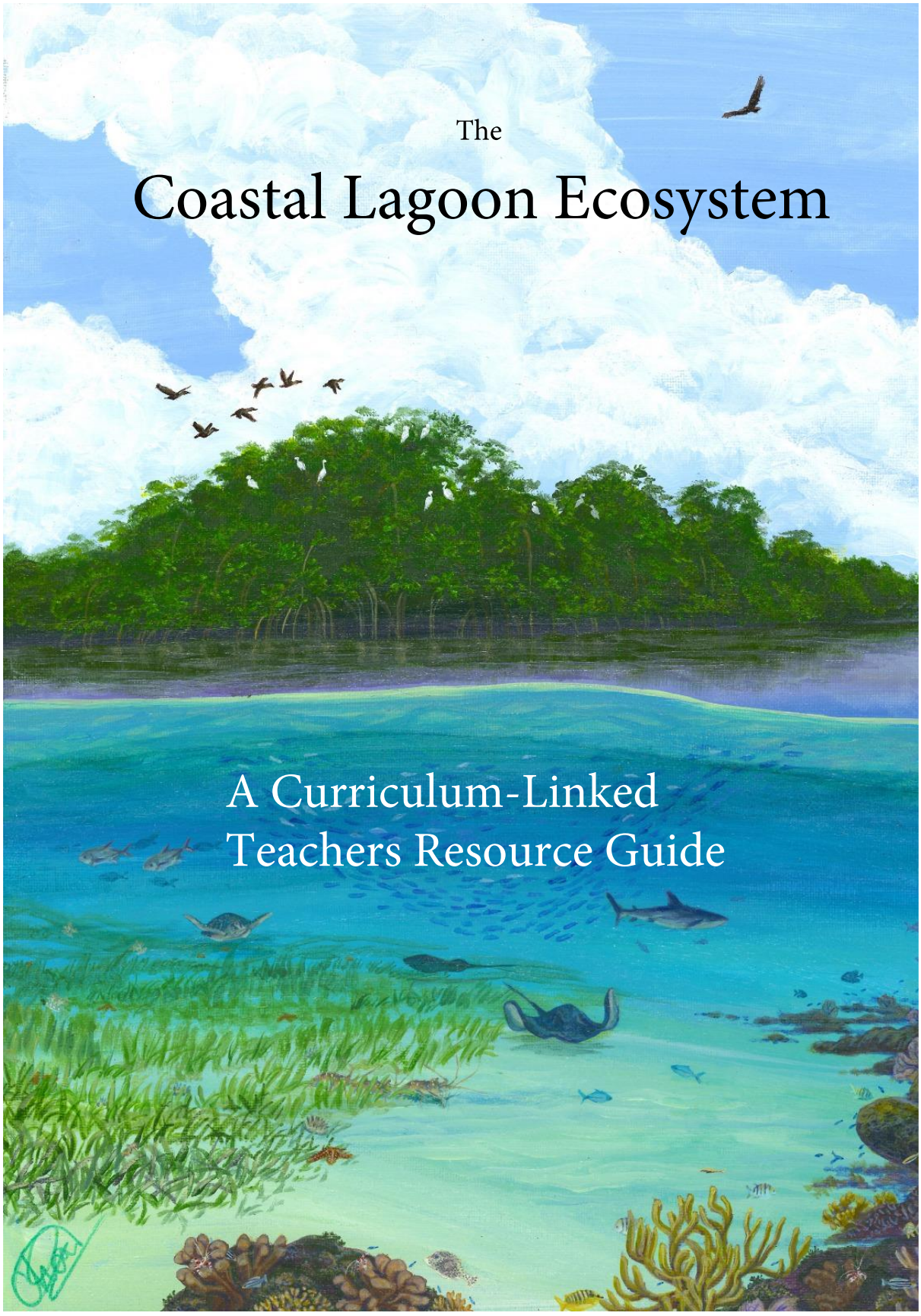

The

# Coastal Lagoon Ecosystem

## A Curriculum-Linked Teachers Resource Guide

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# The Coastal Lagoon Ecosystem in the Cayman Islands

## A Shoreline & Wetlands Resource Book for the West Indies


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### Acknowledgements


I am very grateful for my experiences in the beautiful sea of the Cayman Islands and the time I spent with students and teachers. I appreciate the assistance I received from the Department of Education and Department of the Environment of the Cayman Islands. Thank you to Martin Keeley for sharing his passion for environmental education and for my participation in this project.

*Marnie Laing, Kelowna, Canada, 1st February 2023.*

Our special thanks to our many sponsors and supporters who have made this guide possible.

# Introduction

Work on this guide began in 2019 although the integral parts of the coastal lagoon – mangroves, seagrass and reefs – have been taught separately in Cayman's schools for more than two decades by the principal characters involved in this project. Working closely with the Cayman Islands Department of Education the basic concept was integrate the guide with the science curriculum. It would follow in the footsteps of the *Marvellous Mangroves of the Cayman Islands* – the science-based and in-depth teachers resource guide taught to every Year 5 class in Cayman since its inception in 2001.

While the content was being developed Covid 19 hit. We all went into lockdown and then, in Cayman, were restricted from travelling anywhere except our three islands. Schools were closed and the education system went virtual. Classroom teaching and teacher workshops were inaccessible when they were re-introduced as Covid restrictions were lifted. Young people in their late teens and twenties suddenly found themselves at a loose end and thus, in July 2020, the Cayman Islands Mangrove Rangers was formed. The group which was trained in mangrove ecology also provided educational training through field trips and, finally, school classroom programs. At the same time there was a great deal of concern over the rapid destruction of mangroves in Grand Cayman to make way for developments funded by offshore investors. The Rangers reported areas of illegal destruction to the Department of Environment and began several research projects initially with mangroves and more recently with seagrass and reefs. At the start of 2022 the Junior Rangers was formed and in 2023 a series specialized education programs begun much in the tradition of Scouts and Guides.

The shift to virtual education in the past decade and especially in the past three years of Covid led to the expansion of this guide into that sphere. A totally new and supporting website, https://www.coastallagoon.org/, was established to provide teachers with a host of material that can be used in the classroom and field. Following in the tracks of *Marvellous Mangroves* we have introduced a new "how to" series which guides the teacher on the steps required to carry out the activities themselves. We will be adding similar resources in an ongoing process as we find new and exciting ways to educate.

We will also be following the trail of *Marvellous Mangroves* around the world! *Marvellous Mangroves* is now being taught in 18 countries worldwide and has been translated into eight languages. At the same time we will be introducing Mangrove Rangers to different countries as a way of focusing young people on the practical aspects of conserving these wonderful ecosystems.

Since its inception, the Mangrove Action Project (MAP), https://mangroveactionproject.org/, has been the primary supporter of *Marvellous Mangroves* and is now an active partner, together with the National Trust of the Cayman Islands, https://nationaltrust.org.ky/ of the development and introduction of *The Coastal Lagoon Ecosystem* teachers guide and resources.

*Martin A Keeley, 13th February 2023*





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## Cayman Islands Primary Curriculum objectives and how they tie in with the Coastal Lagoon Guide.

| Year | CI Curriculum Objectives | Coastal Lagoon Guide Topics |
|---|---|---|
| 1 | **Animals, including humans.**<br>1. Identify and name a variety of common animals including fish, amphibians, reptiles, birds, and mammals.<br>2. Identify and name a variety of common animals that are carnivores, herbivores, and omnivores.<br>**Plants**<br>3. Identify and name a variety of common wild and garden plants, including deciduous and evergreen trees.<br>4. Identify and describe the basic structure of a variety of common flowering plants, including trees. | **Basic Ecology – Mangroves, Seagrass, Coral Reefs, Life on a Coral Reef** ***Chapters 2, 3, 4 & 6***<br>1. Identify, draw, and label creatures found in Coastal Lagoon Ecosystems.<br>2. Identify and group common carnivores, herbivores, and omnivores found in Coastal Lagoon Ecosystems and<br>3. Identify the three types of mangroves found in the Cayman Islands.<br>4. Describe and label different types of Seagrasses. |
| 2 | **Living things and their habitats**<br>1. Identify that most living things live in habitats to which they are suited and describe how different habitats provide for the basic needs of different kinds of animals and plants, and how they depend on each other.<br>**Plants**<br>2. Observe and describe how seeds and bulbs grow into mature plants.<br>3. Find out and describe how plants need water, light and a suitable temperature to grow and stay healthy. | **Basic Ecology – Mangroves, Seagrass, Coral Reefs, *Chapters 2, 3, & 4***<br>1. Identify and describe the different habitats where mangroves, seagrasses and coral reefs are found.<br>2. Understand how red mangroves reproduce (viviparously). What is a propagule.<br>3. Adaptations of Mangroves to live in salty/brackish water. |
| | **Plants** | |



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| 3 | 1. Identify and describe the functions of different parts of flowering plants: roots, stem/trunk, leaves and flowers.<br>2. Explore the requirements of plants for life and growth (air, light, water, nutrients from soil, and room to grow) and how they vary from plant to plant.<br>3. Investigate the way in which water is transported within plants.<br>4. Explore the part that flowers play in the life cycle of flowering plants, including pollination, seed formation and seed dispersal. | **Basic Ecology – Mangroves, Seagrass and Coral Reefs, *Chapters 2, 3 & 4*.**<br>1. Seagrass Reproduction, Chapter 3.<br>2. Adaptations of Mangroves and Seagrasses. Requirements for growth.<br>3. Mangrove anatomy. The different types of roots (red vs black mangroves) and how they transport water through the tree.<br>4. Seagrass Reproduction, Chapter 3. |
| 4 | **Living things and their habitats**<br>1. Recognize that environments can change and that this can sometimes pose dangers to living things.<br>2. Explore and use classification keys to help group, identify and name a variety of living things in their local and wider environment. | **Human Impacts - Chapter 8**<br>1. Threats to Coastal Lagoon Ecosystems. How do human impacts affect them.<br>**Mangroves – Chapter 2**<br>2. Using a classification key, identify the three different types of mangroves found in Cayman as well as what they are home to. |
| 5 | **Living things and their habitats**<br>1. Describe the life process of reproduction in some plants and animals.<br>2. Describe the differences in the life cycles of a mammal, an amphibian, an insect, and a bird.<br><br>**Properties and changes of materials**<br>3. Know that some materials will dissolve in liquid to form a solution and describe how to recover a substance from a solution. | **Basic Ecology – Mangroves, Seagrass and Coral Reefs, *Chapters 2, 3 & 4*.**<br>1. Mangrove Reproduction, life cycles, from flowers to propagules to trees. Coral Reefs and a-sexual reproduction/spawning. Seagrass reproduction by pollination.<br>2. Animals that live in Costal Lagoon Ecosystems, how these ecosystems support their life cycles.<br>3. Salinity in the Mangroves. How black mangroves separate salt from the salt water absorbed internally (why are the leaves salty?) |



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| 6 | **Living things and their habitats**<br>1. Describe how living things are classified into broad groups according to common observable characteristics and based on similarities and differences, including microorganisms, plants, and animals.<br>2. Give reasons for classifying plants and animals based on specific characteristics.<br>3. Identify how animals and plants are adapted to suit their environment in different ways and that adaptation may lead to evolution. | **Basic Ecology – Mangroves, Seagrass and Coral Reefs, *Chapters 2, 3 & 4*.**<br>1. Classifying different types of Mangroves, Seagrasses, Coral Reefs, and what lives in them, using a Key.<br>2. Classifying different types of Mangroves, Seagrasses, Coral Reefs, and what lives in them, using a Key.<br>3. Adaptations of Mangroves, Seagrass and Corals to survive in their respective environments. (ex. Mangroves have adapted to live in salty environments) |



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**CHAPTER 1: Coastal Lagoon Ecosystems**





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## Chapter 1: Coastal Lagoon Ecosystems

**Related Videos:** Our Planet: Coastal Seas Video

### Importance of Interconnections

Thriving forests, grassy meadows, rocky cliffs, and colorful tropical landscapes are hidden beneath the sea. Various habitats are maintained by a complex balance of different factors, such as water temperature, light and bottom characteristics. When one or more of these conditions are altered, the entire ecosystem may begin to decline. Coastal ecosystems throughout the world are the first to feel the effect of human activities.

The coastal zone is the most productive part of the ocean, and therefore it is important in the global carbon cycle as well as the global cycles of other elements and water. It is also an area of both species' segregation and integration, since species may sort themselves along physical gradients, but some cross these gradients at different stages in their life cycles. It is also subject to the greatest effect of impacts and destruction from human activities. Human generated nutrients and toxic pollutants are carried from the land, are deposited from the atmosphere, and are discharged from ships and oil rigs; fisher, gatherers and hunters sweep wildlife from coastal waters, shores and sea floors; freshwater is captured for irrigation and drinking water, which reduces the natural flow into the coastal zone and human pollution and development threaten marine habitats.



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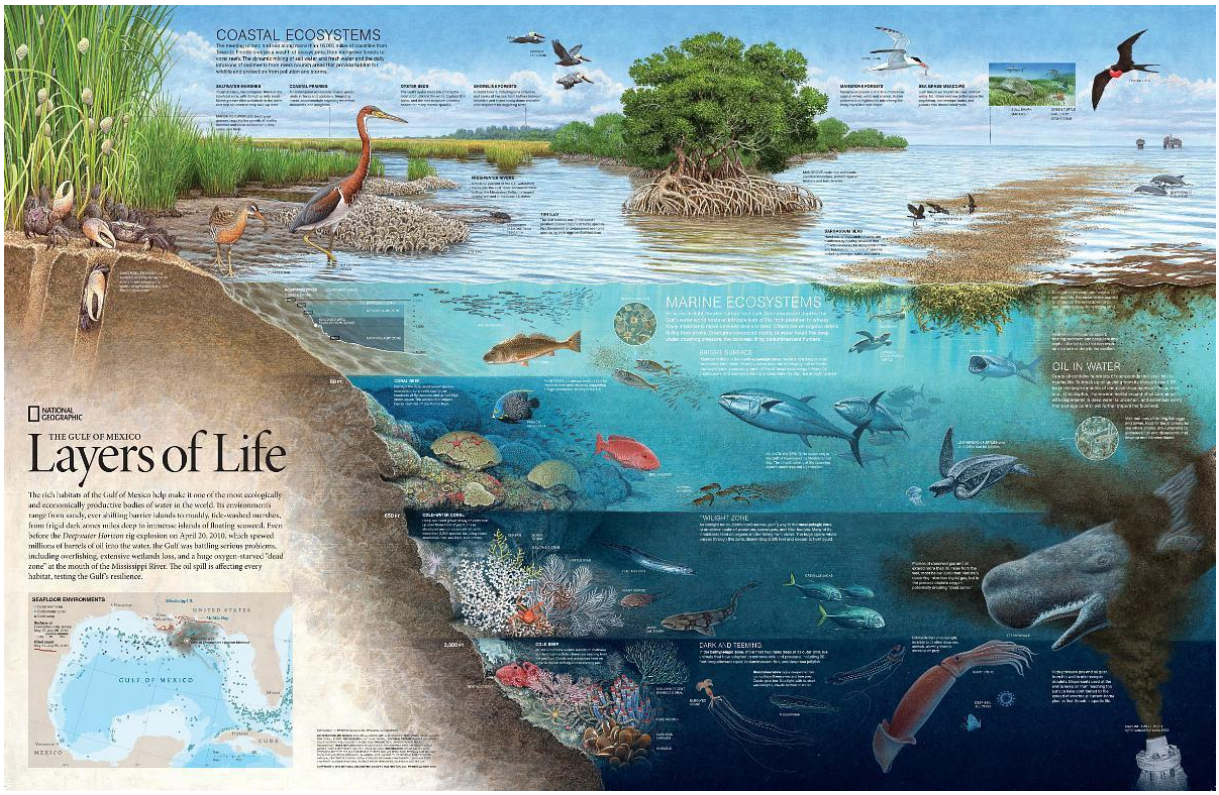


Although we usually think of ecosystems as a collection of living things, an ecosystem is made of both living things and non-living things, called abiotic factors. Abiotic factors form the base of the ecosystem and include things like sunlight, water, wind, temperature, soil, and rocks. Without these factors, no living things could exist. Beaches typically have rocky soil, either sand created from erosion of larger rocks and coral debris, pebbles, or sheer rock faces creating ocean cliffs. These conditions make it difficult for plant life like trees to take root. As a result, there are few large trees around beaches making conditions generally sunny. With these intense abiotic factors, it's a wonder that life flourishes at all on the beach. But many living things, or biotic factors, have made the beach a cozy home. The high wind, changing tides, and salinity can make life tough for plants. If you've ever put salt water on a plant, you know it quickly wilts. However, some plants have evolved strategies to get around these challenges, such as mangroves. The physical conditions affecting the environment are important as are the biological and behavioral interrelationships among different animals. Both the physical and biological environments affect an organism's ability to survive.



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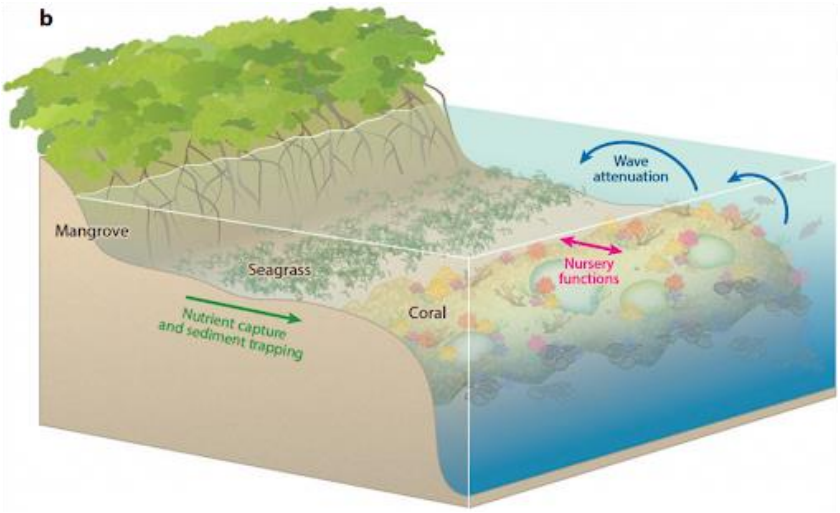


Coastal lagoon ecosystems play an essential role in sustaining life in the sea and serve as a source of food and protection for human communities. Coastal ecosystems provide valuable services such as food, coastal protection, fishing, recreation, education, and water quality, as well as cultural and aesthetic enjoyment. Yet coral reefs, seagrass beds and mangrove forests are in serious decline, partly from global change factors such as high seawater temperatures, partly from direct destruction and partly from pollutants in watershed runoff.

Coastal ecosystems, such as mangroves and seagrasses, can help reduce the risks and impacts of climate change, with multiple added benefits. Below-ground carbon storage in vegetated marine habitats can be much higher than most terrestrial ecosystems. Successful strategies to maintain and promote carbon storage in such coastal ecosystems could assist several countries in achieving a balance between emissions and removals of greenhouse gases. Conservation of these habitats would also sustain the wide range of ecosystem services they provide and assist with climate adaptation through improving critical habitats for biodiversity, enhancing local fisheries production, and protecting coastal communities from storm events.

**Mangrove Forests**

Cayman's mangrove forests make up one of the most unique ecosystems on earth in that they thrive where no other trees can survive, the transition zone between the ocean and land. Mangroves are salt tolerant trees that live in areas saturated with salt water at least part of the time. There are 16-24 families and 54-75 species of mangroves around the world, depending on which scientist you ask.

Imagine that you are approaching a Caribbean Island from the sea. As the island shelf gets shallower and the land gets nearer, the first species of plant that you are likely to see is a Red Mangrove. They grow mostly in places that are permanently wet and salty—on the shores of cays and islets, along the edge of the sea, beside rivers close to the sea, and around salty ponds and lagoons. In the Caymans, North Sound is the most obvious example of this, although the south side of Little Cayman is also dominated by mangroves.



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Cayman has three types of mangroves: Red mangroves, Black mangroves and White mangroves (named for the color of their bark) and Buttonwood which is related and sometimes called a mangrove. Mangroves are better explained as a group of coastal plants with similar adaptations achieved by evolving in similar physical habitats. Two mangrove plants are not always necessarily related genetically. The types of mangroves and their associates at particular sites reflect the physical environments of those sites, rather than close relations between each other. There are nearly three-quarters of a million hectares of mangroves in the insular Caribbean basin. This is more than 5% of all the mangroves left in the world. The Cayman Islands have more than 7,000 hectares, or almost 20,000 acres, of mangrove habitat. The Central Mangrove Wetland in Grand Cayman, of some 3,400 hectares (8,000 acres), represents almost half of the total mangroves found on all three of the Cayman Islands.

Mangroves are important to many local coastal species, both terrestrial and aquatic. For many organisms, mangrove forests serve as the starting place for their food web. Its detritus (fallen leaves and organic material) serves as a nutrient source for planktonic and epiphytic algal food webs. These microorganisms and macroinvertebrates then supply the remaining members of the food web with tremendous amounts of nutrients and energy. Mangroves also serve as a nursery and breeding ground for many reef organisms. Their tangled root systems provide shelter for many marine and terrestrial animals, protecting them from ocean currents and strong winds. The various species of mangroves have things in common, such as the ability to deal with excess salt in their surroundings and spreading root systems that allow trees to grow in mud. But every species grows in a slightly different part of the wetland and has its own special adaptations.



