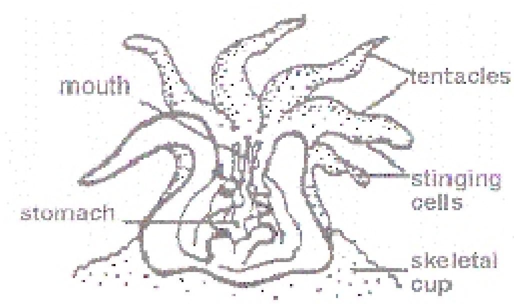
Coral Reef Ecology/Coral Reefs-101

Keynote Presenter: Sharon H. Walker, Ph.D.*
The University of Southern Mississippi-Scott Aquarium
Biloxi, Mississippi

This Keynote Presentation has been slightly modified from the Sustainable Seas' "Islands In the Stream" Video Conference in which I served as an invited, Keynote Presenter three times during 2001 and 2002. These Sustainable Seas "Islands in the Stream" Video Conferences were cooperatively sponsored by the National Oceanic and Atmospheric Administration (NOAA) and National Geographic Society (NGS).

I am delighted to be sharing some basic facts about **coral reefs** with you today. These basic facts involve the following areas:

- **Introduction and Why Are Corals Important To You and Me?**
- **What Are Corals?**
- **Where Are Coral Reefs Found?**
  - **Deep Sea Corals**
- **How Do Corals Reproduce And Grow?**
- **Life/Diversity Within A Coral Reef Community.**
- **And, Conservation For Our Coral Reefs.**

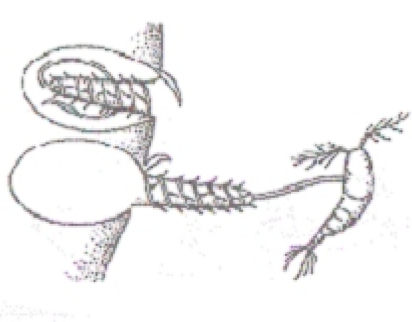


This diagram represents an example of a coral polyp with its anatomy labeled.

Note: Key Words are boldfaced and are contained within a Key Word Glossary. Select Key Words are defined when they are used.

Introduction and Why Are Corals Important To You and Me? Coral Reefs have been estimated to support nearly one-third of all the world's fish species and possibly as many as 500,000 different animal species (*Atlas of the Oceans*, 1994)........... Imagine that you are diving in clear, warm sunlit, turquoise or blue waters between 12 to 60-foot depths. And, during this dive, you are immersed in an underwater garden of beautiful colors, intricate shapes, and a diversity of **vertebrates** (organisms with a vertebral column or backbone such as fish, marine mammals, and reptiles) and **invertebrates** (creatures without backbones such as soft and hard corals, sponges, shrimp, crabs and many, many other marine species). The **diversity** within a coral reef is similar to the splendor of a tropical **rainforest**—both of these **habitats** are valuable resources and essential to the global **ecosystem**. Coral reefs are generally found in areas of low marine productivity; however, the reefs themselves are highly productive. This high productivity is largely the result of the reefs' efficient cycling and re-use of nutrients—which are in limited quantities in the surrounding oceanic waters. As noted in the *Atlas of the Oceans* (1994), the primary production of coral reefs is between 30 to 250 times as great as that of open oceans. Worldwide, we depend on coral reef communities for harboring many species of edible fish and invertebrates; protection from waves and erosion during storm surges; and for a variety of commercial and **medicinal uses** (substances used for surgically replacing broken human bones and for providing treatments for viruses, arthritis, heart diseases, asthma, and cancer). Despite the ecological significance of coral reefs and their unequaled beauty, they are being threatened by human activities of over-fishing, pollution, boat groundings, aquarium collection techniques, incorrect snorkeling and diving practices, and bleaching.

