges from simple to complex, that is, simple equals smooth, straight, steep, barren, solitary; complex equals rough, overhangs, holes, horizontal surfaces, layers of growth, group of habitats.

Hard bottoms: Areas of the seafloor composed of rock or other hard substrate.

Hard corals: Those corals with calcareous skeletons in various shapes, depending on the species; often form reefs and islands.

Hermatypic: Organisms that incorporate calcium carbonate into their structures and occur in large enough quantities to contribute significantly to reef building.

Heterotrophy: The consumption of organic matter (usually other plants and animals) to support nutrition.

Hydroids: A large group of animals akin to corals. Hydroids are very small polyps that frequently form colonies resembling seaweed. Colonies may be sheathed in a tough cuticle and typically bear two to four different types of polyps for feeding, defense, and reproduction.

Hydrothermal vents: Faults in the seafloor where hot fluids and gasses issue and vent communities may exist. (Not found in the Gulf of Mexico).

Invertebrates: Animals with no backbone. Of the animal species on Earth, 95 percent are invertebrates.

Molluscs: A group of soft-bodied animals, terrestrial, marine, and freshwater, usually partly or wholly enclosed within a calcium carbonate shell; includes snails, clams, and squid.

Nepheloid layer: Bottom waters in which soft sediments are resuspended up to 65 feet from the seafloor by currents. Some locations experience this almost constantly, others only sporadically.

Nodules: Shells and other materials cemented together into clumps by coralline algae.

Octocorals: Corals with flexible skeletons and polyps bearing eight tentacles.

Partly drowned reefs: Natural rock structures composed of the remains of reef-building organisms, but because of deep submergence and lowered levels of light, typical reef-building organisms other than coralline algae do not thrive.

Petroleum seeps: Faults on the seafloor where migrating oil and gas leave the bottom and may reach the sea surface. These areas may support chemosynthetic communities.

Photosynthesis: Process by which organisms use light energy and carbon dioxide, via chlorophyll, to produce carbohydrates for metabolism.

Relief: Elevations of a substrate above the surrounding seafloor.

Sea stars: Echinoderms with a flattened body and typically five flexible arms used for locomotion and feeding. Use their strong arms and many tube feet to open the shells of molluscs.

Sea urchins: Echinoderms with rigid spines covering a spherical body, having a calcified internal shell called a test with openings at top and bottom for the anus and mouth, respectively.

Sea whips: Gorgonians with a long, thin, unbranched, flexible axial skeleton bearing polyps with eight tentacles.

Seafloor: Bottom of the ocean; substrate that composes the benthic environment.

Sedimentation: The process of particles suspended in the water column settling on the substrate and its attached living organisms.

Soft bottoms: Areas of the seafloor composed of mud, sand, and gravel.

Solitary corals: Hard or soft coral polyps that live singly, not forming colonies.

Sponges: Primitive marine animals composed of individual cells not organized into tissues. Variable shape draws water in through many pores, filters it, and expels it through large opening(s).

Substrate: Literally, the "layer below"; the bottom of the ocean, upon which organisms grow.

Suspension feeding: Collecting and consuming particles and plankton mixed into the water column.

Tube worms: Numerous species of marine worms that form and live in tubes. The tube is secreted of calcium carbonate or made of mud, sand, and debris glued together by mucous. The worm may draw a current through the tube and/or extend an appendage or the front of its body to feed. In the case of chemosynthetic communities, they are highly specialized worms with chemosynthetic bacteria.

Turbidity: The restriction of light and vision through water caused by the suspension of particles or plankton.

Vestimentiferans: Large tube worms living in thick colonies around deep hydrothermal vents in some oceans, including the Pacific. The Gulf of Mexico species are thought to be the oldest animals on earth.

Zooxanthellae: Photosynthetic algae that live in the tissues of animals, such as corals and clams, providing a significant nutritional benefit.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.

MMS Securing Ocean Energy & Economic Value for America