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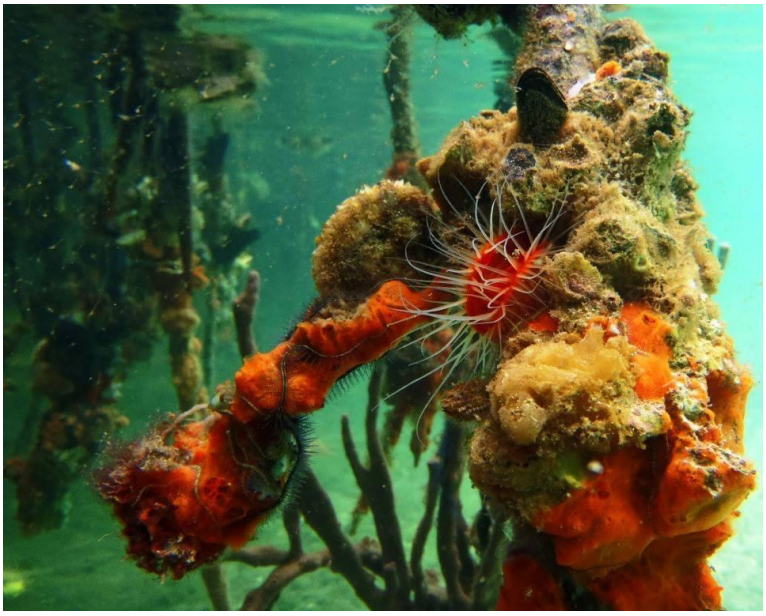
One of the best things about exploring the mangroves is that you never know what you will discover in the saltwater forests. Feeding barnacles, seahorses of all sizes, eagle rays, anemones, orange sea sponges, feather dusters and juvenile sharks peek out from the roots and seagrass beds. Herons and egrets are common in the trees, but owls and pelicans can also be found.



Mangrove protection is critical! Naturally resilient, mangrove forests have withstood severe storms and changing tides for many millennia, but they are now being devastated by modern encroachments. Today, mangrove forests are among the most threatened habitats in the world-- disappearing at an accelerating rate, yet with little public notice. Lenticels in the exposed portions of mangrove roots are highly susceptible to clogging by crude oil and other pollutants, attacks by parasites, and prolonged flooding from artificial dikes or causeways. Over time, environmental stress can kill large numbers of mangrove trees. Meanwhile, stricter local governmental regulations and enforcement protecting mangroves are necessary. Also, involvement of local communities in sustainably managing and protecting their coastal resource base, including the nearby mangrove forests, is essential.

**Seagrass Meadows**

Moving seaward from the mangroves we typically find seagrass beds. Seagrass is one of the most important plants on earth as it is the basis for many important ecosystems. There are about 60 species of seagrass found worldwide. These mostly range from the size of your fingernail to plants with leaves as long as 7 meters. Seagrass is an important source of food and provides shelter for many species in the coastal ecosystem. Some of the shapes and sizes of leaves of different species of seagrass include an oval shape, a long spaghetti like leaf and a ribbon shape. The highest concentration of species occurs in the Indo-West Pacific region. Seagrasses are aquatic flowering plants that make up a large part of the marine food web. Like the mangroves, they are also spawning and nursery grounds for many marine organisms that live in the reef.

Four different species of seagrasses exist in the Cayman Islands and the most common is turtle grass. Turtle grass, a type of seagrass which gets its name due to the fact that it



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is an important source of food for green turtles, is easy to identify with its broad flat green blades that make up lush meadows growing over the sea floor. Turtle grass beds are an important component of Cayman's marine environment.

Seagrass beds are a home to a huge diversity of marine life. Snails, juvenile fish, crabs, shrimp, juvenile lobsters and many other invertebrates live amongst the grass fronds or can be found buried in the silt held in place by the grass' root system. With their abundant supply of resources turtle grass beds are ideal feeding grounds for adult lobsters, large fish and green turtles. Indeed, some scientists consider healthy turtle grass beds to be the most productive marine ecosystems on the planet. Our three species of marine flowering plants include Turtle Grass, Midrib Seagrass, and Manatee Seagrass.

Seagrass is dependent on mangrove ecosystems, being unable to survive in areas with high levels of sediment floating in the water. Mangroves help them by slowing down the movement of the water, thereby preventing fine silt from clouding the water and blocking the sunlight. In this way, the seagrass is able to photosynthesize and flourish under calm, sunny conditions, allowing for perfect nursery grounds for coral reef species. Therefore, this process of seagrass protection affects the reefs that depend on the young marine organisms and, consequently, the mangrove itself, which depends on the coral reef, the amazing connectivity of the three ecosystems. These processes will be further discussed in the Seagrass Chapters.



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**Coral Reefs**

The warm clear water, spectacular colors and multitude of living things captivates those who behold a coral reef. Few things in the world can connect people as well as sharing stories of experiences in the oceans and discoveries on the coral reef.

Coral reefs are the most diverse communities on the planet. These tropical marine communities occupy less than 1% of the ocean floor but are inhabited by at least 25% of all marine species. Scientists estimate that more than 25,000 described species from thirty-two of the world's thirty-three animal phyla live in reef habitats - four times the number of animal phyla found in tropical rainforests. Coral reefs are one of the oldest continuous environments on Earth. Tropical rain forests and coral reefs are similar in that the basic physical structure of both communities is produced by organisms. Coral reefs are massive; in fact, they are considered not only biological communities but geological structures, the largest geological features built by organisms.

*Photo by Darvin Ebanks*

In addition to their high diversity, coral reefs are very productive marine communities. They play a critical role as habitat and nursery grounds for 10% to 20% of the world's fisheries. They are intimately connected to other marine communities such as mangrove forests, seagrass beds, and the open seas as water currents transport larvae, plants, animals, nutrients, and organic materials. They are very delicately balanced systems, depending on the interaction of hard and soft corals, sponges, anemones, snails, rays, crabs, lobsters, turtles, dolphins, and other sea life. The nearby mangroves are the nursery and breeding grounds for such marine life. They provide shelter and nutrients to many species, including most juvenile reef fish.

Mangroves, seagrass meadows and coral reefs are interconnected, and all three habitats must remain healthy for each to thrive. Mangroves filter pollutants and trap sediments that would otherwise smother seagrass and coral. Sediments that collect in seagrass areas may eventually build up to become an area which will support mangrove growth. Seagrass meadows also help filter the water to increase clarity for coral reef inhabitants by trapping sediment and slowing water movement. In turn, coral reefs protect mangroves and seagrass from ocean storms by slowing the surging waves. Barrier or



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fringing reefs protect coastlines, and the lagoon formed between the reef and the mainland is protected from waves, allowing mangrove and seagrass communities to develop.

All three communities assist in keeping nutrients available and limit nutrients from being scattered and lost into the surrounding oceanic waters. The interaction of these coastal communities' results in important physical and biological support for the other communities.

**Cayman Traditions and the Marine Environment**

Cayman has a rich seafaring history and as an island community, a strong connection to the sea. Caymanians depended on the sea as a necessity. What became important was shipbuilding and seafaring. People made use of local materials such as coral fans for flour sieving, skins of fish for scrubbing and the washwood plant for soap. To make hats, baskets, roofs and the prized rope, silver thatch palm was used. The rope was a significant item as it did not rot in saltwater and could be traded for other essentials.

During the early years of the islands, Caymanians became great shipbuilders and made excellent sailing vessels and small hand tools and set out for fishing hundreds of miles away from home. Meanwhile, the women twisted thatch rope for the purpose of trade with the nearby countries.

Shipbuilding and its related activities of wood cutting and rope making were among the earliest forms of livelihood in Cayman. Catboats played an important part in the history of the Cayman Islands. The boats were largely built by fishermen for their own use, or by small, family-owned shipyards and were made to suit the conditions in which they were to be used. They were designed specifically for turtling, being extremely maneuverable and stable in rough waters - if you know how to handle them!



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Catboats were always painted bright blue to make them less visible to the turtles. Although a variety of wood was used in construction of catboats, the Fiddlewood was used for timbers and sternposts. Fiddlewood has rather unusual bark, pale brown and very thin, with vertical cracks. It slowly sheds small papery flakes, sometimes appearing a little like White Fiddlewood, but the bark shedding is much less abundant in Fiddlewood. Native to Grand Cayman, Cayman Brac, the Greater Antilles and the Bahamas, Fiddlewood grows in rocky woodlands. The wood is heavy and very hard and therefore makes great posts.

The historical use of coral limestone in wattle and daub house construction is important in Caymanian culture. "Wattle" is woven green-wood panels (usually Sea-grape, Strawberry or Cabbage wood) used to fill the spaces between vertical posts and horizontal beams of the ironwood. Traditionally daub was made by burning live coral rocks gathered from the reef flats with various woods in a lime kiln. Daub is a plaster-like substance of coral lime which covered the spaces. DAUB was a plaster made of lime, sand and water. Lime for this purpose was obtained by building a lime kiln. Reaching several feet high, a kiln consisted of alternating layers of partly dried wood and coral. Wood for the kiln came from Sea-grape (*Coccoloba uvifera*) and Indian Almond (*Terminalia catappa*) trees and the coral came from panshoals which lie just below the level of the reef. Coral rocks taken directly from the sea were ideal because, being water-logged, they powdered easily in the heat of the kiln. Kindling, usually Candlewood (*Amyris elemifera*), was placed in a hole left in the center of the circular kiln. As the kindling burnt away the heated coral would fall into the heart of the fire where the intense heat reduced it to a fine lime powder.



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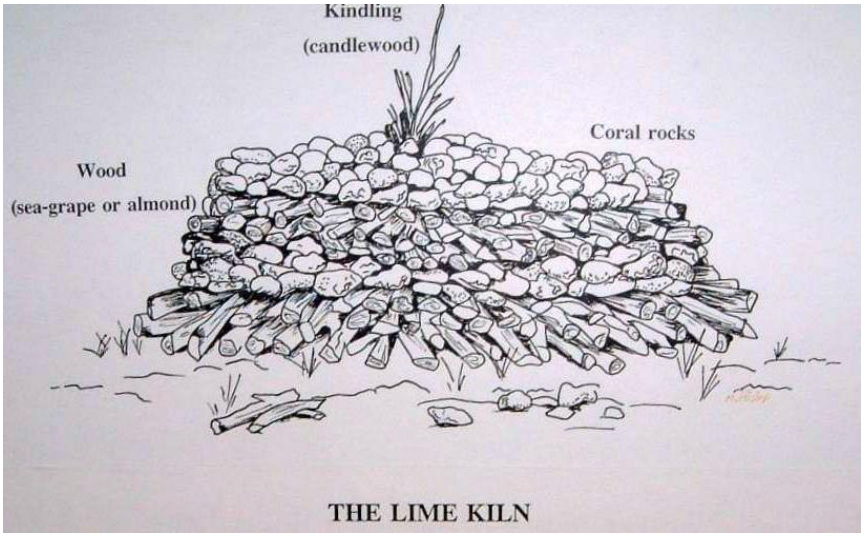

The Lime Kiln – Cayman Islands National Museum

The combination of wattle and daub provided a very strong wall some 4-6 inches thick. This use of coral is now not compatible with our present need to have pristine and diverse coral reefs to maintain our tourism industry and local fisheries. The labor-intensive preparation of the daub was often a neighborhood effort. There was very little cash available on the Islands at the time, so people shared the labor and their resources. Large quantities of coral rocks had to be collected, transported, broken up and then baked in a large kiln all night to create lime ash. The lime ash was then mixed with water and sand until pliable, then daubed on to the wattles, inside and out, to a thickness of six inches. When dry, it would resist rain and sun, and even hurricanes.

Houses built in this way are sometimes called "wall" houses. For a period of more than 150 years these simple, two-room wattle and daub houses were the primary style of construction in the Cayman Islands.

Mangroves provide many important functions vital to the health of Cayman's environment, including providing an ideal habitat for birds, fish, and a wealth of different invertebrate species. Mangroves have been important for Cayman. Caymanians used to make red dye from the red mangrove tree and Barkers in West Bay is named for the process of barking these trees. Black mangroves were also used in smoke pots.



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Mangrove wetlands also provide storm protection. The extremely strong root systems create a perfect protection against large waves and storm surges that accompany hurricanes and other storms. The mangroves have been an area where people have kept their boats in preparation for storms and that practice was even used during Hurricane Ivan.

Long before tourism and the financial services powered Cayman financially, the principal economic element of the Cayman Islands was turtling. Locals ate and sold the meat and exported the large shells overseas so that it could be used in finished goods that were sold in Europe. When the first Europeans came to Cayman, they found one of the largest turtle nesting grounds on earth. For nearly 200 years, ships of all nations came to these shores to 'turn' green and loggerhead turtles and dry their flesh, an easily obtainable source of protein for ship or plantation stores.

Cayman became the center of the Caribbean turtle industry, but by 1800, the turtle population had dwindled, and the local turtling fleet turned their attention to the south coast of Cuba and the coastline of Central America. Until the early 1960s, Cayman ships still supplied the largest share of turtles entering foreign markets from the Caribbean. These were mostly caught on the Mosquito Coast of Nicaragua. The Cayman Islands officially banned turtle hunting in 1988; however, in honor of Cayman's turtling heritage, certain individuals are permitted to hunt turtles under license in accordance with the Marine Conservation Law. While typically some of these individuals apply to renew their license annually, in the past few years, no turtles have been taken under a license.

The Cayman Islands economic and social history is connected to the marine turtles. The impact of turtles on the development of the Islands is demonstrated by the significant role the turtle plays as a symbol of the Islands, its currency, national seal, and flag. However, the present turtle population in the waters of our three islands is only a shadow of what was once considered the major nesting ground of the green sea turtle.



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**Exploring Coastal Lagoon Ecosystems**

Environmental education of coastal ecosystems is an important component of marine and coastal resource management for creating awareness of environmental concerns. This interconnects with the important mission of sustainable social and environmental community initiatives including conservation and wise use of all environments through local and national actions. Interactive environmental education is a method of bringing an environmental awareness closer to the public where solutions may be put to constructive and continuous use. A positive exposure to natural environments early in life creates a lifelong desire to interact with these settings. Experiences with the natural environment can become deeply fixed in the mind of a young child. It is commonly believed that the tendency for a lack of stewardship over the environment can be avoided by intervening at an early age with positive, direct experiences in nature. If successful, such educational experiences can have a significant effect on the future of a nation's natural resources.

The division of the ocean into its various physical regions is convenient for research and regulation, but the marine environment is first and foremost a collection of interconnected and interdependent ecosystems. It is often difficult to define one marine habitat except in the context of others, especially when discussing animals that spend different stages of life in different habitats.

Nowhere is this interconnectedness more consequential than in the coastal zone, where the continuity does not stop at the end of the sea but includes critical interactions with the land and the atmosphere as well. The marine ecosystems that exist in the coastal area, including mangrove forests, seagrass meadows and coral reefs, are presented in this guide to examine their important interrelationships. Each type of ecosystem is discussed in this guide with an outline of its ecological processes, biodiversity, and the role of humans in changing the ecosystems.



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*Photo by Courtney Platt*

Classroom Activity: Coastal Ecosystems: Understanding Coastal Ecosystems

The purpose of this lesson is to have students understand tropical coastal ecosystems and how they interrelate.



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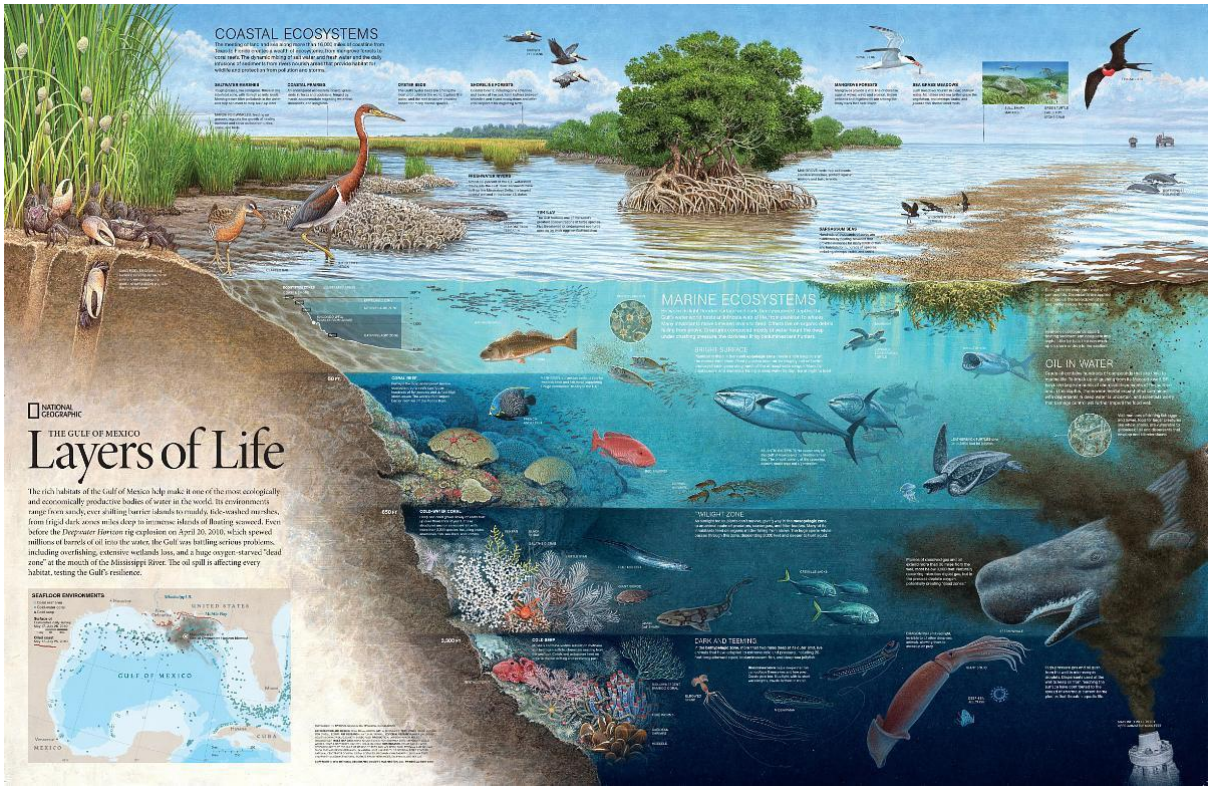


The **goals** for this lesson are for students to:

1. Define the term coastal ecosystem.
2. Gain an understanding of how the components of the coastal ecosystem interrelate.
3. Gain an understanding of the basic function of coastal ecosystems.

The **concept** being taught in this lesson is that coastal ecosystems are vital and relate to everyone's life in the Cayman Islands.

**Lesson Behavior Objectives**: Upon completion of this lesson students should be able to:

1. Focus on specific types of coastal ecosystems by writing them down.
2. Make a cross-section drawing of each of the components of the tropical coastal ecosystem in relation to each other.

**Materials Needed**:
Video: Netflix Our Planet, Coastal Seas
https://www.youtube.com/watch?v=r9PeYPHdpNo&list=PLe2nGhEGXFVuzg3QxZpOxt2A_us1gxKgh

Video: Ocean Soul https://www.youtube.com/watch?v=Od7XZ_aIPS8

Pen or pencil
Paper (plain)



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Colored pencils (optional)

**Sequence of Lesson:**

1. Outline what the week will cover as we learn about Coastal Ecosystems, including field trips.
2. Write down the term Coastal Ecosystem on the board and search previous knowledge by having students write down the ideas that come to mind.
3. Ask for responses and write them on board.
4. Connect with lines elated ideas and explain the process to the students.
5. Show the video and ask students to re-define ideas from the video.
6. Start "vocabulary tree" on the board adding new words as they occur – discuss and define them.
7. Do a "pop quiz' on how much students remember from the video. Connect thoughts and ideas.
8. Draw a cross-section of the tropical coast seashore (lagoon) on the board. Ask students to name each component – mangroves, beach, seagrass, coral reefs.
9. Leave off important parts (fish, birds) and ask students to fill in what is missing.
10. Have students draw their own version of the tropical seashore using in their exercise books the drawing on the board as a guide.
11. Have students write the new vocabulary tree in their exercise books and add new words.

**Closing:** Have students relate some of their seashore experiences (fishing etc.)

**Coastal Ecosystems Coloring Page**



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**Field Trip - Beach Exploration**
Sandy Beach – Where Land and Ocean Meet



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**Significance of Sand and Shore**
A special habitat exists where the ocean meets the land, the tide, or coastal zone. Water, rock, and wind create a difficult environment where strange and beautiful animals and plants flourish. They are able to survive by adapting and developing different techniques of living in this continually changing place. We may explore this ecosystem by taking a walk along the shore and into the shallow coastal waters. It is here where we may learn about the partnership between change and stability and take our first glimpse into the ocean world.

The diverse shorelines of Grand Cayman are an excellent setting for environmental education opportunities. Factors contributing to the beach location and shape include wind, degree of wave energy, location of manmade structures, sand placement and accompanying vegetation, longshore drift, onshore and offshore topography. The seasonal variability of the wind and waves is also an important factor. A beach is a collection of materials. To understand a beach, you have to think about the source of material. Vegetation on the beach serves as an anchor to promote the stability of the sediment movement and prevent intense erosion, especially during storms and the winter season. Therefore, we generally see a wider beach in the summer season and a narrow beach during the winter.

*A proposed location to study various shoreline characteristics is off Boggy Sand Road. Good and workable outcrops are located in this area, as well as a section of Ironshore and fine-grain sandy beach. Proposed activities are intended to be simple and accessible, and to encourage students to develop their knowledge of science and environmental issues. Field trips can take place on a small beach walk and possibly snorkel along the shore. Questions, discussions, and activities occur regarding what was seen and through actual interactions with the environment and participation in a particular activity.*

Activity 1: **Exploring the beach**



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Students may explore the beach in small groups. By sorting through various objects found on the beach, students can group these objects into those that show evidence of animal life, plant life, or evidence of humans. They may also learn the difference between living and non-living objects.

Activity 2: **Investigating the sand**

Students with (but possible without) hand lenses investigate in groups to compare the color, size and shape of grains from several types of formations on the beach – ranging from the Ironshore to the sandy beach to the beach-rock. One of the most common features of the tropical coasts is beach-rock formations. These formations are buff-colored, medium to coarse-grained, moderately soft to highly calcareous and contain tiny shells and numerous coral fragments. Ironshore formations are also well recognized and prevalent on the island. Students can discover that sand grains and subsequent formations can be created from animals, plants, rocks and even debris produced by humans. These differences can teach students about where the sand came from and how it caused its current formation. They also learn some basic ideas of the movement of sand along the shore, and how human intervention can influence this environment.
https://www.caymancompass.com/2006/05/01/the-origins-of-cayman-s-sand-2/

Activity 3: **Wave activity**

Students can learn about the interconnection between the world's ocean and conditions of our local coastline, as well as the relevance of these conditions to living organisms on the beach and people. Areas of differing sand densities – compact sand versus 'boggy' sand and loose rocks – can aid in learning about wave action and energy, and the effect on the sandy beach. There would also be a discussion on hurricane activity and impact on shore and near-shore environments. The force of waves in a coast environment may be enhanced through possible data collection, organization of facts and group discussions.