What Are Coral Reefs?....... Coral reefs are comprised of many different species of coral; corals are living animals. There are hard corals and soft corals. Hard corals have an external skeleton made of calcium carbonate ($CaCO_3$) and soft corals embed bits of $CaCO_3$ inside their bodies. Even though corals vary in shape, size, and consistency (hard or soft), they all contain individual polyps. A **polyp** is a tiny animal that looks like an anemone or upside-down jellyfish. In hard corals, polyps sit inside small $CaCO_3$ cups. In soft



An enlarged stinging cell located on a coral tentacle.

corals, each polyp contains $CaCO_3$ spikes which hold many polyps together, like a fan or whip.

Reefs are formed when hundreds of hard coral colonies grow on “top of” and “next to” each other. These breathtakingly beautiful coral reefs of the world cover less than one half of one percent of the world’s ocean floors. And even with this small percentage, these underwater gardens and empires serve as a home to an estimated 25 percent of all oceanic species. Coral polyps stay deep within their $CaCO_3$ cups during the day and emerge during the night and wave their tiny, stinging **tentacles** in the water to catch microscopic organisms known as **plankton** (drifting or wandering plants and animals).

Now, I want you to think about these polyps—see them in your mind and through this “video clip” excerpted from David Hamman’s 1996 *Coral Sea Dreaming* journey to Australia’s Great Barrier Reef. Also, be aware that one characteristic that makes coral polyps very unique is the fact that plankton is only a portion of their diet. Most polyps also allow one-celled, special plants—**algae**—to live within their bodies. These one-celled algae are known as **zooxanthellae** and use sunlight and **carbon dioxide** to conduct **photosynthesis**, a process that produces oxygen and other nutrients needed by the coral polyps. In return for this living arrangement, the algae get protection and a constant supply of carbon dioxide (CO_2) and other materials they need for photosynthesis—primarily from the waste products of the coral polyps. This mutually beneficial relationship is known as **symbiosis**.

Now let’s make an edible coral polyp with the objective being to review its parts. This activity is contained within the *Bilingual Coral Reef Resource Guide* (pp. 8-9) and may be found online at <www.aquarium.usm.edu> and “go to” Resources. The original source was the *Coral Reef Teacher’s Guide*. Students will work in groups of two or four. The students need to wash their hands prior to this activity.

Materials:

- White baking chocolate or similar candy coating

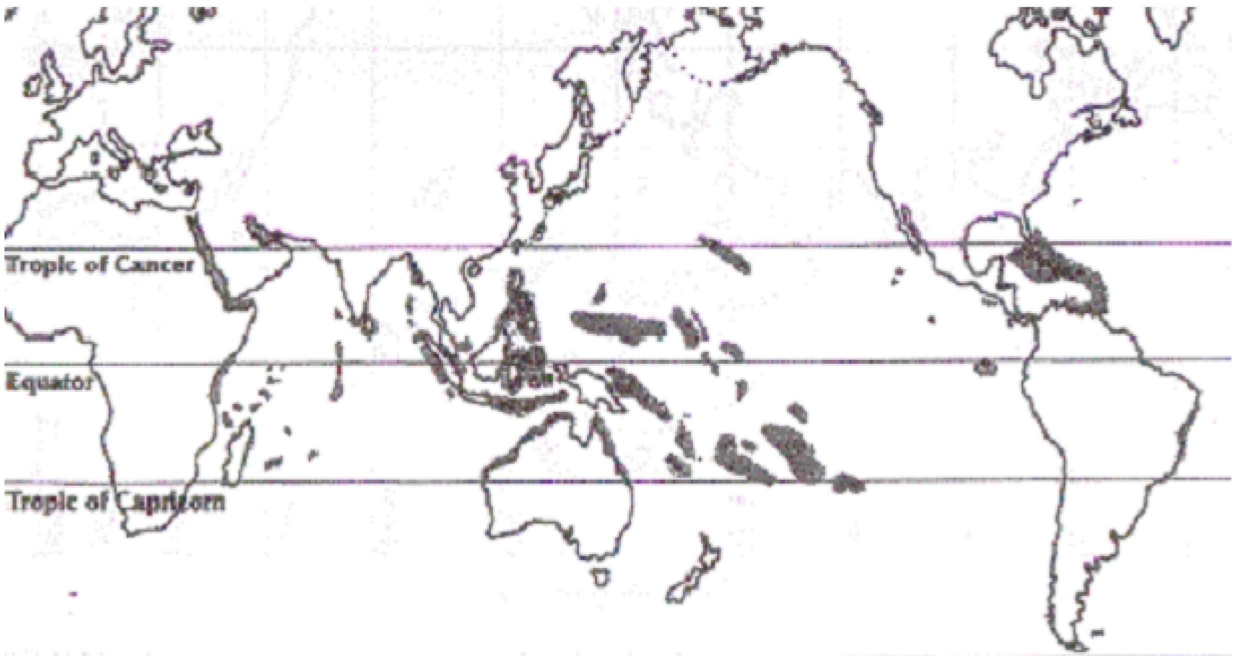
- One marshmallow per student
- Toothpicks
- Red or black licorice
- Blue, red, or green edible sprinkles
- Microwave oven for melting white chocolate and six small, shallow microwave dishes
- Paper plates
- Spray bottle of clean, tap water