Activity 4: **Creature feature**

Students learn that most life on the beach is to be discovered in the sand. Describing creatures and their lifestyles on the sand beach will focus on the necessary adaptations to survive in the coastal conditions. A student may select an individual creature (real or imaginary) and then create various views of its habitat. These include an overhead panoramic view and a profile view of the organism in the sand with their own individual adaptations to the beach conditions presented.

**Field Trip Activity: Role of Shipwrecks in the Marine Environment**



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The Gamma is a steel freighter now resting on the shoreline between George Town and Seven Mile Beach. In 1980, the Gamma ran aground on an offshore reef during a storm. The ship's owners didn't feel that it was worth salvaging and left her to rest on the reef. Sometime later, after another storm, the ship was forced up onto the beach which is where she rests today. The owners hired a salvage company to remove any existing precious metals off of the rusting hull. Thus, all of her brass portholes and fittings are now gone. These pieces were brought to the United States and sold as scrap metal. Some of the local fish we may see include trunkfish, blue tangs, peacock flounder, parrotfish, rock beauty and angelfish.

*Photo by Irene Corti*

**Lesson Behavior Objectives**: Upon completion of this lesson students should understand.

1. A positive effect of shipwrecks is that they provide homes for all kinds of marine life, especially coral.
2. These animals grow all over underwater wrecks. An artificial reef is a human-made underwater structure, usually built for the purpose of having more marine life in areas where there isn't already a reef.
3. Wrecks also become artificial reefs. They are hard surfaces to which algae and invertebrates such as barnacles, corals, and sea sponges attach. All of this attached marine life in turn provides food for fish.

**Materials Needed**:
Snorkel equipment
Notebooks and pencils
Underwater cameras if available

**Sequence of Lesson:**
Wreck of the Gamma - Location: Southern end of Seven Mile Beach



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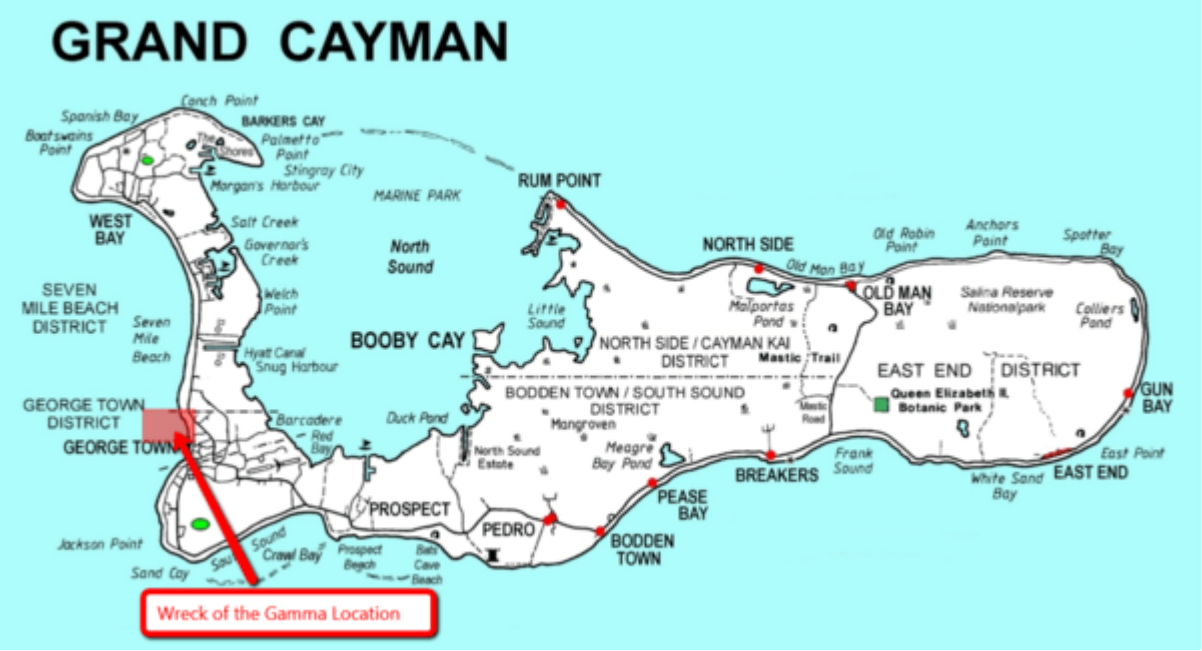
The Wreck of the Gamma is located close to shore and has easy access for students to snorkel.

1. Orientation with students as to snorkel buddies and best practices once in the water
2. Snorkel around the wreck and observe any life growing on it
3. Observe what is growing around the wreck in the sea bottom
4. Do the students observe many fish near the wreck vs if they snorkel away from the area
5. Have the students write observations in a notebook



*Map showing location of Wreck of the Gamma*



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**CHAPTER 2: Mangroves Forests**





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**Chapter 2: Mangrove Forests**

Related PPT Presentation: Mangrove Forests - Coastal Lagoon Curriculum
Related Videos:
Importance of Mangroves - Mangrove Action Project
NASA and Mangroves
Mangrove Massacre - Vote For Our Mangroves!

**Realm of the Mangroves**
Throughout the tropics and subtropics, wherever coasts are gently sloping and temperatures average 24°C (80°F), coastal wetlands are inhabited by extraordinary trees called mangroves They are found at river mouths, fringing sheltered bays, around lagoons and ponds, and on islets and cays. There are nearly three-quarters of a million hectares of mangroves in the insular Caribbean basin. This is more than 5% of all the mangroves left in the world. The Cayman Islands have more than 7,000 hectares, or almost 20,000 acres, of mangrove habitat.

Mangroves can be found along the coastlines of most islands, wherever the coastal shelf is shallow. They tend to be more extensive on sheltered shorelines and inlets. Nearly 70% of the wetlands of the Caribbean are found in Cuba. A further 19% are in the Bahamas. This does not mean that the wetlands of other countries are not important. Even the smallest mangrove can be very important to the ecology of an area. In the Cayman Islands, the Central Mangrove Wetland in Grand Cayman, of some 3,400 hectares (8,000 acres), represents almost half of the total mangroves found on all three of the Cayman Islands.

Worldwide, there are more than 50 species of mangroves, only seven of which are found in the insular Caribbean. Some species are closely related to each other, while others look similar or have similar adaptations but are not related at all. All share an amazing ability to grow in places shunned by other plants. Mangroves flourish only in the



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narrow, inhospitable zone where the tropical sea meets the land, and saltwater and freshwater mix. They alone love the tropical places that are too hot, too salty, too wet, and too exposed to wind, rain, tides, and storms for other plants.

**Trees in the Sea**

The various species of mangroves have things in common, such as the ability to deal with excess salt in their surroundings and spreading root systems that allow trees to grow in mud. But every species grows in a slightly different part of the wetland and has its own special adaptations. Most Caribbean wetlands, including those found in the Cayman Islands are dominated by just four species of mangroves. They are Red Mangrove *Rhizophora mangle*, Black Mangrove *Avicennia germinans*, White Mangrove *Laguncularia racemos*a, and Buttonwood, or Button Mangrove *Conocarpus erectus.*

Imagine that you are approaching a Caribbean Island from the sea. As the island shelf gets shallower and the land gets nearer, the first species of plant that you are likely to see is a Red Mangrove. They grow mostly in places that are permanently wet and salty—on the shores of cays and islets, along the edge of the sea, beside rivers close to the sea, and around salty ponds and lagoons. In the Caymans, North Sound is the most obvious example of this, although the south side of Little Cayman is also dominated by mangrove.

With their stout, curved prop roots, which arch down into the water from their trunks, and their long, slender aerial roots, which are like thin fingers reaching into the water, Red Mangroves cannot be mistaken for any other tree. Like other roots, theirs have two main functions—support and breathing. Extraordinary conditions require special adaptations (changes in structure and function that make a plant or animal more suited to its environment), and the prop roots are very different from normal roots. Arching around the main trunk like tangled legs, they support and spread the weight of the trunk, branches, and leaves, and thus enable the tree to stay upright in muddy, tidal, and windy conditions. Like the aerial roots, the parts above the water are covered with tiny pores or lenticels (which look like small knobs), through which the tree can breathe.



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This is necessary because the mud on which Red Mangroves grow is so low in oxygen that no ordinary roots could breathe there. If the lenticels are covered with water for too long, the mangroves will die. This often happens as a result of a hurricane.

Clinging to the edge of the land, the Red Mangrove roots trap sediments and build up the land behind them. When the coastal shelf is shallow, they grow out into the sea, extending the land and protecting it from storm damage and erosion. The reproductive cycle of the Red Mangrove is adapted to help this process.

It all begins when the Red Mangrove bursts into flower. This usually occurs in spring or summer, and Caribbean mangroves can flower all year round. The waxy bright-yellow star-shaped blossoms attract bees and are quickly fertilized. The mature fruits stay attached to the tree while they develop into little plantlets (called **propagules**). The roots of the propagules begin to grow while they are still attached to the parent tree. When they are 20–30 cm (7–12 in) long, the dart-shaped, heavy propagules fall from the tree and plunge deep into the mud below. Some are washed away by waves and currents and float for many months before they wash up in a nice muddy place. As soon as they get to a suitable spot, the propagules are ready to grow. In the right conditions, they spring up densely, growing more than 60 cm (23–24 in) a year, reaching out into the sea over shallow reefs or mud banks or filling in shallow ponds and channels.

*Mangrove Propagule*



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Forming food for other living things makes Red Mangrove ecosystems among the most productive in the world. An average-sized Red Mangrove tree can drop more than two tons of leaves a year. Red Mangroves provide a sheltered nursery that nurtures young fish, shellfish, and turtles before they move out into the open ocean to make it on their own. Many thousands of other creatures make their homes in and under the roots of Red Mangroves, all completely dependent on the food, water, and shelter that the mangroves provide. Above the water, many species of birds and insects live, nest, or hunt in the trees' branches and among the leaves.
Red Mangroves also provide a protective barrier that filters sediments and pollutants that wash toward the sea from the land, keeping them from working their way onto the reefs and destroying the coral. In addition, mangroves provide us humans with food, and with shelter from hurricanes and other storms, and filter our groundwater, keeping it clean. Throughout the tropics, wherever coastal mangroves have been cleared away, coastal fisheries have collapsed.

Red Mangroves grow on the seaward edges of the shore. Their roots trap sediments, and the level of the mud rises. Over time, conditions become drier and less suitable for Red Mangrove seedlings and more suitable for other species. This process is called succession.

The roots of Black Mangroves have found a different solution to the problems of growing in mud— which is black and smelly because of the large amount of rotting plant material it contains. Horizontal roots spread out from the main trunk, with vertical roots sticking up from them. They form a carpet of thin, knobby fingers called pneumatophores around the base of the tree. The pneumatophores are generally long enough to stick out above the water at high tide so they can breathe. The above-ground parts trap sediments and pollutants washed toward the sea by rivers and streams from



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the land and help to protect the coral reefs and seagrass beds. Below ground there are fine roots sticking out sideways, which absorb nutrients from the mud.

Black Mangroves can grow on the edges of ponds that are much saltier than sea water (water that is saltier than sea water is called hypersaline). They can tolerate tidal areas, in which the mud is sometimes exposed for part of the day or year and evaporation increases the salt level, or salinity, of the soil. They can have high levels of salt in their sap, and they control the amount of salt in their tissues by excreting salt through their leaves. Look closely at a leaf and you will see the crystals of salt. Lick or wash them off, and a few minutes later more will form. Often, thousands of Fiddler Crabs forage among the mangrove roots, taking advantage of fallen leaves and washed-up pieces of food.

White Mangroves prefer more freshwater than Red or Black Mangroves. They can often be found further inland than the other species. Like Black Mangroves, they have pneumatophores. However, these are wider and often knobbier (sometimes flattened like small toadstools), and grow less densely, than those of Black Mangroves. Like Black Mangroves, they excrete some salt from small glands on their leaves.

Buttonwoods, also called Button Mangroves, are often found growing among the Black and White Mangroves, often on the landward edge of a wetland. They are found on rocks beside the sea, or among other trees on the berm. The presence of Buttonwood is a good indication of drier, better- drained soil conditions.



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**Mangrove Functions and Benefits**
Wetlands throughout the Caribbean provide a great variety of benefits and functions both to the natural world and to people. The description of these functions that follows this introduction will give you more details, and the activities provide a way to demonstrate to your students exactly what these benefits and functions are.

For small islands prone to hurricanes and all the damage they inflict, perhaps one of the biggest benefits of mangrove wetlands is that they protect our islands from severe storm damage—as long as we leave them alone! Wetlands also help clean, through natural filtration, the very water that we rely on for our lives—and at the other end of the human food-processing cycle, they can also help in the treatment of human waste.

Mangrove wetlands represent habitat at the base of the food chain that provides us with much of our food, whether it's the fish we catch and eat that began their lives in the wetlands, or the crops we eat that rely for their health and survival on the nutrients provided by wetlands soil.

**Wetland Resources**
Mangrove forests provide timber, fuelwood, roundwood for house construction, and sticks for yams and fish pots. Red Mangrove timber is highly valued for building docks because it remains strong when wet. Sustainable harvesting is possible, and a model for it has been developed in St. Lucia.

Mangroves are sometimes cleared, ponds excavated, and surface water flows redirected to create fish and shrimp ponds. These ponds are seldom as productive as the natural ecosystems they replace. Many rapidly become too salty for aquaculture and are abandoned.


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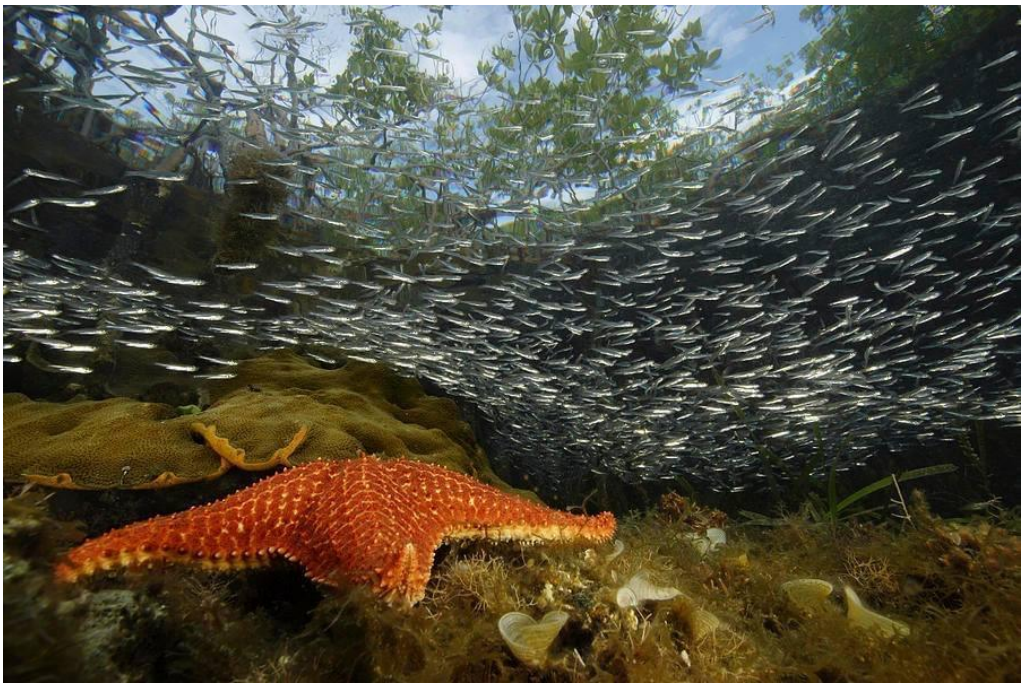
Beehives in Black Mangroves produce very high-quality honey.

Cattle and goats graze on mangrove seedlings and other wetland plants. Farmers often set fire to salt marshes and freshwater marshes to encourage the growth of soft new shoots for forage. This damages the wetland and prevents regeneration of mangroves.

Many fishermen around the Caribbean depend on mangrove wetlands because they provide nurseries and feeding grounds for many commercially important species of fish, including jacks and snappers. Typically, fish spawn on reefs some distance from shore. Currents and tides sweep the young fish toward the land and into the mangrove roots, where they find abundant food and protection from predators.



Similarly, commercial species of crabs migrate to the shore in the mating season, there to release their eggs. Only 50 years ago, these crab migrations were huge and dramatic, involving thousands of crabs, which would crawl over houses on their way to the sea and make roads dangerous for driving. Today, in many places the numbers of crabs are so much reduced that the crab migration is barely noticed.

Commercial shrimps do things the other way round. They lay their eggs in the rivers. The young migrate to the sea to grow, returning to the wetlands to breed.

Other commercially important species that depend on wetlands include lobsters, conch, and oysters. When wetlands are filled, destroyed, or polluted, the fisheries collapse. The effects can be felt hundreds of miles away, because healthy wetlands are often sources for young fish, conch, and lobsters down current.

**Wetland Services**

Some coastal wetlands catch fresh water, helping to maintain the balance between the salty water of the sea and the fresh groundwater under the land. When wetlands are

drained, there is less fresh water in the ground, and coastal wells may be polluted by seawater draining in to take its place.

In some wetlands, there are beautiful springs or blue holes, where fresh water bubbles out of vertical caves in the limestone. These supply water for many coastal communities. There may also be under- water springs in the beds of rivers or even under the sea. Underwater springs help to maintain the conditions that fish and shrimp need to grow and reproduce.

Wetlands catch stormwater, soaking it up like sponges, and releasing it slowly after the peak has passed. In this way, they help to prevent floods. They also protect coral reefs and seagrass beds, which can be damaged by sudden flooding with fresh water.

The roots of wetland plants help to bind and stabilize the soils along the coast, while their leaves, branches, or trunks break the force of hurricane and storm winds. They help to protect property by reducing coastal erosion and storm damage. They also trap sediments that are washed to the coast by rivers, and so protect the reefs and seagrass beds. Often these sediments include large amounts of dangerous substances, including excess nutrients from fertilizers, pesticides washed from agricultural land in the upper watersheds, or heavy metals from mining. The wetlands stop these environmental contaminants from getting to the sea, and can often transform them through biological, chemical, and physical processes into harmless substances.

The wetlands of the Cayman Islands are likely to be able to grow fast enough to keep up with the rise in sea level due to global warming. This means that their importance for coastal protection will increase.

**Important Qualities of Wetlands**

Coastal wetlands in the Cayman Islands are among the most productive ecosystems in the world. Wetlands cover only 6.4% of the Earth's surface, yet they account for 24% of global productivity. Wetlands plants trap large amounts of carbon, turning it into food for other plants and animals.

Wetland plants produce oxygen through the process of photosynthesis. Excess nitrogen, like that contained in fertilizers, is broken down in wetlands through a process called denitrification. Atmospheric levels of carbon and sulfur, both of which have increased dramatically as a result of the burning of fossil fuels and peat, are lowered by wetlands' ability to act as sinks (natural catchment basins) and to reduce these elements to harmless forms.

The wetlands of the Caribbean are also extremely important for biological diversity or the richness of living things. Many species of plants and animals are found only in Caribbean wetland and nowhere else in the world. One example is the West Indian Whistling-Duck. Some species, like the Swamp Bloodwood, are found only on a few islands. Others are found only on one island, or even in only one wetland. The Royal Palms of Cuba, Jamaica, and Hispaniola are examples of species that are endemic to the wetlands of those islands.
Some species that live in Caribbean wetlands have never been studied. Much remains to be discovered.



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Destruction of wetlands throughout the region means that many species that were once common have become rare. They include the magnificent but widely feared American Crocodile (now extirpated in the Cayman Islands) and several species of birds, including the West Indian Whistling Duck.

Increasingly people are seeking natural beauty and quiet places to get away from city life. In the wetlands, they find beautiful landscapes, quite different from the ones they left. Besides hunting and fishing, activities such as canoeing, walking, and birdwatching attract millions of people to wetlands every year. Artists and photographers also are drawn to wetlands because of the many species of plants and animals that can be seen there.

**Gardens of the Sea**

Wetlands and mangrove forests are teeming with life—full of living things that are different in unexpected ways. In the mangrove world, trees have roots that breathe and look like legs, jellyfish swim upside down, barnacles feed with their feet, and crabs live in trees.

**Adaptation to Mangrove Life**

Growing in waterlogged soil poses special problems for plants.

- Standing up: The roots of wetland plants do not have much to hold onto because wetland soils are sloppy, so staying upright can be a problem. Mangroves have developed prop roots to help spread the load of the trunk over a broader area. Other trees, like Swamp Bloodwood, have buttresses. Some places are too wet to support trees, and only grasses and herbs grow there. Some plants, like Phragmites, spread by falling down across the water. In open water, plants like water lilies float on the surface.
- Breathing: Wetland soils are often black and smelly. This is because they are low in oxygen (or **anoxic)**. Waterlogged soils are often anoxic because oxygen

spreads more slowly through water than through air. This slows the decomposition of plant materials. The bacteria that live in anoxic conditions produce sulfur-rich compounds—and bad smells. To compensate for the lack of oxygen, wetland plants often have roots that grow out into the air—aerial roots or breathing roots, also called pneumatophores.

- Getting rid of salt: Some wetlands, like saltwater ponds, are even saltier than the sea. This occurs when water evaporates from the surface, leaving salt behind. Water or soil that is saltier than the sea is hypersaline. Plant cells cannot function properly if they contain too much salt. Some plants, like Red Mangroves, try to prevent salt from getting into their tissues. Others, like Black Mangroves, can tolerate more salt than usual in their sap, and control the salt in their tissues by excreting it through specialized salt glands in their leaves.
- Getting enough water: It seems odd that plants growing in the sea should be short of water; but where the water is salty, fresh water can be hard to get. Plants that grow in salty water often have thick, waxy leaves (like Red Mangrove) that help to reduce water loss, or fleshy leaves (like Black Mangroves) that can store water. These adaptations are also found in plants that live in dry places.

Mangrove wetland animals have to live, feed, and reproduce in a world dominated by mud and water, where the amount of water and mud is constantly changing. When the tide is high, tidal wetlands are flooded. When it goes out, water levels fall. Pools may be cool at night and close to boiling in the heat of the day. Pools that are governed primarily by rainfall may get very salty in times of drought, then be suddenly flushed by fresh water after rain. Food is abundant, but it may be salty, indigestible, or in the form of small particles.

Animals need special adaptations to live and feed in this changeable world. For example, Fiddler Crabs have lots of legs to spread their weight over a larger surface area and keep them from sinking in, so they can move over the surface of the mud, gobbling up tasty morsels like Red Mangrove leaves that have washed up. When animals are not feeding, they need a safe place to hide—or they may become prey themselves. Fiddler Crabs, for instance, burrow into the mud.

Using birds as an example, here are some mangrove wetland plant habitats and what they provide for various species.

- Red Mangrove roots provide perches for small herons to stand on and hunt from.
- Sedge marsh provides cover for birds to hide in, and soft ground on which to nest.
- Black Mangrove canopy provides nesting habitat for herons and warblers, and warblers and vireos can hunt for insects among the leaves.
- Sesuvium mats provide low cover around ponds, offering nesting habitats for terns, nighthawks, and sandpipers.
- Holes in trunks of Black Mangrove trees provide nesting habitat for parrots and woodpeckers.

Birds are adapted by their shapes to the areas in which they feed and nest. Long-legged herons, with their long, heavy bills, wade in deep water and hunt larger fish and frogs, and occasionally crabs. Small herons like the Green Heron have short legs but move very fast. These herons stand in the mangrove roots above the surface of the water and



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lean down to stab fish. The Snowy Egret, an intermediate-sized heron, flies near the surface and dips its feet in the water to attract fish or wades in mid-level water. With its fine, sharp beak, it spears fish that are not hunted by the larger and smaller herons.

The Black-necked Stilt is adapted to wade in water and has a long, stiletto-like stabbing bill that can take insects like water boatmen off the surface of the water or probe the soft mud. Different sandpipers have different lengths of bill and leg, ensuring that they use different areas of the pond or fore- shore, from the edge to mid-level, and different depths of mud. In this way, they do not compete with each other for the same food. The Ruddy Turnstone takes prey from under small stones and off the surface. Diving birds like the Kingfisher and Least Tern take their prey from the deeper parts of the water.

Adaptation allows many species to share the same wetland.

**Roots and Root Dwellers**

Roots are very useful to Red Mangrove trees, but they are equally useful to the hundreds of species of other plants and animals that make their homes on or near them. Once the Red Mangroves have started to grow in the mud, plants and animals settle on them. Red Mangrove roots host a fairyland of fantastic creatures and plants. Multi-colored sponges (bright red, orange, yellow, or sky-blue), algae, corals of many shapes and colors, sea squirts (tunicates), fan worms, oysters, and sea anemones are just a few of the living things that crowd onto the roots. These creatures take advantage of the mangrove root surfaces to settle in places where there is nothing else to hold onto. Once there, they can feast on the detritus carried in by the tides, the decomposing leaves of the mangrove trees, and the other animals that seek shelter among the roots.



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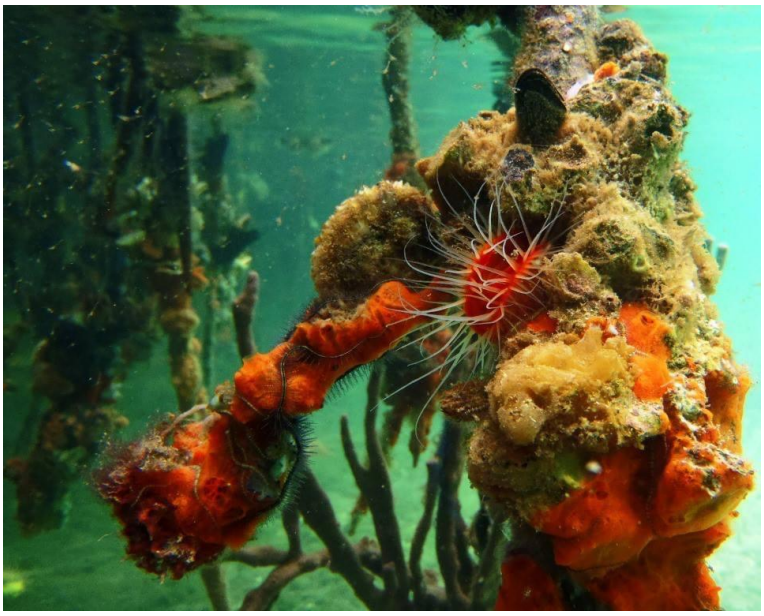

A mangrove root looks simple—but it is not. It is made up of several zones, the highest of which is almost always dry. The animals that live there (like lizards, crabs, and snails) do not like to be wet too often. The next zone is wet during high tides. Animals in this zone—barnacles and oysters, for example—have to feed when the tide is high and shut down tight when the tide is out. Below them, animals and plants are usually wet but have plenty of light. Look for sea squirts in this zone. At the bottom, conditions are more stable. There is less light but more food falling from the surface. Animals that feed by filtering food from the water, such as fan worms and sponges, are common in this zone. Some animals, like upside-down jellyfish, just lie on the bottom of a pool with their feet up, waiting for food to fall on them.

The dense growth of roots protects animals and plants from waves and currents, and stops large predators from getting in. The currents carry the fry of many fish, shrimp, lobsters, and crabs into the mangrove root ecosystem. There they hide, feed, and grow among the roots. These include the young of many favorite commercial varieties—snappers, parrotfish, lobsters, and many others. Some creatures spend their whole lives in the water, while others move freely between the air and the water. Crabs and snails often live on the edge.

**Haven for Life**

All the energy in the world comes from the sun. Mangrove leaves and the algae that grow on man- grove roots capture this energy by photosynthesis, converting it into leaves, trunks, and branches. This is called primary production. With plenty of sunshine, water, and mineral resources, the mangroves can produce very efficiently; in fact, they are among the most productive ecosystems in the world. A healthy mangrove in the Cayman Islands drops between 7 and 15 tons of leaves per hectare. What happens to these leaves?

Mangrove leaves are tough, and few things eat them, but some crabs have developed a taste for them. Examine the leaves on a mangrove tree closely and you will probably see where they have been nibbled. The crabs are called primary consumers. The unlucky



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ones are eaten by night-herons. The night-herons are secondary consumers, which eat primary consumers.

Take a look at a shallow pool in the Red Mangroves. It is likely to be lined with yellowing leaves— those that are not eaten on the tree fall into the water. They may look as if they are being wasted, but appearances are deceptive. As soon as a leaf enters the water, it is attacked by microorganisms: bacteria and fungi. These are called decomposers. Look closer. Some leaves may have patches of bright pink. This is a fungus, busily breaking down the leaves. Take a leaf out of the water. It will probably feel slimy. This is due to the bacteria and fungi on its surface. Decomposers convert the cellulose of the leaves into proteins and simple sugars. When a leaf hits the water, it is about 3% protein. Microbial action converts a further 19% into protein—excellent food for the young fish, lobsters, and shrimp that are growing up in the area.

As the fish and shrimp feed and grow, they get too large for the narrow spaces between the roots. Soon they must venture out. There they may be eaten by bigger fish, such as barracuda, that feed in the channels and lagoons. These bigger fish, along with other animals and birds that eat primary and secondary consumers, are predators. Predators lurk in the canopy of the Red Mangrove trees or out in open water, ready to swoop down and feed on the unwary. Green Herons often skulk on roots near the water, ready to spear a fishy victim. Spiders, geckos, anole lizards, and Yellow Warblers feast on the mosquitoes that breed in the water. Other birds like Brown Pelicans roost and nest in the canopy, close to their open water feeding grounds.

Much of the food produced in mangroves is washed away (or exported) by tides and currents and provides food and nutrients for animals and plants along the coast.

**Food Chains and Food Webs**

Plants and animals in any given ecosystem or habitat are linked by their feeding relationships. Just like the mangrove swamp, every habitat creates decomposers: bacteria, fungi, and some insects that break down dead plant and animal matter (called **detritus**) into minerals and humus. The fertile soil that results enable producers—green plants—to grow, providing a food source for primary consumers—animals that eat plants and grasses, which are also called herbivores. (Carnivores eat other animals, and omnivores, like humans, eat both plants and animals.) These animals in turn provide a food source for predators—animals that eat consumers. Predators can be either secondary consumers, which eat only primary consumers, or tertiary consumers, which eat secondary consumers, or both. For example, the Ching Ching (Greater Antillean Grackle) eats insects (primary consumers) as well as lizards and fish (secondary consumers). So, the Ching Ching is both a secondary and a tertiary consumer. This is called a food chain.

A food chain is one feeding cycle within a larger or more complex food chain called a food web. A food web begins with the process by which the sun's energy is captured and shared among living organisms. A simple mangrove food web is shown in Figure 5.

**Human Impacts and Mangroves**

Although mangroves contribute to the economy in many ways, these benefits are not obvious like the benefits from the same area of a commercial crop such as sugar cane or



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bananas. Mangroves are essential to maintain coastal fisheries, protect property and coastlines from the effects of hurricanes and storms, protect coral reefs from sediments and pollutants, and provide useful products, including timber. Unfortunately, these resources seem to belong to no one. The person who owns the land on which they are found rarely benefits from them, and their value is not reflected in the price of the land. Mangrove wetlands are frequently seen as expendable, and little care is taken of them.

Throughout the Caribbean, mangrove wetlands are being destroyed or degraded. Everywhere— including the Cayman Islands—the pressures are the same. Most of the population and economic activity takes place on the coast, and there is an ever-increasing demand for coastal land. Most of the more accessible land is already taken up, so pressures on mangrove wetlands are increasing.

**Mangrove Wetlands Destruction**

Wetlands are being destroyed in many ways. Though not all of these apply to the Cayman Islands, some examples are:

- Filling for ports, tourist resorts, housing, airports, and industrial sites • Drainage for agriculture (including rice)
- Excavation for fish and shrimp farms
- Dumping of garbage
- Dredging of channels for navigation and drainage
- Cutting of forests for timber and charcoal
- Drowning as a result of hurricanes and rising sea levels
- Pollution from sewage, garbage dumps, fogging for mosquitoes.
- Construction of groins, docks, piers, causeways, runways, and roads

**Long-term Effects of Mangrove Destruction**

When mangrove wetlands are lost or degraded, their economic and ecological functions are disrupted or destroyed. Some of the most obvious results are loss of fisheries, increased flooding, increased coastal damage from hurricanes, and increased salinity of coastal soils and water supplies. The people who feel the costs of wetland destruction are the fishermen and other people who make their living on the coast. The people who reap the benefits from the developments usually live far away, in cities and towns.

**Natural Processes That Affect Wetlands**

Mangroves can also be destroyed by natural processes, including hurricanes and storms, diseases, and pests. Hurricanes are the most serious of these. Hurricanes can uproot trees and remove branches and leaves. Most mangroves can recover from moderate hurricane damage—but global climate change means that the number and severity of hurricanes will probably increase. More, and more severe, hurricanes could make it harder for mangroves to survive the other stresses they face.

Global warming will also cause a rise in sea levels. If they are healthy, mangroves may be able to grow fast enough to keep up with the rise and go on protecting our shorelines. Recent hurricanes such as Lenny, Georges, Mitch, Gilbert, and Hugo caused



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billions of dollars' worth of destruction in the West Indies and Central America. Much of the damage occurred in coastal areas that were probably once protected by mangroves. It is only a matter of time before a similar storm makes landfall in the Cayman Islands.

**Impact of Wetlands Loss**

When wetlands are lost or damaged, the wildlife they support is lost or damaged too. The impacts spread far beyond the wetlands. For example, White-crowned Pigeons are favorite game birds on many islands. They breed and roost in the mangroves. When mangroves are destroyed, or hunting is not properly managed, their populations are reduced. The White-crowned Pigeons feed on seeds and spread the seeds of forest trees. When pigeon populations are reduced, forests can no longer regenerate properly.

Unfortunately, human beings often do not realize the consequences of wetlands loss until it is too late. Once they are gone, we begin to notice increased lowland flooding, the dying out of species, and pollution of streams. The groundwater will also begin to disappear.

While it is true that the Earth is an interconnected and dynamic whole, this "big picture" point of view is difficult to convey on local and individual levels. To a farmer in need of more crop acreage, an island planning board desperate for housing sites, or a construction firm building a hotel that will provide jobs for hundreds of people, the loss of a wetland or two in exchange for the benefits of their project seems like a reasonable trade-off. Unfortunately, changes in one corner of an environment can begin a chain of events with the power to affect everything from microscopic organisms to the earth's atmosphere. Wetlands are an interconnected system that contributes to flood control, pollution control, and habitat for many plants and animals, including humans.

Mangrove forests are a very unique and complex kind of coastal wetland. They have evolved over the centuries not only in relation to their internal systems, but also to the functioning of eco and human systems that surround them. In other words, they are an open system, and thus, are directly related to all that is around them. With this way of thinking, mangrove forests become even more complex and, at the same time, more difficult to protect.

**Books:**

The Sea, the Storm, and the Mangrove Tangle
by Lynne Cherry

Mangroves: Trees in the Sea
by Jerry Greenberg



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## Mangroves Field Trip

Mangrove forests make up one of the most unique ecosystems on Earth in that they thrive where no other trees can survive, the transition zone between the ocean and land. The mangroves, in turn, provide shelter for an incredible variety of terrestrial and aquatic organisms.

Mangroves are a unique species of plant that are the scaffolding on which an entire ecosystem is built. The value of the mangroves to humans, to other organisms, and to the physical landscape of the coast cannot be given a price tag. It is important to understand why the mangrove community is so important and to take steps to preserve what is left.

There are numerous areas on the Cayman Islands where mangroves exist. Those closest to the water are the most vigorous of the salt-tolerant seashore terrestrial pioneer plants. Notice how they constantly grow seaward, their growth limited only by the flood of sea water.

The Different Species of Mangroves

The first trees you will come upon from the water will be **Red Mangroves**, *Rhizophora mangle*, easily identified by its Rhododendron-like leaves and prop roots. These trees grow along the shore reducing the water flow so well that minute particles settled out due to the low current flow create a fine sediment area seaward. The Red Mangrove thus builds up the soil under its roots by both filtering out fine particles and by contributing masses of leaves and other detritus which eventually forms a rich, highly organic, anoxic soil.

**Sketch and label these roots and leaves in your notebook.**

**Look for some propagules attached to the parent, floating or recent rooted propagules. Sketch it in your notebook.**

The next tree in the succession is the **Black Mangrove**, *Avicennia germinans*, whose pencil-shaped pneumatophores project from its roots. These abundant 10-12 cm long vertical projections permit the Black Mangroves to live in the anoxic mud laid down by the Red Mangroves. Black Mangroves have narrow, pointed opposite leaves, often with salt crystals on their lower surfaces. Observe the root structure by the pattern of pneumatophores.

**Sketch and label these roots and leaves in your notebook.**

Around the inner edge of the mangrove stands you may find **White Mangroves**, *Laguncularia racemosa*. These are recognized by their rounded, opposite leaves, each attached by a distinctive red petiole (leaf stalk). Two tiny glands may be seen as slitted bumps at the junction of leaf and petiole. White Mangroves or Buttonwood Trees are the last stage of mangrove succession. They grow on still higher land, and in comparison, to the other mangroves, they are rarely flooded by sea water.



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**Sketch these leaves in your notebook.**

Special Characteristics of the Mangroves
All of the mangrove plants, although unrelated, have developed similar modifications for survival in this marginal habitat.

**Write and fill in the following chart in your notebook.**
**Conditions of the trees include things like flowering, fruiting, defoliated by hurricane.**

| | **Unique Characteristics** | **Condition** |
|---|---|---|
| Red Mangroves | | |
| Black Mangroves | | |
| White Mangroves | | |
| Buttonwood | | |

**List the important functions of the mangroves:**

**Traditional uses of mangroves include:**

**Observe and identify any animals in the mangrove.**

**Human Activities**

| Impact | Evidence | Extent |
|---|---|---|
| Garbage | | |
| Woodcutting | | |
| Fires | | |
| Agriculture | | |
| Other | | |

The shore side trees (on dry land) are: Coconut Palms, Sea Grape, Mahoe and Plopnut.
**Make sketches of these in your notebook. Note the difference between the leaves of the Mahoe and Plopnut.**



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## Classroom Activity: Salty Currents

This activity demonstrates the mixing of fresh and salt waters.

Materials

- Two 5- or 10-gallon aquariums or clear plastic containers of similar size and shape (if using aquariums, make sure the one that contains salt water will not be used later for freshwater fish)
- Two small (6 or 8 oz) glass bottles, such as soda or mineral-water bottles, with caps Salt (coarse or table salt)
- Food coloring
- Paper and pencil for recording results
- Easel paper or flip chart
- Labels, or permanent marker for labelling bottles

Many kinds of wetlands (including mangroves) are located where fresh water from the land meets salt water from the ocean. The most obvious characteristic of sea water is its saltiness, or salinity. But most kinds of wetlands, from salt ponds to estuaries, are less salty than the ocean, and organisms face a constant fluctuation in salinity as both tides and freshwater flow interact. A good example of this is where the water from the Central Mangrove flows into the North Sound of Grand Cayman. Salt water is denser than fresh water and tends to sink to the bottom, so the organisms often have to deal with “layers” of different salinities. Fresh water, being lighter than salt water, floats to the top of ocean water. Wind, waves, and tides can stir up the layers, so wetlands animals must be prepared for quick changes in salinity. On a secondary- school level, this activity works with Chemistry and Physics classes as it demonstrates density through the movement of saltwater and freshwater currents.

**Procedure**

1. Ask two students to half-fill both aquariums with cold fresh water. Also fill the two small bottles with water. Cap and label one of the bottles “fresh water”. To the other one, have a student add enough salt to make a very salty mix (approximately two teaspoons, which is much saltier than sea water). Cap the second bottle and have a student shake it up until the salt is completely dissolved. Label the bottle “salt water”.

2. Lead the class in a discussion to predict what will happen when the two bottles are placed at the bottom of the aquarium or basin and uncapped to let the water escape. Record students’ predictions on easel paper or a chalkboard and encourage them to give reasons for their predictions.

3. Ask students to suggest how we might observe what the water in each bottle will do when it comes into contact with the water in the aquarium or basin, if the waters all look the same. Teacher direction may be required to lead the students to think of adding food coloring to the water in the bottles as a solution to the problem.
4. Add food coloring to both small bottles of water. Have a student shake up each of the bottles to make sure the food coloring is completely dissolved.

5. (Note: If you do the saltwater demonstration first, the results are more surprising to the students, and usually give a clue to whether their predictions are correct for the second demonstration.) Have a student lay one bottle on its side on the bottom of one of the aquariums and then uncap it. Observe what happens as the bottled water leaks into the

basin. Discuss the reasons for what happened. Compare the predictions to the actual event. Leave the basin undisturbed to see what will happen to the water over time. Follow the same procedure with the second bottle of water.

6 (alternative). If you have only one aquarium or container, follow the same procedure, but use two different colors to distinguish the saltwater mix from the fresh water.

**Discussion/Reflection**
Culminate the activity with a discussion of wetlands and estuarine areas. Deep ocean water is always colder than the water in a shallow estuary. Water entering both the estuary and wetlands as run-off from streams and rivers is usually colder than the water already in the estuary and wetland areas, which has been warmed by the sun. How do differences in water temperature influence the plants and animals that live there? Plant growth is faster in warm temperatures, and this is one reason that wet- lands and estuaries are so productive.

Students may draw or write about the experiments on paper or in a science log as a follow-up.



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**COASTAL ECOSYSTEM: Mangrove ID**

All About Mangroves

The **purpose** of this lesson is to have students understand and identify the different kinds of mangroves and their importance .

The **goals** for this lesson are for students to:

1. Define the three different kinds of mangroves.
2. Gain an understanding of how mangrove ecosystems function – their importance and value.

The **concept** being taught in this lesson is that mangrove ecosystems are vital habitat and are essential to the way humans live in tropical coastal areas.

**Lesson Behavior Objectives**: Upon completion of this lesson students should be able to:

1. Identify the different parts (leaves, roots etc.,) of different kinds of mangroves.
2. Draw each part of the mangroves in their books or paste in the different parts and label them.
3. List the main functions of mangroves telling why they are important.

**Relationship to Previous Lesson:** Mangroves are the interface between land and the sea in coastal ecosystems

**Materials Needed**:

Mangrove Presentation
Mangrove film?
Leaves, roots, stems, seeds, etc., of red, black, and white mangroves and buttonwoods.
Illustrations of the three different species.
Pen or pencil
Paper (plain)
Colored pencils (optional)

**Sequence of Lesson:**

1. Discuss the main functions of mangroves based on videos seen and students recall. Write answers in a list on the board.
2. Have students write up the lists from the board.
3. Examine the Red Mangrove seed (propagule).



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**a.** Drop the seed into water. Which end falls first? **b.** Separate the top (attachment) from the seed. How are they attached?
4. Examine the Red Mangrove leaf.
**a.** Is there a difference between the top and bottom sides? **b.** What is the shape of the leaf?
5. Examine the Red Mangrove root illustration.
**a.** Is there a main trunk? **b.** How do you think the roots' function?
6. Examine the Black Mangrove leaf.
What is the difference between the top and bottom of the leaf? *[The bottom has salt pores.]*
7**.** Examine the illustration of the Black Mangrove root system.
**a.** Estimate the extent of the root system and the tree cover (canopy). Is it larger, smaller, or the same? (Check this during field investigation or homework.)
**b.** Predict the function of the roots. (With older students, try to design an experiment to test your predictions. For example, try breathing through a snorkel while under water. Explain that this is how Black Mangroves get their carbon dioxide)
8. Examine the White Mangrove leaf and stem.
How does the leaf function? What do you think the little bumps are on the stem just below the leaf?
9. Examine the illustration of the White Mangrove root system.
**a.** How are the roots similar to those of the Black Mangrove?
**b.** Predict the function of the roots. (With older students, try to design an experiment to test your predictions.)
10. Have students draw pictures of each set of leaves, roots, and stems.