1. Give each group of four students a paper plate.
2. Give each student within the group a marshmallow on a toothpick and six, two-inch, thin strips of licorice. The marshmallow represents the coral polyp body and the licorice will represent the **tentacles**.
3. Give each group, two ounces of melted candy coating in a shallow container (the candy represents the $CaCO_3$ **[limestone]** skeleton).
4. The students in each group should work together in rolling the marshmallow in the melted candy coating and then stand the four marshmallows in the paper plate (the marshmallows can be placed close enough together so they resemble a coral colony).
5. The students should then make holes in the marshmallows with their toothpicks so they can insert the six, two-inch lengths of licorice representing tentacles (students should make sure they remove the toothpicks).
6. Students should slightly dampen the marshmallows with a fine, light mist of water (one spray should dampen each group's plate of four marshmallows). Then add sprinkles which represent **endosymbionts**, i.e., use only one color of sprinkles per coral polyp.
7. Students should discuss and review the components of the coral polyp.
8. The students should then pretend they are **predator** creatures eating the polyps.

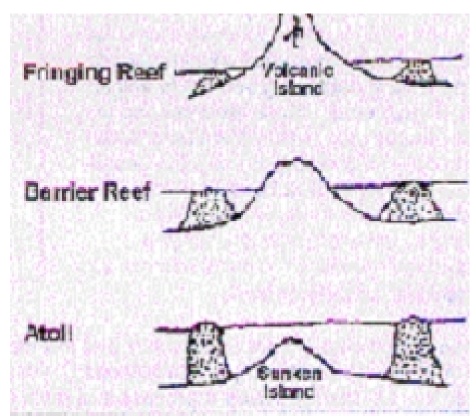
This activity involves science, language arts, and math. Teachers may wish to evaluate and assess their students through individually maintained class journals, participation in cooperative learning groups, and subsequent class discussions. Art and written essays should also be components of this newly acquired coral reef knowledge.

Where Are Coral Reefs Found?

True reef-building corals are normally thought to form only where the water is clear, warm, and shallow. The temperature normally does not fall below 20° C (68? F) and the water depths usually do not exceed 100 meters (325 ft.). The temperature range is 18° to 29° C, but 24° C is optimum. Most corals grow in water depths of 40 meters or less.



Therefore, these conditions are typically met in tropical waters near the equator, on the eastern sides of continents, and around oceanic islands within 30 degrees north or south of the equator. These **latitudes** and **longitudes** allow the formation of most coral reefs in bodies of oceanic waters between the Tropic of Cancer and the Tropic of Capricorn.