**Closing/Extensions**

If you can find Black, Red or White Mangrove seeds, especially ones that have already begun to grow roots, bring them back to the classroom together with water and samples of mud and detritus from a nearby pond or mangrove swamp. Put the water and mud and detritus that you have brought back into a container (preferably one like an aquarium) and plant the seeds in the mud and detritus. Every few days, add water obtained from the same location where the seeds were found. Initially, the water will stink, but if the seeds take root, they will ultimately remove the smell. ***~Marvellous Mangroves***



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**Classroom Activity: Microscopic Plants and Animals**

**Topic:** Microscopic Plants and Animals in Mangrove Food Web

The **purpose** of this lesson is to have students use a microscope to observe the microscopic organisms and detritus in water that form the base of the food chain.

The **goals** for this lesson are for students to:
Observe microscopic organisms and detritus by using a microscope.
Learn to identify these organisms and detritus and place them in a food chain.
Build a food chain incorporating these organisms.

The **concept** being taught in this lesson is that there are huge numbers of microscopic organisms and detritus that make up the base of the food web in mangrove pond wetlands.

**Lesson Behavior Objectives**: Upon completion of this lesson students should be able to:
Find, observe, describe and identify microscopic organisms found in mangrove pond water by using a microscope.
Draw a picture of the creature found.
identify where the microscopic organism fits in the food web and draw a food web with it included.

**Relationship to Previous Lesson:** Shows just how many microscopic plants and animals exist at the bottom of the food web.

**Materials Needed**:

- Microscopes (one per 2 or 3 students if possible)
- Plastic bucket and several containers containing wetland water samples
- Eye dropper
- Glass slides
- Copies of sheet, "Microscopic Study – Sketch and Identify"
- Field guide on invertebrates
- Pencils
- Data recording sheet for microscopic organisms
- Video-microscope

**Sequence of Lesson:**
1. Explain to the students that there are many different forms of microscopic plants and animals in the water, which they already know is rich and diverse in species. Distribute identification charts and field guides on invertebrates and have them look at one or two of the species, pointing out the ones they are likely to see.
2. Students will be divided into small groups of 2, 3 or 4 depending on the number of microscopes available.

3. Explain in detail how to use a microscope, pointing out the different features and how they work.
4. Pass out microscopes. Also pass out slides and eyedroppers, explaining that they are glass and will break if dropped.
5. Demonstrate how to take a water sample from the containers and put it onto the slide using the eyedropper. Explain that too much water will mean that the creatures in the water will have too much space to swim around in, and the water will also go all over everywhere! Explain how to use the eyedropper: do not tilt it so the creature can go into the rubber "bulb" or it will stick there and not come out. Also explain that the creatures they will be looking at are alive and will be returned to whence they came, so students should try to avoid killing them.
6. Have each group collect their water samples that have been brought back in the bucket.
7. Let the students try to search and find creatures in their water samples. Tell them they will have to identify and draw their creatures.
8. If students make an exciting find, have them bring the slide to the front of the class so they can observe it on the video-microscope.
9. After about 45-50 minutes, pass out copies of the "Microscope Study – Sketch and Identify" sheet, and have students fill them in. Explain that if they cannot identify their creature, they should give it a name that reflects its appearance like, "Fuzzy-legs" or "Rodney".
10. When time is up, have the students return all their water samples, including those on slides, to the bucket, again explaining that they will also go back to the pond.

**Closing:** This is a great opportunity for students to familiarize themselves with the enormous spectrum of invertebrates while practicing research and careful comparison skills. Some of the creatures may not be easily identifiable from the invertebrate charts, so students will have to look in textbooks or go to the local library or university to try and find out what they have found. Have them chick similarities with samples of which they have pictures by looking carefully at the shape of the animal, number of segments, legs, wings, etc.

References
Marvellous Mangrove Program



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**CHAPTER 3: What is there to Sea in the Grass**





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**Chapter 3: What is there to *Sea* in the *Grass?***

Related PPT Presentation: Seagrass - Coastal Lagoon Curriculum
Related Videos:
Ecosystems on the Edge: Underwater Light and Seagrass
5 amazing things seagrass does for our planet
Marine Plants Can Save the World: Part 1 Seagrass
Natural Wonders of the Caribbean

In the shallow waters next to the land, in nearly all the seas around the world, are secret underwater gardens. These gardens are home to a special saltwater plant called Seagrass. Seagrasses are flowering plants (also known as angiosperms) that have adapted, over millions of years, to life in the sea. They are the only flowering plants that have adapted themselves to living in marine (saltwater) and estuarine habitats. The plants root in sediments on the sea bottom and have shoots that appear above the sea floor. They are more closely related to terrestrial lilies and gingers than to true grasses. Seagrasses are marine plants with the same basic structure as land plants. They form meadows in shallow coastal water with sandy or muddy bottoms and estuaries. While most of us know something about the ocean and coral reefs, we know little about seagrass meadows.

Moving seaward from the mangroves we typically find seagrass beds. Seagrass is one of the most important plants on earth as it is the basis for many important ecosystems. There are about 60 species of seagrass found worldwide. These mostly range from the size of your fingernail to plants with leaves as long as 7 meters. Seagrass is an important source of food and provides shelter for many species in the coastal ecosystem. Some of the shapes and sizes of leaves of different species of seagrass include an oval, a long spaghetti like leaf and a ribbon shape. The highest concentration of species occurs in the Indo-West Pacific region.

Seagrass beds are a home to a huge diversity of marine life. Snails, juvenile fish, crabs, shrimp, juvenile lobsters, and many other invertebrates live amongst the grass fronds



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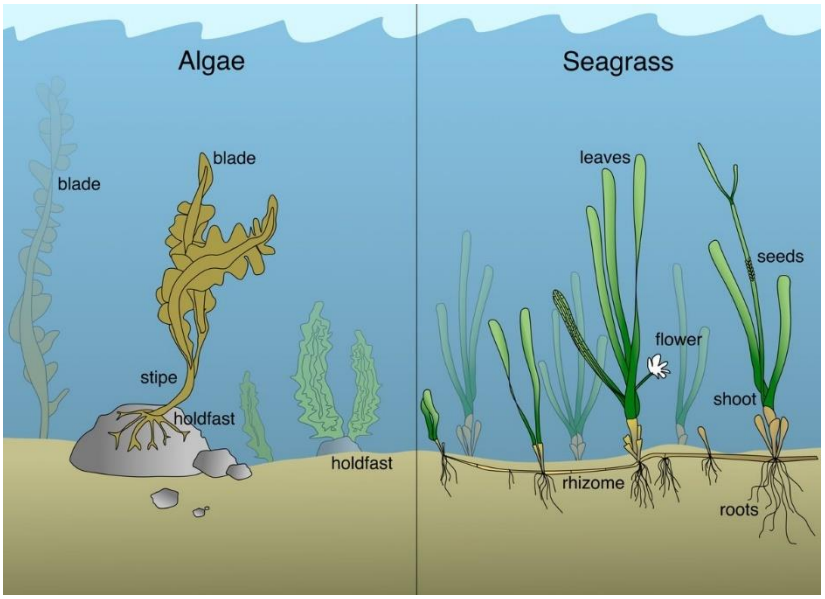
or can be found buried in the silt held in place by the grass' root system. With their abundant supply of resources turtle grass beds are ideal feeding grounds for adult lobsters, large fish, and green turtles. Indeed, some scientists consider healthy turtle grass beds to be the most productive marine ecosystems on the planet.

Four different species of seagrass exist in the Cayman Islands and the most common is turtle grass. Turtle grass, a type of seagrass which gets its name due to the fact that it is an important source of food for green turtles, is easy to identify with its broad flat green blades that make up lush meadows growing over the sea floor. Turtle grass beds are an important component of Cayman's marine environment. Like their relatives on land, seagrass root systems are able to secure loose sediments together and therefore prevent erosion of the sea floor. The wide flat blades of the turtle grass also dampen wave action and encourage suspended silt in the water to settle out more quickly, increasing water clarity. If not for healthy turtle grass beds, many of our beautiful lagoons might not be as crystal clear as they are today.

**Seagrass Requirements for Growth**

Seagrasses are commonly mistaken for seaweed, but they are quite different from seaweeds, which are an algae species. Seagrasses are different from algae in several ways. Algae produce spores where seagrasses produce flowers and rarely have 'roots below the surface. Seagrasses, like terrestrial grasses, have well defined root and shoot systems, leaves and underground stems called rhizomes. These can form an extensive network below the surface. Seagrasses are vascular plants which means they have a network of veins to move nutrients and dissolved gases around the plant. Algae does not have this type of structure. Unlike land plants that have oxygen available from the soil around their roots, in the underwater sand or mud that seagrass grows in on the seafloor, there is very little oxygen available, so instead seagrass exchanges oxygen and carbon dioxide through its thin leaves. The roots of the seagrass act as an anchor into the sediment.




Roots can be simple or branching and all have fine hairs to help absorb nutrients. Seagrass pumps oxygen into the sediment via their roots. Seagrass has flowers, fruits,



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and seeds. Pollination occurs in the water and the pollen from the male seagrass flowers is mainly dispersed to the female flowers by tidal currents.

There are approximately 72 different seagrass species that belong to four major groups, while there are over 500 species of algae. Seagrasses have been able to successfully grow in the marine environment because of five properties:

1. The ability to live in a salty environment;
2. Growth when fully submerged;
3. Clear water for good light;
4. A well-developed anchoring system;
5. The ability to complete their reproductive cycle, or pollination, underwater;
6. Water temperature influences the rate of growth and the health of seagrass.

Seagrasses need nutrients to grow which are often obtained from nearby mangroves. They also require light, therefore thriving in clear water. They flourish in shallow, protected coastal waters where there is shelter (such as a sandbar) from drying winds and from wave action and strong currents which could create turbulent muddy water. They cannot grow easily where a low tide will expose the plant and dry it out.

Different species have different **salinity** tolerance and seagrasses adapt to their marine environment. While the roots of seagrasses serve to anchor the plants they are not necessary for water intake. Roots share the function of nutrient collection with the leaves which can absorb food and water directly from the surrounding water. Flowering is not common for most tropical species and the spread of seagrasses is largely through vegetative propagation by the growth and branching of rhizomes. Flowering, however, generally takes place in winter or early spring. The flowers are very small. Water carries the pollen from the male to the separate female flowers. The resulting fruit is often carried some distance from the parent plant before the seeds are released.

Seagrasses are closely related to land plants, evolving from land living flowering plants. Seagrasses only flower for a short time each year and like many land plants, flowering is linked to the seasons. In contrast to land plants, which are unable to tolerate even small quantities of salt, some seagrasses can tolerate a salinity range from 4 to 65 parts per thousand (2x seawater concentration). Typically, seagrasses grow best in salinities of 35 parts per thousand. Not all species tolerate all salinities equally well, and salinity tolerance may be a factor promoting different species distributions along salinity gradients, for example, different species having the ability to grow in different environmental conditions from the estuary to farther up the mangrove ecosystem. Some seagrasses can survive in a range of conditions including fresh water, estuarine, marine, or hypersaline.

**Light availability** is the most dominant factor in seagrass growth. Seagrasses are plants that need light for photosynthesis. Quite often seagrass can exist in sea bottoms where there is not much oxygen and oxygen supplied to the rest of the plant is needed to regularly supply their root zone. Although these light requirements exist, the shallow areas where seagrasses grow can also get too much light, particularly in Cayman's warm clear coastal areas, which can cause temporary photo damage. UV exposure can have



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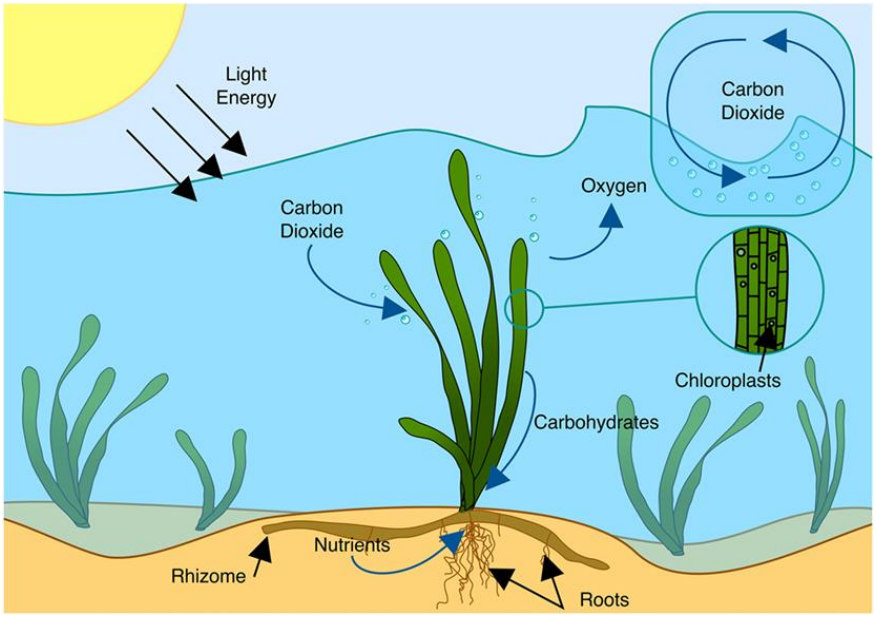
significant impacts on seagrasses. Land plants have small pores on their leaves called stomata, through which they can take in carbon dioxide from the air and release oxygen. Seagrasses lack stomata. Instead, they have a thin cuticle layer which allows gases and nutrients to diffuse directly into the leaves from the surrounding water.




**Temperature** has a significant impact on the rate of growth and the health of plants, particularly when temperatures are too high or too low. Photosynthesis and respiration, the two most important processes, are slow at very low temperatures, but increase with increasing temperatures. When temperatures are too high, up to 38 degrees Celsius, respiration exceeds photosynthesis, resulting in a negative energy balance within the plant. Seagrasses show high sensitivity to seawater warming, decreasing their growth and even causing the plants to die. Seawater temperatures above 40 degrees C will stress seagrass and death occurs at temperatures above 45 degrees C.

Seagrasses require tw**o key nutrients,** nitrogen, and phosphorus, for growth. In coastal regions, seagrasses appear to be mainly limited by nitrogen and secondly by phosphorus. Nutrient availability to seagrass depends on the type of sediment they grow in, but most seagrass live in sand or mud sediments where their roots and rhizomes anchor the plants to the sea floor. Seagrasses have less nutrient requirements than other aquatic organisms such as algae and phytoplankton. It is estimated that seagrasses require about four times less nitrogen and phosphorus per weight than phytoplankton cells. This gives the seagrasses an advantage for growth in environments with low nutrients compared with other primary producers. Nutrient levels are typically low in the water column of warmer areas, but nutrients can also be taken up from the sediment and decomposing leaves.



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**Seagrass Locations and Distributions**

Seagrasses occur in coastal areas around the world and are found in diverse habitats. Seagrass meadows occur in most shallow, sheltered, muddy marine coastlines and estuaries. These meadows may contain only one species or may consist of a community including many species, sometimes with up to 12 species present in one location. The depth range of seagrass is usually controlled at its deepest edge by the availability of light for photosynthesis.


When conditions are suitable, seagrasses form dense underwater meadows, some of which are large enough to be seen from space. Wave action, low tide exposure, clarity and saltiness of water determine how well the seagrass species survive along the coastline. Exposure at low tide, wave action and associated turbidity and low salinity from freshwater inflow regulate seagrass species survival at the shallow edge. Seagrasses thrive in areas protected by fringing or barrier reefs, in sheltered lagoons such as South and North Sound.

Species recorded in Cayman include turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii* and *Halodule bermudensis)* and manatee grass (Syringodium filiforme). The most common species in the Cayman Islands is turtle grass (*Thalassia testudinum*). The broad flat green blades are easily recognizable making up the thick meadows over the coastal sea floor and is an important source of food for green turtles.

**The Important Role of Seagrass in Coastal Ecosystems**

Seagrass meadows have a number of ecologically essential functions. A critical function is that this environment enhances the diversity and abundance of sea life. These meadows are habitats for many organisms and are a nursery ground for commercially important shellfish and fish species. Juvenile finfish found in seagrass beds include snappers, grunts, groupers, and many others. Other commercial species found in these beds are queen conchs, lobsters, and shrimps. Some animal species which are not of commercial importance are also found in seagrass beds. These include sea urchins (commonly referred to as sea eggs), sea cucumbers, sea sponge, starfishes, brittle stars,



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snails such as Murex, octopus, and anemones. Even sea horses may be found in seagrass beds. Of course, seagrass beds are also grazing grounds for turtles. There is an incredible diversity and abundance of organisms in this environment.


Microalgae that live on seagrass are very productive and create a large supply of food for small invertebrates and fish, which also use seagrass blades as a protective habitat. As a result, this ecosystem attracts larger marine organisms, especially fish for it's good feeding ground. Like mangroves, seagrass meadows serve as important "nursery grounds" for the juvenile stages of crabs, lobsters, and fishes, and as important feeding sites for adult fishes and birds.

Seagrasses are central to a web of life. However, their usefulness does not end there. The dead seagrass leaves also play an important role in coastal ecosystems. The decaying dead leaves (**detritus**) support a diverse community of decomposers that thrive on rotting material. This becomes food for worms, sea cucumbers, crabs and filter feeders such as anemones. Some of these living and dead seagrass blades are also washed to other areas of the ocean which feed organisms in the deeper ecosystems. As the leaves further decompose, nutrients are released, such as nitrogen and phosphorus, which dissolve in water, are reused by seagrasses and phytoplankton. Plankton, both plant and animal, is a food source for juvenile prawns and fish, as well as other filter feeders.

Another important function of seagrass is its ability of its roots to slow the flow of water, capturing sand, dirt, and silt particles. Their roots trap and help to stabilize the sediment. This not only aids in water clarity and quality, but also protects coastlines from erosion and storm surge. Seagrass can work as a filter for nutrients in runoff that comes from the land before it is washed out to sea and to coral reefs. Seagrass meadows cover much greater areas than coral reefs and they increase water clarity by stopping the movement of sediment in the water, allowing it to settle and preventing it from moving out to the coral reef. In nutrient poor regions, the seagrass plants themselves help nutrient cycling by taking up nutrients from the soil and releasing them into the water through their leaves, acting as a nutrient pump.

Seagrass meadows are rated the third most valuable ecosystem globally, on a per hectare basis, only following estuaries and wetlands. One square meter of seagrass can



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generate 10 liters of oxygen every day through photosynthesis and therefore this amazing area is known as the 'lungs of the sea'. Atmospheric carbon is captured by coastal mangroves, seagrasses, and salt marshes at a rate five times faster than tropical forests. Seagrasses are capable of capturing and storing a large amount of carbon from the atmosphere. Seagrasses take carbon from the water to build their leaves and roots similar to how trees take carbon from the air to build their trunks. As parts of the seagrass plants and associated organisms die and decay, they can collect on the seafloor and become buried, trapped in the sediment. It has been estimated that in this way the world's seagrass meadows can capture up to 83 million metric tons of carbon each year. The carbon stored in sediments from coastal ecosystems including seagrass meadows, mangrove forests and salt marshes is known as "blue carbon" because it is stored in the sea. While seagrasses occupy only 0.1 percent of the total ocean floor, they are estimated to be responsible for up to 11 percent of the organic carbon buried in the ocean. One acre of seagrass can pull out 740 pounds of carbon per year (83 g carbon per square meter per year), the same amount emitted by a car traveling around 3,860 miles (6,212 km).

**Seagrass Interactions with Mangroves and Coral Reefs**

Mangroves, seagrass meadows and coral reefs are interconnected, and all three habitats must remain healthy for each to thrive. Mangroves filter pollutants and trap sediments that would otherwise smother seagrass and coral. Sediments that collect in seagrass areas may eventually build up to become an area which will support mangrove growth. Seagrass meadows also help filter the water to increase clarity for coral reef inhabitants by trapping sediment and slowing water movement. In turn, coral reefs protect mangroves and seagrass from ocean storms by slowing the surging waves. Barrier or fringing reefs protect coastlines, and the lagoon formed between the reef and the mainland is protected from waves, allowing mangrove and seagrass communities to develop. All three communities assist in keeping nutrients available and limit nutrients from being scattered and lost into the surrounding oceanic waters. The interaction of these coastal communities' results in important physical and biological support for the other communities.


**Threats to Seagrass Meadows**

As researchers continue to demonstrate the practical importance of marine connectivity, the concept is slowly being incorporated into conservation planning. Seagrass loss is often linked to coastal development or construction of buildings along the coast. All species of seagrass can be affected by pollution and damage in the environment. Our impact on the environment increases as human populations grow.

Poor water quality (particularly high levels of nutrients) caused by pollution is the biggest threat to seagrasses around the world. As pollution flows into the sea, seagrasses die from being shaded from light, covered by faster growing algae, buried by sediment from a land base source or harmful chemicals. Water quality problems are particularly serious in countries that are growing rapidly, but where there are not many laws to regulate pollution or for seagrass protection.

Boating, trampling, ports, dredging, and any activity that physically damages seagrass or alters the conditions around seagrass meadows can put pressure on seagrass systems. Small-scale threats to seagrass, such as damage done by boat anchors, can make it harder for seagrass meadows to cope with climate change, ocean acidification, and sea-level rise. In addition to these direct human activities, climate change, sea level rise, and increasing severity of tropical storms were seen as potential risks for seagrasses. Changes in salinity and the levels of nutrients in the water may cause the decline of seagrass dominated communities and increase macroalgae dominated communities

Global loss of the area covered by seagrasses between 1990 and the early 2000s have been estimated at up to 7% per year, or an area equal to two football fields every hour, making them one of the most rapidly declining ecosystems on Earth. Human activities listed above pose threats to the thousands of species that make their home in seagrasses, including many types of fish, sharks, turtles, marine mammals, and marine invertebrates such as octopus, squid, cuttlefish, sponges, shrimp, and crabs. As previously described, some seagrass meadows also store significant amounts of blue carbon. When these habitats are destroyed, this carbon is released into the atmosphere. As we think about preserving national assets such as mangroves and other wetland areas, we must include conservation methods for seagrass communities as well to help protect their valuable ecological functions. Scientific evidence of the value of seagrass meadows is growing and it is obvious that we need to improve seagrass protection around the world.