There are three types of coral reefs and they are:

a) **Fringing reefs**—when a reef forms close to shore.

b) **Barrier reefs**—as a reef matures, the oldest corals near the shore may die and the reef will then be located offshore as a barrier with a lagoon in between it and the shore.

c) **Atolls**—when corals grow around a volcanic island, an atoll results as the island weathers/subsides, leaving only a ring of corals visible near the sea's surface.

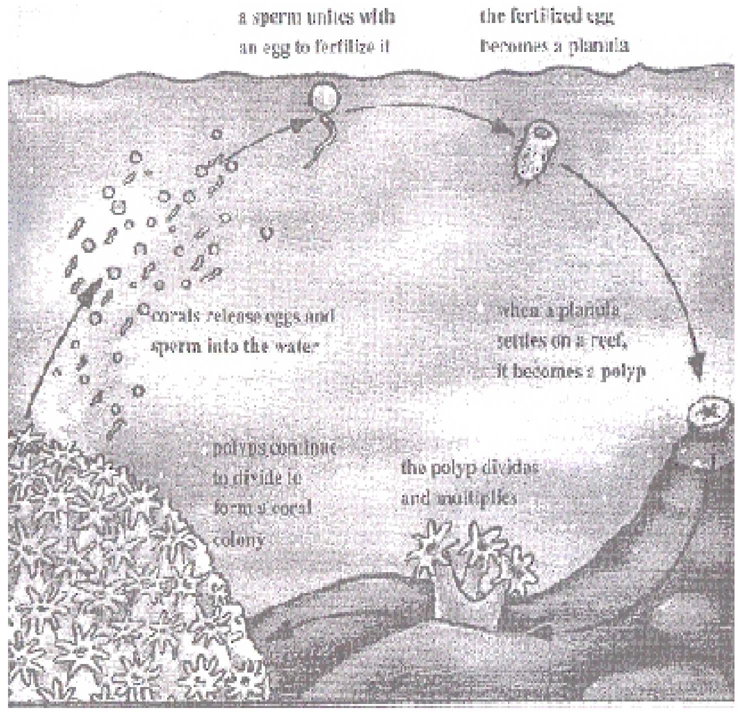
Deep Sea Corals

To most people except a few scientists and fishermen, the thought of deep sea corals was non-existent due to the understanding that corals are primarily known to occur in warmer and more sallow waters. Only recently has legislation been passed to ban deep sea trawling on coral reefs off the coast of Norway. Further, in North America, there is little knowledge of the existence of deep sea corals by the general public and the broader scientific community. However, deep sea corals (hard and soft) have been known since 1862 and are known to be distributed from the northeast/New England-Gulf of Maine and Georges Bank through the Hudson Canyon to Blake Ridge off Georgia's coast, as well as off the coasts of Greenland, Iceland, and the Faeroes to northern Norway. Deep water corals are found on the upper and middle continental slope areas (3,000 to 4,000 meters) in the colder and deeper waters of the Southern Hemisphere, as well as in the north Atlantic and Pacific Oceans.