Project Seagrass, an environmental charity, has launched an online platform that crowdsources imagery and location information in a centralized database. Users can upload photos of seagrass beds onto the app, called Seagrass Spotter, and tag locations from anywhere in the world. This information will help countries that have a lot of seagrasses, but not a lot of data, to improve efforts to protect the rapidly receding underwater plants. Seagrass grows in salty, shallow waters in many parts of the world, but mapping has been spotty, which has presented challenges for thorough research and data collecting efforts. To participate, you can use the available Seagrass Monitoring App.

**Protecting Seagrasses and Managing Threats**

Possible management solutions to help protect coral reefs, mangroves, and seagrasses involve reducing the impacts of human activities. Reducing local stress on seagrass will support its ability to stand up to the impacts of larger-scale, longer-term stress, like climate change. Improving local water quality, preventing damage to seagrass meadows, creating protected areas of seagrass, reducing overfishing and stress from coastal development will aid in creating a healthier coastal ecosystem. Protecting seagrass will protect the biodiversity found within the meadows, will help fight climate change, and will provide food security for humans. Organizations at local levels are taking small steps to protect seagrasses which in turn can work toward a brighter future for these secret undersea gardens. The best possible management effort will take into account all users of seagrass ecosystems, so that they can be used but not overexploited for future generations.

Although seagrass meadows are threatened the world over, we recognize that some significant positive changes are taking place. Throughout the world, communities, NGOs and governments are beginning to embrace the monitoring of seagrass meadows, we have increased evidence of successful seagrass restoration and our knowledge of the ecology of seagrasses is rapidly improving. We have greater appreciation for the value of seagrass in the global carbon cycle and there is a willingness of governments to include seagrass conservation in ways to mitigate carbon emissions. These successes are important, but are only the beginning from where scientists, conservationists, policy makers and managers worldwide should direct a course of targeted strategic action in order to achieve a brighter future for seagrass.



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Monitoring seagrass resources is important as a valuable tool for improving management practices and it allows us to understand whether the health of the ecosystem and condition is stable, improving or declining. Successful management of coastal environments needs regular monitoring of the status and condition of natural resources. Monitoring is critical in improving our understanding of seagrass resources and to coastal management in order to effectively change management practices or take action for successful results. The easiest way to protect seagrasses is by preventing damage in the first place.

Locally, there are efforts underway to educate the public about the benefits of seagrass and how they can help to protect seagrass. There are many ways you can help: don't litter and be aware when applying fertilizers and pesticides, as excess amounts can wash down gutters and drain to the sea. When you are out on the boat, slow down and avoid shallow areas. *Know Your Depth and Draft*; when in doubt about the depth, slow down and idle. If you are leaving a muddy trail behind your boat, you are probably cutting seagrass. Tilt or stop your engine if necessary. If you run aground, pole or walk your boat to deeper water. Never try to motor your way out as this will cause extensive damage to seagrass and may harm your motor. It is also helpful to know the times for your low and high tides, even Cayman this will make a difference in these shallow areas.

You can also support marine conservation initiatives and learn about these special marine habitats and volunteer to monitor their health by joining the National Trust or the Mangrove Rangers.

Articles on local issues:
Caribbean-Wide, Long-Term Study of Seagrass Beds Reveals Local Variations, Shifts in Community Structure and Occasional Collapse 2020
DoE warns against Barkers seagrass removal 2019



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**Field Trip Activity: What is there to *Sea* in the *Grass?***

**Topic:** Seagrass ecosystems

The **purpose** of this lesson is to have students understand and identify seagrasses, where they can be found, their habitat, function and their importance. Two essential methods to gather ecological information in a standardized way are: **Transect Sampling** (using a single line) and **Quadrat Sampling** (counted within a grid). These sampling methods provide more accurate data than random sampling or simply guessing, but they take less time than counting every specimen in a certain area. Sampling helps us estimate & compare!

The **goals** for this lesson are for students to:

1. Learn to identify seagrass species
2. Gain an understanding of sampling for data collection

Drag a net in the seagrass and who knows what you may come up with. There's sea life of all shapes and sizes living in the seagrass along the shore. From seahorse to sea urchin, pipefish to starfish, the varieties of sea life are amazing. These seagrass beds are a rich ecosystem. Wear closed toe shoes that can get wet and get ready to wade and bring a change of clothes.

**Relationship to Previous Lesson:** Interrelations of coastal ecosystems
Reference Youtube Video and Quadrat usage
https://www.youtube.com/watch?v=oRXmFH76REM

**Materials Needed**:
50-meter measuring tape
3 x 50cm x 50cm quadrats per group
6 tent pegs or clips/weights to secure quadrat on bottom
Magnifying glass
Monitoring datasheets
Clipboard, pencil, and ruler
Glass dome for underwater viewing, if available, aquarium or any glass vessel can be used.
https://www.seagrasswatch.org/idseagrass/

**Sequence of Lesson:**
Choose an area within a fairly uniform section of the seagrass meadow next to shore.
Divide the students into groups and assign each group a transect line.
Lay out the transects parallel to each other, about 25cm apart and perpendicular to shore; 5 m, 25m and 45 m from shore.
Within each of the quadrats placed for sampling, complete the following steps:

1. Describe the sediment composition: Dig your fingers into the top of the substrate and feel the texture. Describe the sediment by noting the grain size, is it sand, fine sand, fine sand and mud, mud.
2. Describe other features and ID / count any creatures you can see: Note and count any other features which may be of interest, example: number of shellfish, sea cucumbers, crabs, sea urchins, evidence of impact.
3. Estimate seagrass percent cover:
4. Estimate the total percentage cover of seagrass within the quadrat - use the percent cover photo standards as a guide.
5. Estimate seagrass species composition: Identify the species of seagrass within the quadrant and determine the percent contribution of each species to the overall cover. Use seagrass species identification keys provided.
6. Measure the length of the seagrass: Measure height of the dominant seagrass species, measure from the sediment (bottom) to the leaf tip of at least 3 shoots.
7. Estimate algae percent cover: Estimate percentage cover of macro-algae in the quadrant. Algae are seaweeds that are not attached to seagrass blades but may overlie the seagrass. Use "algal percentage cover guide" for reference

At completion of monitoring

1. Check data sheets are filled in fully. Ensure that your name, the date and site/quadrat details are clearly recorded on the datasheet. Also record the names or number of other observers assisting.
2. Remove equipment from site. Remove all pegs and roll up the tape measures. If the tape measures are covered in sand or mud, roll them up in water.
3. Wash & pack gear. Rinse all tapes, pegs and quadrats with freshwater and let them dry. Review supplies for next quarterly sampling and request new materials Store gear for next quarterly sampling.

As a class, total all species, population, and percent cover again, then analyze:

1. Question: Did anyone see data outside the areas sampled by our transects & quadrats? Why would it be important to write field notes about this in a report? What does this tell you about error in sampling?
2. Question: Did anyone think some data we were looking for was hidden because we couldn't touch anything? How would our results change if we could move things that we find along transects or in quadrats? Do you think it's okay to change data because you think something is there, even though you didn't see it?
3. Question: Which visual estimation method – transect or quadrat – do you think is better to estimate percent cover of sample populations & why?
4. Question: When you chose your transect line, did you look for a place where there was probably more interesting data to record? What does this tell you about **bias** in ecological sampling? What about **randomization**?

**Vocabulary**

a. **Transect Sampling**–counted on points of a single line
b. **Quadrat Sampling–**counted on points of a grid
c. **Transect Point**–measured distance on a transect line
d. **Reliable** - yielding the same results in different experiments or studies.
e. **Intercept Point or point Intercept**–where 2 lines of a quadrat cross



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f. **Percent cover**–portion of total area1 species covers at a specific site
g. **Error**–Statistical Error is caused by random (unpredictable or unintentional) variation in making a measurement, whereas systematic eros is caused by an unknown but nonrandom fluctuation. If the cause of the systematic error can be identified, then it can usually be eliminated. Such errors can also be referred to as uncertainties.
h. **Bias –** a personal preference that causes unfair judgment. In science, a sampling error caused by systematically favoring some outcomes over others.
i. **Randomization** – the making of random arrangement in order to control the variables in an experiment
j. **Field Notes** – additional information scientists record when doing observations at a study site

Reference:

Consortium for Ocean Science Exploration and Engagement
http://www.cosee.net/

Seagrass Watch
Seagrasswatch.org



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# Sea Turtle Word Search

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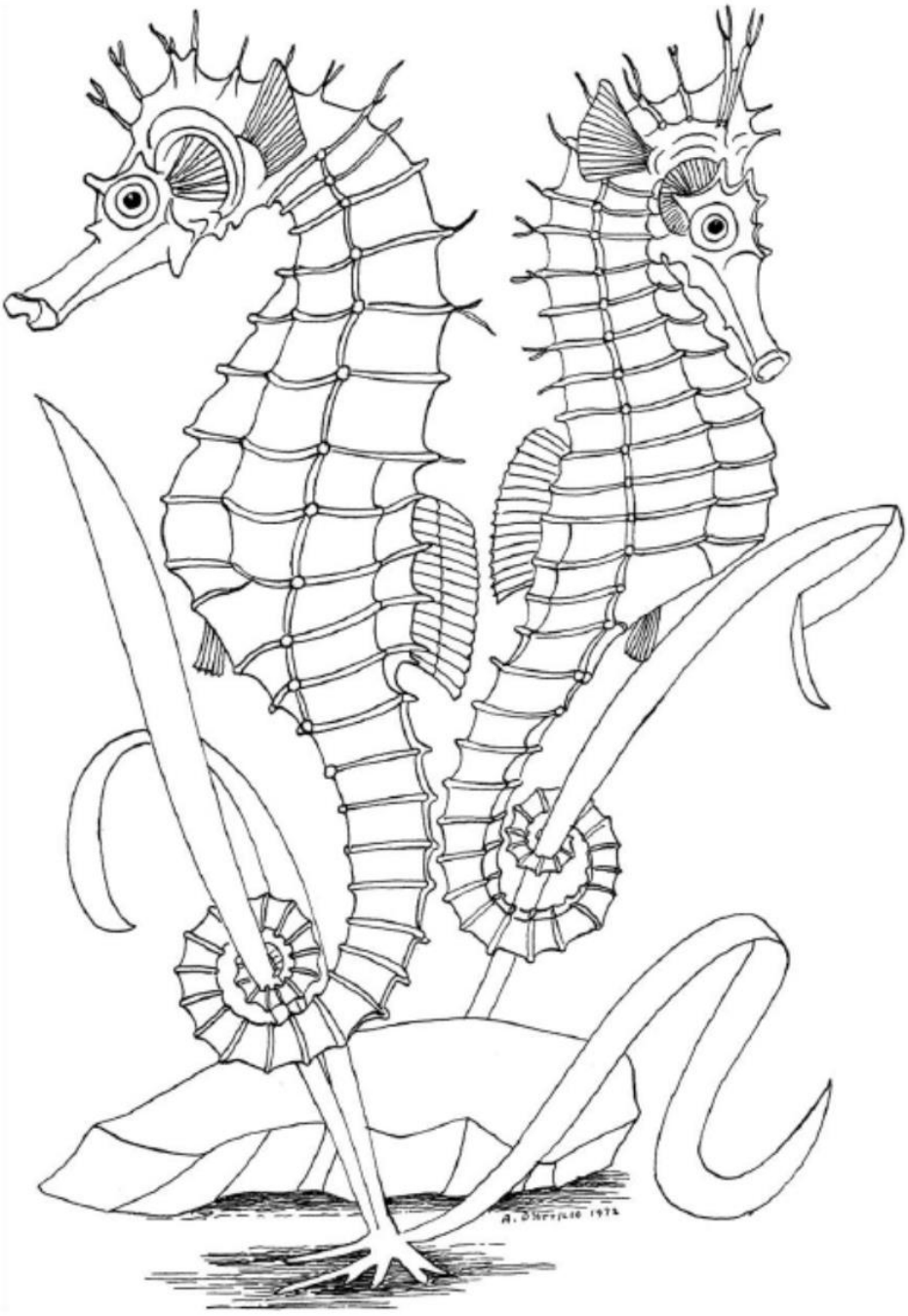
Coastal Ecosystems Coloring Page





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## Classroom Activity: Importance of Light

Seagrasses need light to produce food through photosynthesis. The light that the seagrasses receive must penetrate the water column in order for it to be efficient. There are many things that can prevent the seagrass from receiving light. Suspended sediments and chemicals are two of the major restrictors.

Lowering a secchi disk into the water. The depth at which you can no longer see the secchi disk is called "secchi disk depth."

This activity will show students the importance of light availability in seagrass health.

Materials

- 3 or 4 very large buckets
- Flour (represents milky waters found in some areas of the world)
- Mud
- Gravel or sand
- Glitter (represents shiny rocks found at the bottom of the water)
- A well-lit area (outside is best)
- 4π light meter*

* If you do not have access to a 4π or 2π light meter, you may use a secchi disk, purchased for less than $30 from scientific equipment supplier, such as Science First. If you do not have a secchi disk, you can easily make one. Directions are included below.

Procedure (if light meter is used)
Fill each of the buckets ¾ of the way with water. Place the light meter at the bottom of the first bucket. Record the light reading then take the light meter out. Add the mud to the bucket. Observe the bucket and place light meter in the bottom of the bucket. Record the reading from the meter. Repeat these steps for the next two or three bucket but add different ingredients to each.

Procedure (if secchi disk is used)
Fill each of the buckets ¾ of the way with water. Lower the secchi disk into the first bucket to show students that you can see to the bottom. Take the secchi disk out. Add the mud to the bucket. Observe the bucket and lower secchi disk into the bucket until you can no longer distinguish the black from the white. Measure how deep the secchi disk was lowered. Record the depth and any other observations. Repeat these steps for the next two or three buckets but add different ingredients to each.

Discussion
Discuss the results with your class. Ask them what the difference was between the different ingredients that were added. Ask how the different ingredients affected the amount of light at the bottom. Make connections between the ingredients used and the real restrictors in a seagrass habitat.

*How to make a secchi disk



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*Secchi disk in the water.*

Secchi disks can be ordered from scientific supply stores and can be found for less than $30. If you choose to make your own, below are some basic instructions.
Obtain a white Frisbee, plastic lid, white plastic plate or laminated white piece of paper (circle). Cut out a circle with a diameter of 20cm. Punch a hole in the center. The color of the secchi disk will be split up into alternating black and white sections (2 white, 2 black, see photograph below). You can use a black permanent marker or black acrylic paint to color in the black portion of the disk. Tie a knot at one end of about 5 ft of rope and place string through the hole. Attach some weights to the bottom of the disk so it easily sinks to the bottom of the bucket. Metal washers work well for this purpose. You may wish to mark the rope every cm for ease of taking measurements. Your new, homemade secchi disk is ready for use!

**Classroom Activity: Save the Beach**

Students will compete with other teams to construct the best "barricade" that prevents sediment from spreading in a container during a "hurricane." The components of the barricade will represent the parts of seagrass. (There is also an alternative activity that is faster and involves less clean-up)

Objective


Setup for the activity, including fan, sand, barrier, and tape sticky side up.
Students will gain a better understanding of the following ecological service provided by underwater grasses: underwater grasses help stabilize sediments.

Materials

- Cookie sheets / flat Rubbermaid containers (or outdoor water table if available)
- Sand
- Large fan
- Masking tape or labeling tape
- Timer
- Assortment of items to build a barrier such as Combs, Window screen, Marbles, Coins, Yarn, Easter Grass, Toothbrushes, etc.

Procedure

1. Students should work in groups of about 4-5, following the instructions outlined in the Student Worksheet, below. Each group should be given a tray with a tape line, and a collection of supplies to build their barricade. If you are not able to give each group the same supplies, put the supplies in brown lunch bags and have the groups pick a bag at random.
2. Give the groups 10 minutes to build their barricade. They may only use **2** types of the given supplies for their final product, so that they don't just throw everything on top of the sand.



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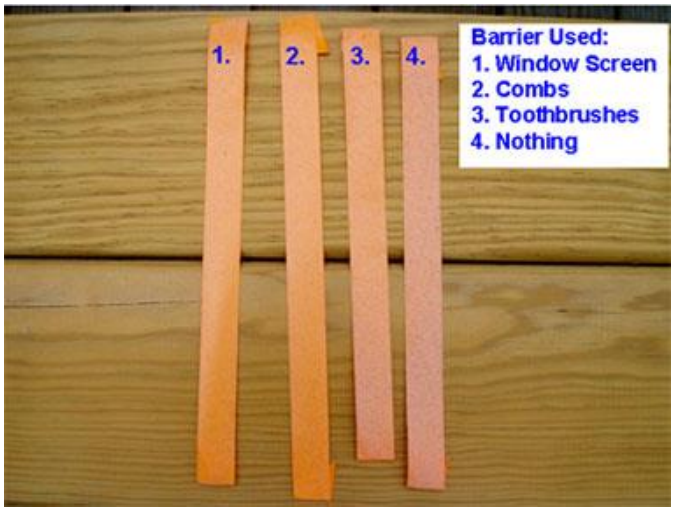

*Results after using several types of barriers. Light-colored sand covers the orange tape (#1 has the least amount of sand, #4 the most).*

3. When they are ready or their time is up, students will bring their tray with their barricade up to the fan station. Anchor a piece of masking tape or lab tape sticky side up on the other side of the line as shown in the Part 3 Results image in the Lesson Resources. Test each group's barricade by turning the fan on for 15 seconds. Remove the tape line and compare it to all the other groups. The group with the least amount of sand stuck to their tape wins! See the Part 3 Results Image (right) for a relative comparison using sample materials. (Since the blowing sand gets all over you may want to do this part of the experiment outside or somewhere that can be easily vacuumed.)
4. Explain that the wind and waves cause the underwater sediment behave similarly to the sand in their experiment, even though it was not under water. Seagrasses help protect the shore by trapping and stabilizing sediment and reducing wave energy. The combi (sticking with its teeth up) is similar to the leaves of seagrasses and the screen is similar to the rhizomes. In this case the leaves trap the floating sediment particles in the water column and the rhizomes stabilize the sediment already on the surface.

**Classroom Activity: Be the Particle**

Seagrasses are important in keeping the water clean. When suspended particles run into the seagrass, they settle to the bottom. If there is a large, uniform seagrass bed then the particles will settle faster. If there are patches of seagrass, it will take longer to settle. If there is no seagrass, the particles will take a long time to settle.

Objective
This activity will show students how seagrasses are important in settling sediment and other particles suspended in the water.

Materials
- 10-15 chairs
- 3-5 Blindfolds

How to play
Choose three to five students to participate in the first round. Each student must either keep his/her eyes closed or be blindfolded. Clear out a large space in your classroom and place most of the chairs in one general area. Make sure that they are pretty close together. When you say start, these students will walk straight. If they run into a chair, they must sit in it. When all students have either made it through or sat down, the round is over. For the next round, choose new students. This time, after blindfolding the students place small clumps of chairs (3 or 4) in different places. The point is to spread the chairs out to represent small patches of seagrass. Have the students walk through again and when all are done, the round is over. For the final round, blindfold the students and spread very few chairs (2-4) around the area. Have new students walk through and when they are done, the final round is over.

Discussion
After the activity is over, ask the students questions about the difference between each round. Make the connection between the chairs and the seagrass. The students should see that suspended sediment particles settle to the bottom after being trapped by seagrass. A uniform seagrass bed has the greatest chance of causing the sediment particles to settle.



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**Classroom Activity: Predator Prey Interaction**

Seagrasses provide a safe habitat to many small fish and crustaceans. If seagrass meadows are present, it is hard for predators to find their prey. However, on mudflats there is nowhere for these small animals to hide.

Objective
This activity will show students the role of seagrass in the protection of small fish.

Materials

- Construction paper
- About 80 Paperclips
- 4 Blindfolds
- 2 Plastic bins

Procedure
Rip the construction paper into long strips (construction paper represents seagrass). Place all of the ripped paper into one bin. Use half of the paperclips in the bins with the construction paper. Attach some of the paperclips to the construction paper and spread the rest on the bottom of the bin. Spread the other half of the paperclips in the bottom of the other bin. Pick 4 students to participate. Blindfold each student. Assign two of the students to one bin and the other two to the other bin. Each team will have 30 seconds to pick through their bin (students may only directly reach down and pick up paperclips, not rub their hands against the bottom). Once someone has picked up a paperclip, they may place it outside of the bin. After 30 seconds, count the number of paperclips that were picked out of each bin.

Discussion
After the activity is finished, ask students what the difference was between the two bins. Make the connection between the paper and the seagrass. The team with the seagrass in their bin should have captured fewer paperclips because the seagrass protects the "prey" from predators.



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**CHAPTER 4: Coral Reef Exploration**





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## Chapter 4: Coral Reef Exploration

Related PPT Presentation: Coral Reefs: Coastal Lagoon Curriculum
Related Video: Coral Reefs 101: National Geographic

Coral reefs are believed to have the highest biodiversity of any ecosystem on the planet, even more than tropical rainforests. Biodiversity is the variety of living species that can be found in a particular place. These tropical marine communities occupy less than 1% of the ocean floor but are inhabited by at least 25% of all marine life. Scientists estimate that more than 25,000 described species from thirty-two of the world's thirty-three animal phyla live in reef habitats - four times the number of animal phyla found in tropical rainforests. Tropical rain forests and coral reefs are similar in that the basic physical structure of both communities is produced by organisms or living things. Coral reefs are massive; in fact, they are considered not only biological communities but geological structures, the largest geological features built by organisms.

Coral reefs are one of the oldest continuous environments on Earth. Coral reefs first formed more than 500 million years ago in warm tropical climates, and since that time they have successfully developed and supported an extensive variety of plant and animal life. Although they have a long history, coral is particularly sensitive to natural and human disturbances that continue to challenge the survival of these beautiful ecosystems.