Since these deep water coral reefs have been known for more than a century, it is interesting that we have such a limited knowledge about their biology, the role they serve in promoting species diversity and interaction within the reef community, and the population of corals themselves, to include their reproduction, growth, and distribution. I encourage you to become more familiar with the *Deep East 2001 - A Voyage of Discovery* expedition in which scientists and educators explored new resources and ocean dynamics off the east coast of the United States. Results of this voyage by Drs. Les Waling, Peter Auster, Scott France, and others can be found at <http://oceanexplorer.noaa.gov/ explorations/deepsea01/logs/sept11/sept11.html>. Some of these findings may be from a *Washington Times* article by Sarah Marciz on April 23,2003 at <http:cchps.alantisforce.org/washtimescoral403.html>. In this article, Drs. Stephen Cairns, Peter Auster, and/or Ken Sulak shared that cold-water, deep sea corals look similar to the faster-growing tropical variety. These scientists also used the analogy of comparing the deep sea corals to a redwood in the ocean due to the fact they grow less than 1.3 centimeters (less than ½ inch) per year. Further, these scientists suggested that, in addition to overfishing, mammoth, giant factory trawler ships often dredge the ocean floor with the results being deep-freezing nearly everything brought to the surface. This "deep-sea catch" is processed into a wide variety of products which vary from catfood to fast-food fish fillets. This article further revealed these cold-water corals are sensitive to the heavy trawling gear that often flattens the deep-water reefs and rips them from the ocean floor and that research projects in various countries including Canada, Scotland, and Norway estimate that as much as half of their deep-sea corals may have already been trawled to rubble. Dr. Auster stated that deep sea corals play an essential habitat as fish live, grow, and reproduce in these havens sheltered from predators and the unrelenting currents. Additionally, it is important to note the technology required to reach these deep sea corals has only been available for approximately 30 years and a research submersible and its host ship may cost $20,000 a day while at sea.. Therefore, partnerships with other countries and/or organizations is essential to the success of understanding the value of these fragile, deep sea coral communities. These scientists and select educators used the inner space ship, the deep submergence vehicle, *Alvin*, for their expedition. It is noteworthy to mention the *Alvin*, is America's only occupied submersible capable of diving below 2,000 meters. This NOAA-sponsored expedition met the challenge expressed in the Presidential commissioned report (2000), *Discovering the Earth's Final Frontier: A U.S. Strategy for Ocean Exploration.* I encourage you to visit the Coral Symposium URL at <http://www.amcs.org.au/NEWS/notices/dpscoral.htm>**;** the 1st Deep Sea Coral Symposium was held in 2000.

How Do Corals Reproduce and Grow?

To initiate a new reef, coral polyps reproduce sexually with sperms and eggs. Male polyps release sperms into the water column where they enter female polyps resulting in the eggs being fertilized within the body cavity. Coral polyps exhibiting "internal" fertilization are referred to as **"brooders."** **"Broadcasters"** are coral polyps which shed their eggs and sperms into the water column resulting in external fertilization. This mass process of the release of eggs and sperms is also known as **spawning.** Corals spawn only once a year usually one or two days after a full moon. Spawning may occur in the spring, summer, or fall each year. Larval (baby) corals are known as **planulae**; the planulae develop and leave the polyp, floating with the currents for up to 30 days until they find a suitable **substrate** where they attach and begin to grow into **juveniles** and then adult coral polyps. Sexual reproduction allows coral distribution. To add onto an existing colony, polyps then undergo asexual reproduction in which new polyps divide and multiply by **"budding off"** the parents and form their own $CaCO_3$ cups adjacent to the older polyp. These new "budded" polyps are genetic replicas of their parent.



Some corals are capable of growing 15 centimeters (6 inches) per year. Massive corals such as star or brain coral grow much slower, typically only 0.3 to 2 centimeters (1/8 to 3/4 of one inch) per year. As old corals die, new corals usually settle and grow "on top" the dead skeletons. The Great Barrier Reef in Australia is hundreds of feet thick and millions of years old.

Now, let's review and re-enforce the manner in which coral skeletons form (taken from the *Coral Reef Resource Guide*, p. 26 <www.aquarium.usm.edu>, then "go to" Resources; this original activity was taken from *Life On A Coral Reef: Marine Science Curriculum, Grades 7-8*). The objective of this activity is to demonstrate coral polyps have the ability to extract raw materials from seawater and produce a solid substance. For this activity students should be placed in groups of four.