Over a vast region of the tropics (millions of square miles), the shallow inshore waters are dominated by coral reefs, and such reefs are often used to define the limits of the tropical marine environment. Coral reefs have been estimated to inhabit about 600,000 square miles of the Earth's surface or about 0.17% of the total area of the planet. Although coral reefs can be very big, they grow very slowly. Reefs grow at an average rate of 0.5 cm to 2.8 cm per year.



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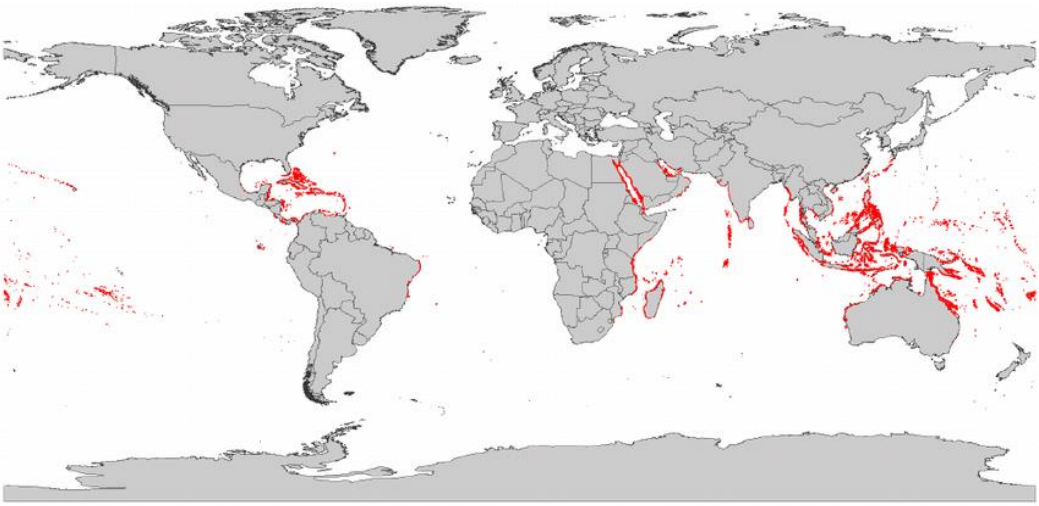

*Map of Global Coral Reef Distribution*

In addition to their high diversity, coral reefs are very productive communities. They play a critical role as habitat and nursery grounds for 10% to 20% of the world's fisheries. The spaces and cracks in the hard coral provide shelter and feeding grounds for many marine animals such as worms, urchins, sponges, sea fans, molluscs, crabs, shrimps, sea anemones and fish. Some of these animals use the dead coral skeletons as a solid place to attach themselves. For many it is a hunting ground, a place to breed and raise young and a safe place to hide as shelter.

The coral reef ecosystem contains delicate and complex interconnected relationships between many organisms. They are intimately connected to other marine communities such as mangrove forests, seagrass beds, and the open seas as water currents transport larvae, plants, animals, nutrients, and organic material.

## The Amazing Coral Polyp

Although a coral reef can seem like an area of only rocks and plants, a coral reef is a living structure made up of tiny coral animals called polyps. Coral polyps are tiny, soft,

transparent, flowerlike animals. The polyp is a hollow sac-like structure that measures from 1mm to 60mm in diameter. Imagine a small animal the size of the tip of your little finger!  Coral reefs are extremely sensitive to external pressures. These animals have a body that only opens at one end, the mouth. Each polyp has a mouth surrounded by a ring of tentacles leading to the stomach.  Coral tentacles are armed with sticky, stinging structures called nematocysts that the coral uses to capture tiny animals in the ocean water called plankton.

The stinging nematocysts allow the coral polyp animal to gather food by paralyzing its prey that is passing by. The plankton is brought into the mouth, passes to the opening where it is digested, and nutrients are absorbed. Solid wastes then pass back out through the coral polyp's mouth.

*The Amazing Coral Polyp*

Corals are invertebrates, animals without a backbone, belonging to the class Anthozoa (AN-THO-ZOA) and the phylum Cnidaria (NI-DARIA). Corals, like other anthozoans having a simple body structure with only one body opening, are closely related to other cnidarians such as jellyfish and sea anemones, which float through the water. Anemones are also similar in that, like corals, they attach themselves to a hard surface.

Corals polyps of the type of corals called **hard corals**, remove calcium and carbonate ions from the sea water and use it to build a hard external limestone or calcium carbonate skeleton. The hard, cup-shaped skeleton is built beneath and around their base which secures the fragile polyp to a surface and serves as its protection. The live polyps sit in cups of the limestone structure and are joined to each other by connecting tissue which covers the coral rock. The cup is called the corallite. This limestone skeleton protects the soft, delicate body of the polyp. The mucus, or 'skin', that forms a layer over corals can be damaged simply by the touch of a hand or contact with a snorkeler's fin. Once damaged, the living layer of tissue is exposed to bacteria, which can prove fatal to coral.

A coral reef is made from the skeletons of millions of coral polyps. Coral polyps are connected to other polyps in a colony. This means that the individual polyps are connected together in a single system, sharing nutrients, as well as being individual animals at the same time. A colony is formed of millions of polyps connected together.



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As the coral grows, new polyps are formed. Old coral reefs may be over 100 feet thick, but the living part is only a thin top layer of corals and other organisms, perhaps only a few feet thick on the surface. When polyps die, their skeletons remain, and a new generation of polyps can grow on top of them. After many years, coral growth can form a solid rock structure of great size. They are responsible for building the coral reefs which can be found in many places throughout the warmer oceans.


**When Corals Met Algae**

Reef building corals are dependent on a close relationship with tiny algae (plants) that live within their tissue, the **zooxanthellae** (ZOO-ZAN-THELLY). The algae provide the polyp with food through the process of photosynthesis in which the plant cells use sunlight coming through the water to convert the carbon dioxide and water in the polyp tissue into oxygen and carbohydrates. The oxygen is used by the polyp for respiration and the carbohydrates are used for energy to build its limestone skeleton, similar to the process used by clams, oysters and snails to create their hard shells. In return, the polyp provides the zooxanthellae with nutrients, protection, a place to live, and carbon dioxide, a by product of respiration which is vital for photosynthesis. Corals cannot obtain enough energy from feeding alone to build large colonies and form reefs and zooxanthellae provide the corals with the majority of their energy. Coral reefs are found in the tropics where the warm, clear, shallow water allows enough sunlight to reach the algae living within their tissues. This relationship allows the corals to produce skeletons faster and form reefs. The zooxanthellae are the corals' "solar panels" and provide enough energy to build their skeletons rapidly.

Generation after generation of polyps add to the skeleton, forming corals of an incredible array of shapes and sizes. Coral colonies can grow bigger than a small house and can be several hundred years old. Over thousands of years, the skeletons of many coral colonies living together form reefs.



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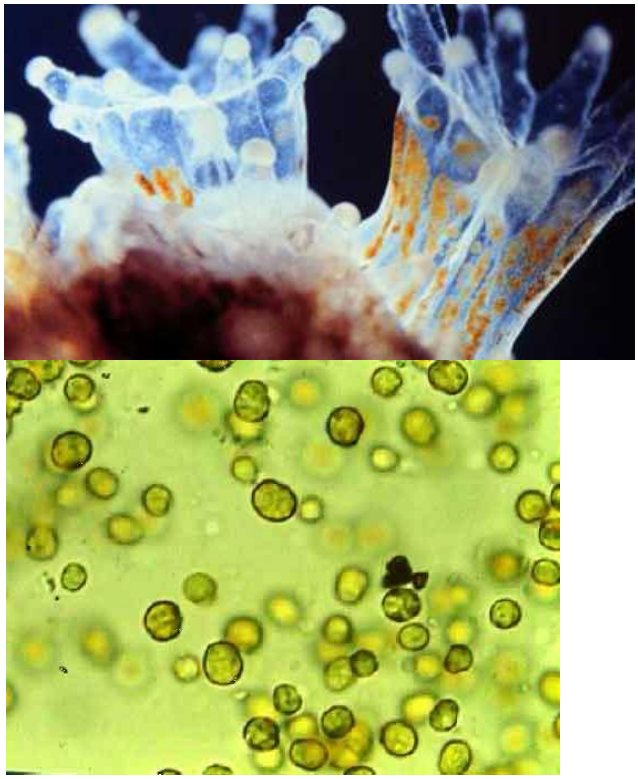

*Zooxanthellae*

Most coral polyps have clear bodies. The color of the coral comes from the color of the zooxanthellae living in the polyp's tissue. This color can vary from white, yellow, brown, and olive to red, green, blue, and purple. Several million zooxanthellae live and produce pigments in just one square inch of coral. These pigments are visible through the clear body of the polyp and are what gives coral its beautiful color. The color of the coral's limestone skeleton is white without the zooxanthellae.

The relationship between a coral and its zooxanthellae is delicately balanced and small changes in environmental conditions, especially seawater temperature, can disturb or even destroy this relationship. With increasing temperature, the algae may die or leave the coral tissue, causing the corals to turn white or 'bleach'. The bleached corals can only survive for a few weeks without the energy supplied from their algae, and if seawater temperatures don't return to normal the corals cannot obtain new zooxanthellae and will die. The Earth's average temperature has been rising at an unprecedented rate, and this global warming may have disastrous effects on coral reefs. During the last 20 years, bleaching events have increased in severity and massive bleaching events have caused entire reef communities to die. In 1998, coral bleaching was so extensive that thousands of kilometers of reefs were damaged. We will learn more about coral bleaching in Cayman waters in the Human Impacts Chapter.

**How Corals Feed**

In addition to getting energy internally from the zooxanthellae, some corals eat plankton. As we learned in the mangrove section, plankton are both plant and animal, that move passively through the water at the mercy of wind and ocean currents. Most plankton are too small for you to see unaided, therefore the microscope activity allowed you to witness and experience this incredible species. The plant plankton is called phytoplankton and the animal plankton is called zooplankton. It is estimated that as much as 60% of the plankton on the reef are eaten by the coral polyps as they drift by.

Coral polyps are nocturnal, feeding mainly at night by catching the tiny animals, zooplankton, with their tentacles. The zooplankton are carried to the coral by water currents. During the day the tentacles are recoiled, and the coral polyps withdraw into their limestone cups for protection. At night they emerge, when they are less likely to be preyed upon, stretching out their tentacles to capture their food.

*Coral during the day on the right and extends its tentacles at night to feed on the left.*

The tentacles have special cells which capture or paralyze prey, after which the tentacles transfer the motionless prey into the mouth. Digestion of the prey takes place in the hollow gut. The special cells are called nematocysts. All animals in the phylum Cnidaria have these special cells.

Food is shared with neighboring polyps in a colony through connections between individuals. Space on a reef is limited and corals will fight with their neighbors including other plants and animals to prevent overgrowth. Coral polyps on the edges of colonies may use long "sweeper tentacles," loaded with nematocysts, to sting many of their neighbors that grow too close.



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Plants are everywhere on the reef. Some are in the water as phytoplankton, but most are in the sand, on the coral rock and in the tissue of animals such as the coral polyps and sponges. This plant material provides the basic food supply for the entire ecosystem. There are many reef animals that eat the plants and these in turn are eaten by other animals. Therefore, energy is passed along a food chain which leads from the plants to the large meat-eaters, such as sharks and barracudas. The links in the food chain are called trophic levels.

**Coral Polyp Growth**

Corals on the reef reproduce in an event called mass pawning which occurs a few nights of each year. Tens to hundreds of species of corals release their eggs and sperm into the water on the same night. The eggs float to the ocean's surface where they can be fertilized, forming new coral larvae called planulae. The coral planulae swim in the ocean for several days to weeks until they settle on the reef bottom and grow into new corals. Corals can also reproduce asexually by budding. During budding the coral polyp will divide to make a nearly identical copy of itself that will remain attached to the parent polyp. A coral colony will form after repeated rounds of budding and can grow to contain hundreds and even thousands of polyps. As new polyps form, they overgrow older polyps that die and add their calcium carbonate skeleton to the foundation of the reef.

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



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genetic diversity and adapt to new conditions. Fortunate night divers can sometimes witness the milky white releases.


*Coral Spawning: Photos by Ellen Cuylaerts*

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

**Coral Reef Development and Types of Corals**

Corals are found throughout the world's oceans, in polar, temperate and tropical waters. Yet, it is only in the tropics that actual coral reefs are formed. There are two main types of coral: **hermatypic or hard corals** that build reefs; and **ahermatypic or soft corals** that do not build reefs. Ahermatypic corals are distributed worldwide; hermatypic corals are found only in the tropical regions. Coral reef distribution will be further discussed in the next Chapter.

Another important difference between the hard corals and the soft corals is that hard corals contain zooxanthellae within their tissue and the soft corals do not. Zooxanthellae strengthen the growth of hermatypic corals, as well the corals' ability to secrete the calcium carbonate skeletons of the organisms and therefore are very important for reef growth and development.

The coral reef ecosystem is made up of much more than corals and their skeletal remains. Many other organisms live on the reef that also deposit limestone material. Crustaceans, some mollusks and even seaweeds leave behind hard deposits which help build up the reef. Although these creatures help to build the reef, it is the stony corals that create the foundation and most of the structure of the reef.

**TYPES OF CORALS**

**Hard Corals**

Reef-building corals, which secrete a hard external limestone skeleton, are commonly known as hard or stony corals. They characteristically have tentacles in multiples of six and can be found either individually or in colonies. These hard coral colonies develop three basic growth forms: branching, massive, and plate which contribute to the formation of the reef structure.

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

**Soft Corals**

Ahermatypic corals are soft corals and solitary hard corals, they do not contribute substantially to the formation of the reef. Solitary corals grow as individual polyps that do not form colonies. Soft corals are colonial corals that have a flexible skeleton and depend on toxic chemicals in their tissues to protect themselves from predators.




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Some types of corals secrete a flexible or soft skeleton. These are called octocorals, so named for their characteristic eight tentacles. Octocorals include the soft coral, sea fan, black coral, whip coral, and blue coral. Octocorals also grow in colonies on the reef, but do not build reefs. They have branching, ribbon-like shapes and their soft internal skeleton allows them to bend, wave, sway, and spread out in the water. They also grow well in areas where hard corals cannot grow, such as dark caves and overhangs. Some of the soft corals produce toxic compounds that make them unappetizing and protect them from predators. Soft corals thrive in strong currents where they have access to an abundance of plankton.

**Factors Affecting Coral Reef Growth**

Three major physical factors limit coral reef development: temperature, light and depth. Most corals thrive in shallow, clear, sunlit saltwater with a temperature between 26°C and 27°C. If the temperature goes below 20°C or above 29°C for a prolonged period of time, most coral will die. Shallow water coral reefs occupy approximately 284,300 square kilometers of the sea floor (less than 1%). Light is one of the most important factors limiting coral reefs. Reef-building corals prefer clear and shallow water, where lots of sunlight filters through to their symbiotic algae. Corals don't thrive when the water is murky or cloudy for extended lengths of time. Sufficient light must be available to allow photosynthesis by the symbiotic zooxanthellae in coral tissue. Without sufficient light, photosynthesis is reduced and with it the ability of the corals to secrete calcium carbonate and produce the reefs.

Most reefs grow in less than 25 m of water. This explains why coral reefs are restricted to the margins of continents or islands. The depth restriction is due to the light requirement of hermatypic or reef building corals.  It is possible to find coral reefs at depths exceeding 91 m, but reef-building corals generally grow best at depths shallower than 70 m. Other factors influencing coral distribution are availability of hard-bottom substrate, and the presence of species that help control macroalgae, like urchins and herbivorous fish. Sediment and plankton can cloud water, which also decreases the amount of sunlight that reaches the zooxanthellae. Corals are sensitive to pollution and sediments. Sediment can create cloudy water and be deposited on corals, blocking out the sun and harming the coral polyps. Wastewater discharged into the ocean near the reef can contain too many nutrients that cause seaweeds to overgrow the reef. In addition, corals need saltwater to survive and require a certain balance in the ratio of salt to water. This is why corals don't live in areas where rivers drain fresh water into the ocean, areas called estuaries.

An interesting fact is that reefs are reduced or absent from large areas on the west coast of south and Central America and from the west coast of Africa, both of which are areas well within the tropics. The reason for the great absence of reefs in these areas is that the west coasts of both continents are areas of strong upwellings of cold water from the deep, which reduces the temperature of the shallow inshore waters below that required for reef development in many places. Below 50m, the reef-building hard corals start to diminish, then gradually disappear, yet coral communities can still be found in shallow or deep waters.

Coral ecosystems found at depths ranging from 30-40 m and extending to over 150 m in tropical and subtropical regions are called Mesophotic. These coral ecosystems exist in a world between worlds, in the middle light zone and may be thought of as extensions of shallow coral ecosystems and often share common species. These ecosystems are characterized by the presence of corals and associated communities found at water depths where light penetration is low. The term mesophotic literally translates to 'meso' for middle and 'photic' for light. The fact that they contain zooxanthellae and require light distinguishes these corals from true deep-sea corals. Often the corals will grow in forms that allow them to get as much light as possible.

Deep sea coral communities thrive on continental shelves and slopes around the world, sometimes thousands of meters below the ocean surface. Unlike the well-studied tropical coral reefs, these corals inhabit deeper waters on continental shelves, slopes, canyons, and seamounts in waters ranging from 50 m to over 3,000 m in depth. A few species also extend into shallower, cold waters in the northern latitudes. Deep sea corals are found in all oceans, including the Sub-Antarctic. Like their shallow-dwelling relatives, deep sea corals exhibit high biodiversity.

The hard or stony corals provide the main structural framework of the reef system and other organisms, such as coralline algae and protozoans, bind and cement everything together with sheetlike growth that stabilizes the reef. Organisms that don't like to move attach themselves to the hard framework, similar to what you will see along a rocky shore. At the same time, there are areas of sand that require a different set of adaptations. Sand and sediments are created by boring organisms, such as sponges and bivalves (i.e. clams, oysters); green calcified algae, such as Halimeda, which has calcium carbonate leaf like plates that drop off. Grazers, such as parrotfish and sea urchins attack the coral for food, removing nutrients from the polyps, breaking down their limestone bases, and excreting the waste as sand.



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Similarly, there are areas of heavy wave action and strong currents and areas of virtual calm, where water movement is minimal. Still other areas may have a lush growth of the calcareous green algae (halimeda) mimicking seagrass beds. In other areas, there are mangroves or actual seagrass beds. All of these types of habitats are found in a relatively small area. Although corals are the main organisms that form the basic reef structure, there is a bewildering array of other organisms associated with reefs, such that these areas are perhaps the most diverse and species rich areas that exist in the marine environment today. Members of practically all phyla and classes may be found on coral reefs.



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## Activity - Build a Coral Polyp

By building an edible coral polyp, students will learn the anatomy of coral and be able to explain why corals are animals, rather than plants.

Materials

- paper towels/rag for clean-up
- plates (1 per student)
- toothpicks (1 per student)
- plastic straw (1 per student)
- Section of a banana (1 per student)
- Sour candy or Twizzlers cut into 1-inch pieces, or pretzel sticks for younger students (6 per student)
- sugar sprinkles (1 per group of students)
- jam
- Round crackers (1 per student) and Oyster crackers (5-6 per student)
- Coral Polyp handout (1 per student)
- Coral Reef Episode - Netflix series

Activity
Preparation
1. Set out enough plates for each student to have one.
2. On each plate, place...
• 1 piece banana
• 1 toothpick
• 1 straw
• six candy straws/twizzlers • small pile of sprinkles
• 6-8 oyster crackers • 1 round cracker
• small amount of jam

Discussion

1. Ask students, “How many of you think coral is a plant? How many of you think coral is an animal?”
2. Corals are animals! Go over some of the big differences between plants and animals. Make a table on the board.



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*Please see Table for Differences Between Plants and Animals*

3. Show students the coral polyp overhead transparency and discuss all of the labeled parts: tentacles, mouth, gut, skeleton, and zooxanthellae. Find pertinent information for this discussion in the background section above. (Note that it is very difficult to draw a typical coral polyp as there is a lot of variation in their forms. This illustration shows the basic components of coral polyps. Although the skeleton sits underneath the polyp in this illustration, the skeleton is actually outside the polyp itself and the polyp can contract and retract inside the calcium carbonate skeleton for protection.)
4. Ask students,"What makes this coral polyp an animal?"*(It eats other organisms by capturing them with its tentacles. It does not have plant parts. It cannot make food from the sun's energy without the help of zooxanthellae.)*
5. Tell students they are going to do a very cool activity: make an edible coral polyp.
6. Hand out one plate of materials to each student.

**Directions for Making a Coral Polyp**

1. Make a hole (the mouth) in the top half of the banana with a straw. Be careful not to go all the way through the banana as coral polyps have one hole, not two.

2. Create six holes with a toothpick surrounding the central mouth.

3. Poke 6 candy straws or twizzlers (the tentacles) into the holes.

4. Add Sprinkles (zooxanthellae) to the banana.

5. Add round cracker and jam (coral is attached to the substrate).

6. Add oyster crackers around the base (calcium carbonate skeleton).



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7. Students can place individual coral polyps together to form a colony.