Materials/Group:

- One cup of white vinegar in glass container
- One stick white blackboard chalk, broken into several smaller pieces
- One cup of tap water in a glass container
- Six teaspoons baking soda
- A two-cup glass container

Procedure:

1) Mix one cup of white **vinegar** and one stick blackboard chalk (broken into several small pieces).
2) In a separate container, mix one cup of tap water with six teaspoons **baking soda.** Stir occasionally for 15 minutes. Allow mixture to settle and **decant** (pour off) the clear liquid. Discard any remaining baking soda.
3) Combine the two clear liquids into the two-cup glass container. A white **precipitate** will form and settle. This reaction demonstrates a coral polyp extracting calcium from seawater, combining it with carbon dioxide, and producing **argonite**, the hard white material of coral skeletons.
4) This white material represents the white coral skeleton produced by the coral polyp.
5) The teacher may wish to demonstrate that the liquid can be "poured off" and the white precipitate dried to show its solid state, i.e., $CaCO_3$. This $CaCO_3$ is the compound comprising coral polyp skeletons and in the presence of a weak acid, common household vinegar, the $CaCO_3$ will fizzle and dissolve. Depending on grade level and the understanding of chemistry, the teacher may wish to discuss the reactions which have occurred.

This activity involves science, language arts, and math. Teachers may wish to evaluate and assess their students through the maintenance of individual journals, participation in cooperative learning groups, and subsequent discussions. Art and written essays should also be components of this newly acquired coral reef knowledge.

Life On A Coral Reef

As previously mentioned, coral reefs are often regarded as the **rainforests** of the sea. Coral reefs support an infinite diversity of living organisms/creatures. Due to the fact that scientists are only beginning to explore and study the oceans, we are not exactly sure how many species (different kinds) of marine organisms live on/in the coral reefs of the world. It has been estimated that coral reefs serve as the home for 25% of all the marine organisms on the Earth. Very simply, the varied nature of living organisms is known as **biodiversity.** And, the greater the biodiversity (genetic blueprint of living creatures on our planet), the more likely that life on Earth will be ensured of adapting to changes over geologic time.

Note: There are 18 activities in the *Bilingual Coral Reef Resource Guide* comprising pp. 43-81 related to the biodiversity of life within a coral reef community <www.aquarium.usm.edu>, then "go to" Resources. These activities involve fish, invertebrates, plants, marine mammals (whales), and reptiles (sea turtles).

Conservation of Coral Reefs

Coral reefs have existed for millions of years. These coral reefs have survived innumerable environmental changes; however, today these changes are occurring at an alarming rate. Reefs in at least 20 countries to include the United States, Australia, Japan, Indonesia, and Mexico are all showing signs of stress. Many scientists are fearful that if these human induced changes are not halted, healthy coral reefs will not exist in 25 to 30 years. Some of the threats to coral reefs may be categorized as follows:

- **Natural Threats**—Hard and soft corals are vulnerable to unusually strong waves such as those created during hurricanes, as well as dramatic changes in temperature and salinity. **Predation** by a variety of fish (parrotfish, wrasses, file fish, tangs, and many others), invertebrates (worms, sea urchins, seastars, crabs, and shrimp), and fleshy algae can also kill coral reefs. Corals also compete among themselves within a reef community for light and space. Faster growing corals dominate within reef communities; however, slow growing corals, like the brain coral, typically survive physical changes such as severe storms and/or hurricanes. Over thousands of years, coral reefs have evolved mechanisms to defend themselves against these natural threats. These defense mechanisms include extending polyps only at night, producing large quantities of planulae (larvae), and using **toxic** chemicals such as those produced by fire corals; these defense mechanisms all aide corals in their quest for survival. Unfortunately, these **adaptations** will not be able to successfully compete with the rate and numbers of threats imposed by humans if we don't increase positive environmental behavior modifications.

- **Power and Desalination Plants**—these types of facilities use large quantities of seawater and during this process kill many species of fish, invertebrates, and other small plants as the water is filtered through the **desalination** plant equipment or due to the increase in water temperature during the process of generating electricity or removing the salt from seawater. This heated water or change in **salinity** (salt content) may also be **toxic** when it re-enters the original body of water from which it was taken. These types of pollution upset the normal balance of life within a coral reef community.

- **Deforestation**—excessive logging practices result in soil erosion into rivers which is ultimately carried to sea, thereby increasing the **turbidity** (cloudiness) and nutrient load within the water column. An additional negative effect of deforestation is the potential rise of global temperatures due to an increase in carbon dioxide as a result of burning of the forests (fossil fuels). These changes in sea level and water temperature—as a result of global warming—will affect coral reefs by making these shallow waters too warm for polyp growth by causing them to eject their zooxanthallae. This phenomenon is known as **coral bleaching** and significantly reduces corals' ability to grow, repair themselves, and combat diseases.

- **Pollution**—there are two types of pollution which primarily damage a reef, i.e., **sedimentation** which increases the cloudiness and/or turbidity. Zooxanthallae must have absolutely clear water to allow enough sunlight for photosynthesis. Increased sedimentation due to swimmers, divers, and boaters; land run off (**erosion**) from excessive rains; or sediments expelled from oil drilling rigs will deprive a coral reef of sunlight. Land run-off and sewage discharge will also smother the reef with the soil and **sludge** particles. Fertilizers represent the second primary form of pollutants as a result of increased nutrients which allow the algae to grow faster than the corals. These increased nutrients result in an overgrowth and smothering of coral polyps. Further, reef organisms are also damaged or killed by heavy metals, pesticides, and oil. Very low levels of oil reduce reproduction by making it difficult for microscopic larvae to survive and settle on a "hard" substrate. A reduction in reproduction results in reefs not being able to repair damage as quickly as possible.

- **Fishing and Collecting**—In many geographic areas, reef fishes are a significant source of food. Fishing with a simple hook and line is usually not harmful to coral reefs; however, blasting with dynamite, setting traps, and/or using poisons such as **cyanide** can result in irreparable damage. Physical destruction of the coral reefs is obvious and these underwater explosions stir the sediment, thereby preventing sunlight from penetrating to the polyps. Further, traps and poisons often kill more animals than fisher persons can use. These additional fish deaths and their subsequent **decomposition** reduce or deplete the water column of **oxygen.** Too often, recreational fisher persons run aground on the coral, break corals with anchors, dump litter into the water, and/or take too many fish for sustain ability of the populations. Snorkelers and divers too frequently "stand on" and "break off" coral reefs. When collecting reef organisms—if allowed— snorkelers and divers may also stir the coral sediments with their fins, thereby having negative impacts on the coral reefs.

If coral reefs are weakened by silt or pollution, they may never recover. A damaged reef may take 20 to 50 years to recover.

I'd like to thank you for joining me for this first COSEE-Central Gulf of Mexico Keynote Presentation and I will try to answer any questions you might have—online. And, in closing, we all need to remember the adage, "take only photos; leave only footprints," for as humans, we must remember that we are interconnected to all other species. And, the sustain ability and continuation of the Earth's delicate balance is largely in our hands.

Glossary of Key Words/Vocabulary

- **Adaptations**—usually refer to inheritable structural or behavioral modifications. Adaptations may be favorable or unfavorable to the survival of a species.
- **Algae**—an ancient group of primitive plants which "carry-out" photosynthesis.
- **Argonite**—the hard white material of coral skeletons.
- **Baking soda**—a household chemical compound comprised of sodium, hydrogen, carbon, and oxygen.
- **Biodiversity**—a variety of living species within a specific niche, habitat, ecosystem, community, or environment.
- **Broadcasters**—organisms releasing eggs and sperms into the environment.
- **Brooders**—organisms having internal fertilization.
- **Budding off**—asexual reproduction in which smaller individual organisms develop, then "break away/off" from the parent organism.
- **Carbon dioxide**—an essential respiratory gas and an essential component within photosynthesis.
- **Coral reef**—stony ($CaCO_3$) formations naturally constructed from the seafloor by colonial coral polyps.
- **Cyanide**—a toxic chemical, often lethal in very small concentrations to living organisms.
- **Decant**—the process of "pouring off" a liquid after a solution has been formed, usually with an insoluble compound remaining in the bottom of the containers in which the solution was made.
- **Decomposition**—the "breakdown" and recycling of dead and/or decaying organic matter.
- **Desalination**—the process of removing salts from seawater or brackish water.
- **Diversity**—a variety of different biotic (living) and abiotic (non-living) species or factors.
- **Ecosystem**—the interacting biotic (living) and abiotic (non-living) factors within an environment.
- **Endosymbionts**—symbiosis is the mutually beneficial relationship between two different species; the endo-prefix denotes one of the two organisms lives within a

host organism.

- **Erosion**—a process of being “worn-away.”
- **Habitats**—the place or location where a given species lives.
- **Invertebrates**—primitive organisms lacking a backbone or internal skeleton.
- **Juveniles**—an intermediate stage of a living organism.
- **Limestone**—a chemical compound formed by the combination of calcium, carbon, and oxygen which is the basic compound in corals and many shelled invertebrates.
- **Medicinal Substances**—natural or synthetically produced chemicals with are routinely used medically in the cures or potential cures for a variety of ailments and/or diseases.
- **Photosynthesis**—a chemical process in which oxygen and carbon dioxide—in the presence of light—produce nutrients/carbohydrates.
- **Plankton**—floating or drifting plants and animals, usually associated with water depths not exceeding 200 meters.
- **Planulae**—ciliated, swimming larvae of some invertebrate organisms.
- **Pollution**—substances that have harmful effects on living organisms.
- **Polyp**—a single coral organism (animal) that secretes calcite which forms a skeleton. Many polyps comprise a coral colony.
- **Predation**—the act of one organism pursuing another organism which normally results in harm or death to the organism being “preyed upon.”
- **Salinity**—the amount of salts by weight in parts per thousand (grams) dissolved in a kilogram of seawater (ppt).
- **Sedimentation**—the accumulation of organic and/or inorganic matter that forms in a unconsolidated aggregation.
- **Sludge**—the solid portion of sewage that settles to the bottom.
- **Spawning**—the mass release of eggs and sperms into the water column.
- **Substrate**—the “bottom” layer of a designated area.
- **Symbiosis**—a mutually beneficial relationship between organisms such as the zooxanthellae and coral polyp. The zooxanthellae produce nutrients needed by the coral polyp and the coral polyp provides waste products needed by the zooxanthellae.

- **Tentacles**—arm-like extensions from an organism's body (e.g., octopus, jellyfish, anemone or squid) often used for feeding, gas exchange, and/or defense.
- **Toxic**—a form of pollution that is usually harmful to living creatures and the environment.
- **Tropical Rainforests**—a dense, broadleaf forest located near the equator with an annual rainfall averaging 80 inches. Tropical rainforests are found between the Tropic of Cancer and the Tropic of Capricorn. There are also Temperate and Fossil Rainforests.
- **Turbidity**—a measure of the level of clarity or murkiness of water.
- **Vertebrates**—organisms having a backbone, skeleton, skull, and brains, usually higher/more advanced chordates.
- **Zooxanthellae**—tiny, one-celled algae which combine the energy from sunlight with carbon dioxide to produce nutrients needed by the coral polyps.

About the Author..... Dr. Sharon Walker is currently the Associate Dean for Outreach for the College of Marine Sciences (COMS) at The University of Southern Mississippi; the Administrator of USM's, J.L. Scott Marine Education Center and Aquarium; a Professor in the COMS-Department of Coastal Sciences; and the Director for Education for the Mississippi-Alabama Sea Grant Consortium. Dr. Walker has a B.S. degree in Zoology from Millsaps College in Jackson, MS; a M.S. in Marine Sciences from the Louisiana State University in Baton Rouge, LA; and a Ph.D. in Science Education with emphases in Marine Sciences and Administration and Supervision from The University of Southern Mississippi.

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