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## Example table of key differences between plants and animals

*The example table below shows just some of the key differences between plants and animals that students might think of. Keep in mind that the sophistication of students' answers will vary based on grade level.*

| PLANTS | ANIMALS |
|---|---|
| Use sunlight to make energy with photosynthesis | Cannot produce their own energy from the sun and must consume other organisms for energy |
| Have roots, stems, and leaves | Do not have roots, stems, or leaves |
| Generally do not move around from one place to another | Generally must move around from place to place, often to consume other organisms for energy |
| Plants have chlorophyll in their cells that capture light energy | Animals do not have chlorophyll in their cells |
| Plant cells have cell walls | Animal cells don't have walls and their cells are more flexible and variable in shape |



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## Build a Coral Polyp

# Coral Polyp Parts

### What do these parts represent?

Banana

Oyster Crackers

Candy / Straws

Round Crackers

Sprinkles

Hole in the Center

**Build a Coral Polyp** CORAL REEF

How is the coral polyp you built *similar* and *different* from real coral polyps that live on a coral reef in the ocean? Record your ideas in the chart below.

| Part of polyp | What does this part represent in the *real world*? | It is like the real thing because... | It is different than the real thing because... |
|---|---|---|---|
| Banana | | | |
| Hole in the center of the banana | | | |
| Twizzlers or pretzels | | | |
| Sprinkles | | | |
| Broken up crackers surrounding the banana | | | |
| Bottom cracker | | | |
| Jelly on the cracker | | | |

Name _____

Date _____

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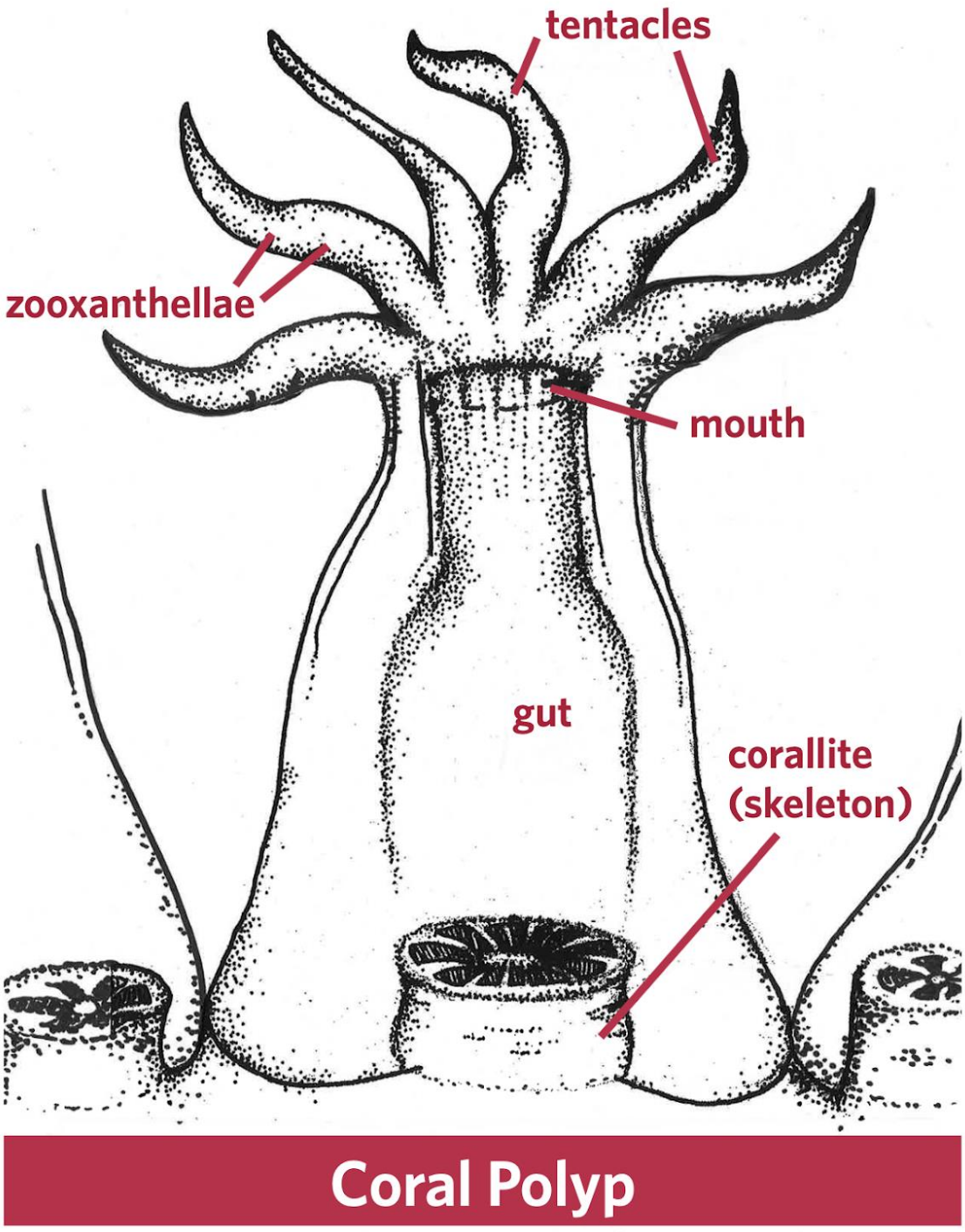




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Wrap-Up

- Hand out one coral polyp worksheet to each student.
- Students draw their coral polyp and answer the questions on the worksheet.
- Remind students that there are a lot of different animals that live on reefs. People
  sometimes call coral reefs the “rainforests of the ocean” because there are so many
  different animals there just like in the rainforests.
- Tell students they can pretend to be predatory fish, such as parrotfish, that eat coral.
  Students can eat their polyps, but since fish don’t have hands encourage your students
  to eat without using their hands.
- Discuss coral reef threats and conservation with your students.
- Explain that coral reefs are in danger of disappearing because of changes that people are making to the oceans.
- What do you think people are doing to change the reefs? (*fishing too much, polluting,*
  *physically damaging the reef by taking coral or anchoring on top of coral, breaking off coral while swimming, taking coral for jewelry, developing coastal areas which can cause increased sediment in the water and smother coral, and climate change is making the water too warm and too acidic)*
- What can we do? (*Reduce, reuse, and recycle to help stop pollution, don’t get too close to reefs, don’t buy coral jewelry, reduce fossil fuel emissions associated with climate change, and help spread the word to friends and family).*

## References

Adapted from:
1. Ayres, R. California Academy of Sciences. *Coral Polyp Party.*
2. California Academy of Sciences' Educator Resource Materials. (2007). *Coral Symbiosis:*
*Coral Polyp and Zooxanthellae.*
University of California Museum of Paleontology, Taxon Lift. *Introduction to Cnidaria.* April 28, 2008 from http://www.ucmp.berkeley.edu/help/taxaform.html



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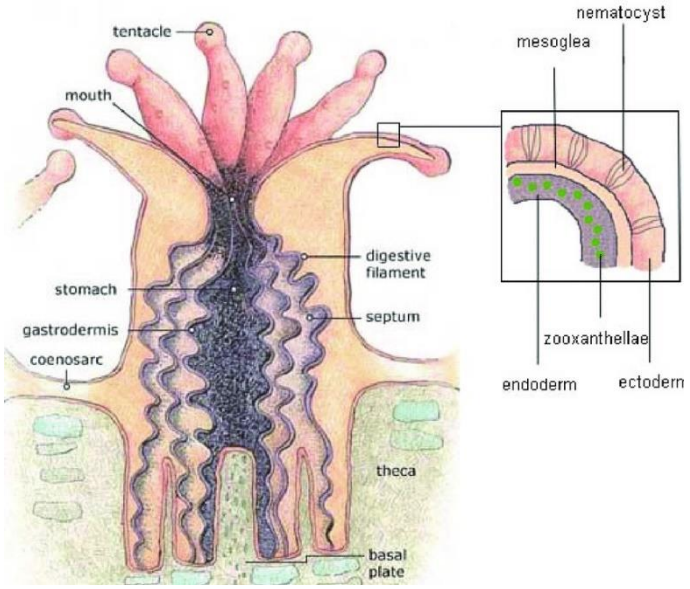
## Classroom Activity:

### Investigating the Coral Polyp

Collect a few dead pieces of rock-like coral material from the beach. These pieces can tell a lot about the animals when they were alive. They can be used in a guided discovery lesson to teach students about the coral polyp. It is important that students know that the substance they call coral is really formed by a once living animal. Instruct students to carry out the following observations of their specimens: a worksheet with questions and spaces for written answers and diagrams may be used to help guide students' observations. Please emphasize to students that they must not take live coral for study.




### Equipment and materials

Dead pieces of coral - coral rock from the beach
Hand lens
Beaker with enough water to submerge specimen
Stem of a papaya tree
Knife
Hammer
Dilute hydrochloric acid (HCl)

1. Look at the coral specimens. You may use a hand lens. Is it alive or dead? What evidence do you have for your answer?
2. Is the material porous (filled with tiny holes or air spaces)? Check by putting a piece in a container of water and look carefully for escaping air bubbles
3. Is the material hard or soft? Try crushing a few pieces with a hammer. Were they easy or difficult to crush?
4. To find out what chemical substance the rocklike coral material is made of, put a small piece of it into some dilute hydrochloric acid. Write down your observations. Use a chemistry textbook and find the name of the chemical which gives such a reaction.
5. Closely examine the holes in the specimen. Suggest what was once in each hole. Note the pattern of the holes on the specimen.
6. Now look at the diagram of a real polyp. Draw a labeled sketch of the coral polyp. Suggest what the tentacles and mouth are used for.



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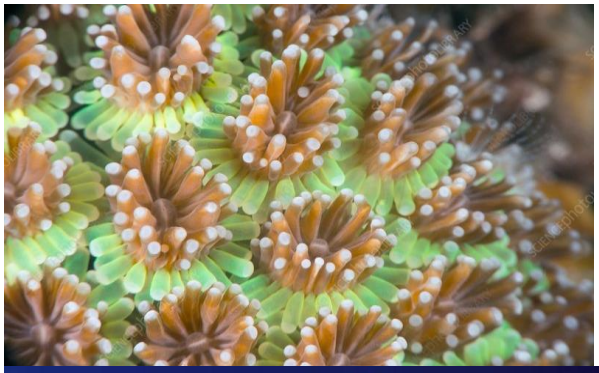
7. To get a better idea of what the middle region of the coral polyp looks like, cut across a stem of the papaya tree and examine the hollow part. Cut the stem down (lengthwise) and note the shape of the hollow part. The inside of a coral polyp is also hollow, but the stem is hard while the coral polyp is soft.

Name:
Date:

## Coral Polyp Observations



Please use this space to write down your observations of the coral-rock and include your drawings:



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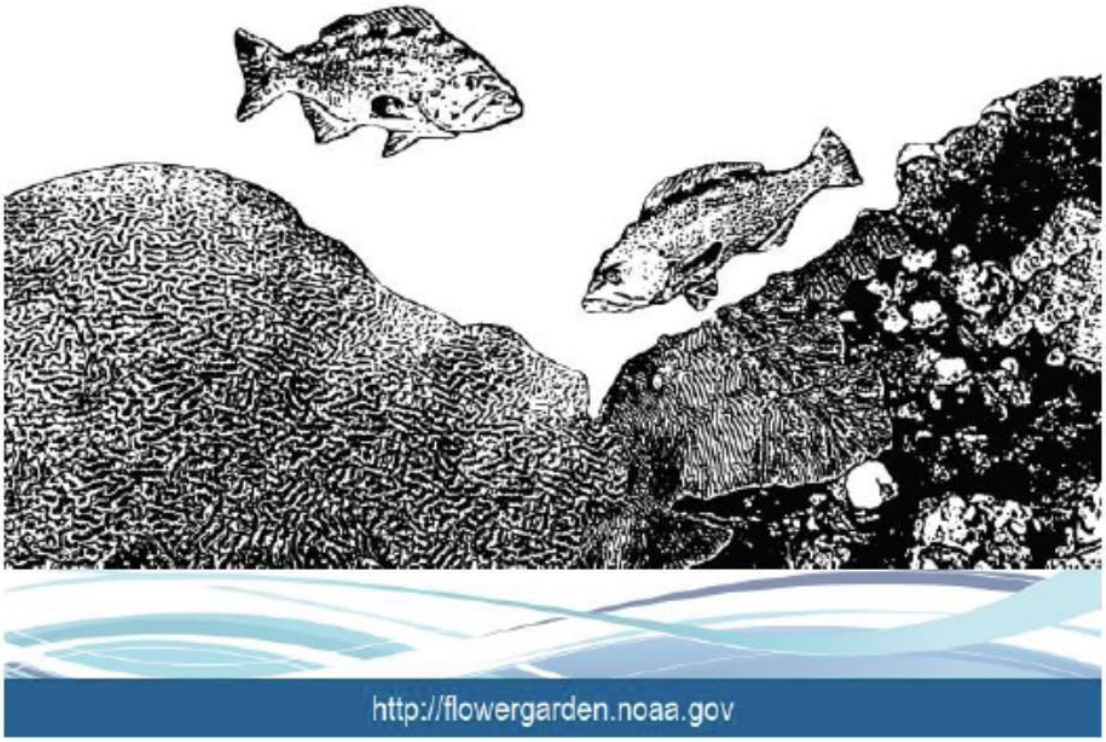
# Coral Reef Word Search

**Word List**

| | | |
|---|---|---|
| Algae | Manta Ray | Salt Dome |
| Barracuda | Marine Debris | Scuba |
| Bleaching | Mesophotic Zone | Shark |
| Boat | Mooring Buoy | Shrimp |
| Brain Coral | Moray Eel | Spiny Lobster |
| Conch | Nematocyst | Sponge |
| Coral | Octopus | Star Coral |
| Crab | Parrotfish | Urchin |
| Current | Polyp | Waves |
| Jellyfish | Reef | Zooxanthellae |
| Loggerhead Turtle | ROV | |



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**Virtual Field Trip Video: Coral Reef Creature**

In the box, draw a picture of one of the creatures you saw on your virtual field trip to the coral reefs. Then answer the questions that follow.

What adaptations does the creature have?

How do the adaptations help it survive on a coral reef?

Is this creature considered a predator or prey? How do you know?



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**CHAPTER 5: Coral Reef Locations and Structures**





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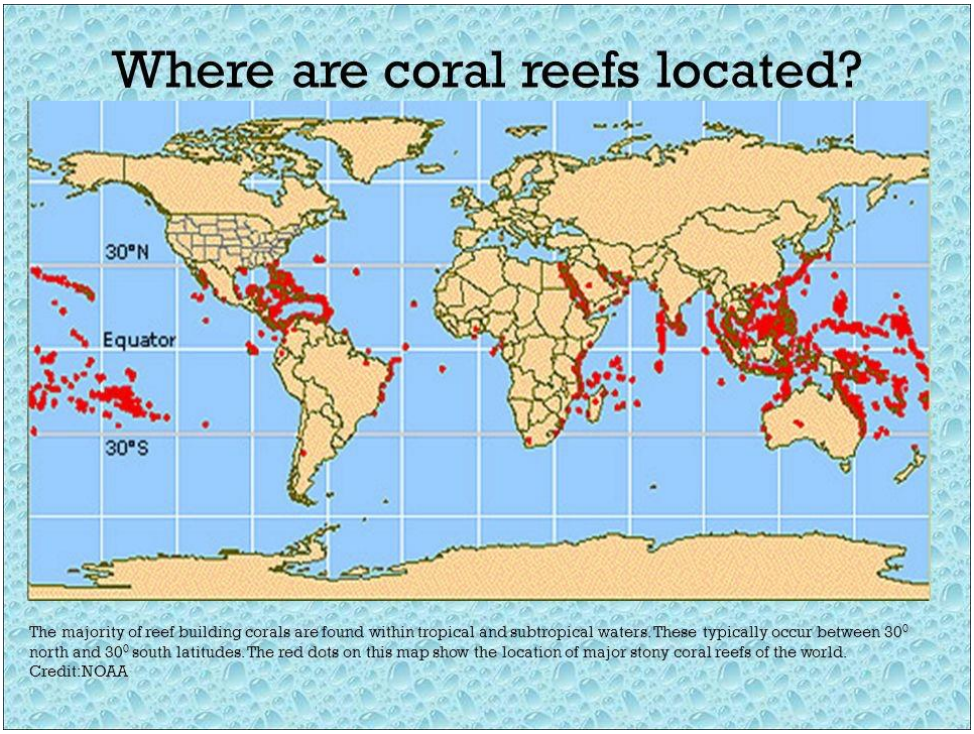
## Chapter 5 - Coral Reef Locations and Structures

### Location of Coral Reefs - Where are they found?

The marine environment is made up of a diversity of habitats, it has the same level of diversity as better-known land-based habitats. There are seagrass meadows and kelp and mangrove forests, undersea canyons and mountains deeper than Mount Everest is high. There are rocky shores and sandy bottoms. There are the beautiful formations and communities of the coral reef.

Coral reefs are found throughout the warm, shallow tropical oceans of the world, most are located between 20°N (tropic of Cancer, 23°27') and 20°S (tropic of Capricorn, 23°27') of the equator. The major coral reef regions in the world are the Indo-West Pacific, the Western Atlantic and the Red Sea. The Indo-West Pacific region spans from the Red Sea through Australia to the Indian Ocean and to Africa. It is the largest coral reef region in the world with the greatest diversity of coral and fish species. The Western Atlantic region spans from Florida to Brazil, and includes the Caribbean, Bermuda, and the Gulf of Mexico. The Red Sea is the smallest of the three regions, located between Africa and Saudi Arabia. It is considered a separate region because of the biodiversity found only in this area. Reefs are also found in the tropical eastern Atlantic and Eastern Pacific, but they are less developed and less diverse.



The majority of reef building corals are found within tropical and subtropical waters. These typically occur between 30° north and 30° south latitudes. The red dots on this map show the location of major stony coral reefs of the world.
Credit: NOAA

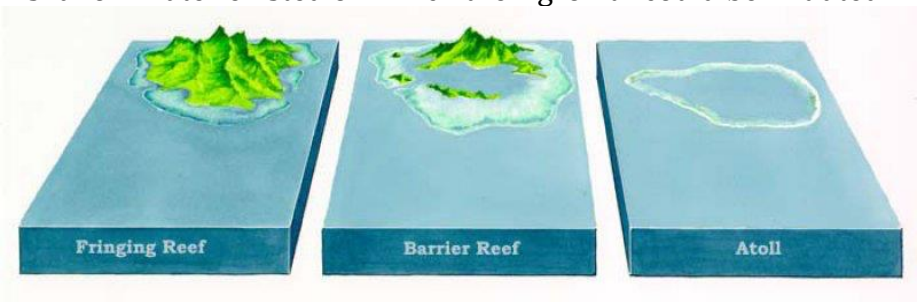
Based upon geographic distribution, 60% of the world's reefs are in the Indian Ocean and Red Sea, 25% are in the Pacific Ocean, and 15% in the Caribbean. The reefs of the Western Atlantic region evolved later than those of the Indo-Pacific/ Red Sea region because of the youth of the Atlantic Ocean. These reefs do not have the great abundance and diversity of reef species that are found in the older Indo-Pacific/Red Sea area where the prehistoric Tethys Sea was located.

Shallow tropical reefs in the Indian and Pacific Oceans boast the most coral species. To date, almost 800 species of reef-building corals have been identified, with new discoveries occurring each year. Of the known species, the majority are found in the Indian and Pacific oceans—an area known as the Indo-Pacific region. There are over 600 species of coral found in the Coral Triangle alone—a region encompassing the waters around the Philippines, Malaysia, Indonesia, Timor-Leste, Papua New Guinea, and the Solomon Islands—making this region the global hotspot of coral diversity.

Reefs in the Atlantic and Caribbean area are younger compared to the South Pacific and Indonesia. These reefs are all geologically very recent, most dating only from the last glacial age or 10,000 to 15,000 years before the present. Perhaps even more remarkable is the finding cited by the world's largest reef system, the Great Barrier Reef of Australia is at least 40 times younger than previously thought, with new estimates of its age ranging from 500 thousand years to as young as 9 thousand years.

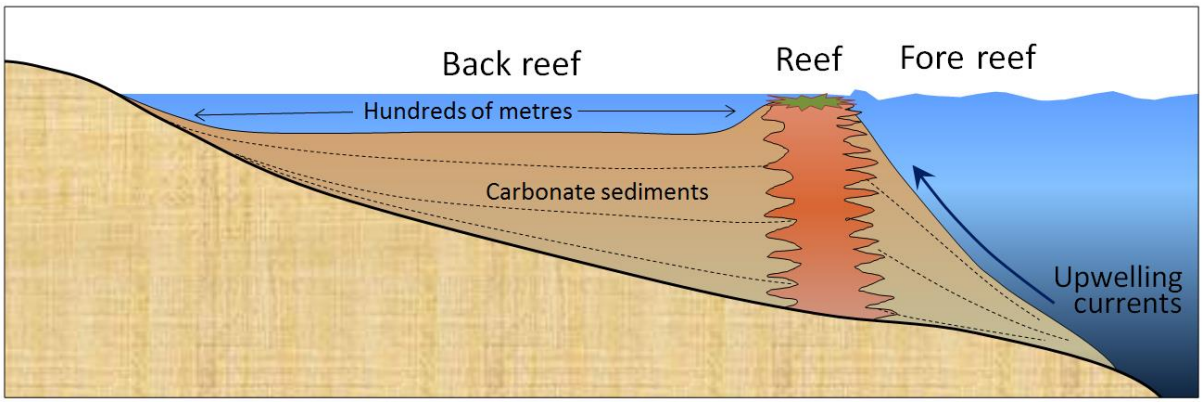
**Types of Coral Reef Structures**

Coral reefs found in the world's oceans exist in different sizes and shapes. The three main types are fringing reefs, barrier reefs and atolls. Fringing reefs form just off the coast of a continent or an island and usually progress from a shallow sandy lagoon to the reef crest where the most wave resistant corals grow. They further develop to the reef face where the majority of the coral species are found. Barrier reefs form farther offshore, usually 10-100 kilometers from the coast, and often form massive walls of coral separated from the coast by a large channel or lagoon. Atolls are circular reefs surrounding a lagoon that form when volcanic islands sink into the ocean over millions of years. The extensive reefs around the Indonesian Island, the Philippines, New Guinea, Fiji, most of the Caribbean Islands and Florida were developed because a suitable substrate in shallow water existed on which their growth could be initiated.




**Fringing reefs**

Fringing reefs grow out from the shores of the land masses where the water is shallow. This type of reef grows near the coastline around islands and continents. They are separated from the shore by narrow, shallow lagoons. Fringing reefs are the most common type of reef that we see. This type of reef can be divided into two areas, the reef front and the reef flat. The reef front is the area on the ocean side. Corals grow very fast in this area because it is where conditions are the best. Behind the reef front is a shallow, flat area called the reef flat. It extends all the way to the shore. Coral rubble (pieces of skeletons of dead coral), sand and a few living corals are found in this area. Very little coral growth takes place on the reef flat because conditions are not very favorable.




There are many reasons why conditions on the reef flat are not as good as those on the reef front. Water is often trapped here at low tide. When the sun is very hot, water evaporates and the water that is left can become very salty and very hot. When it rains, the fresh water collects here, the water may not be salty enough. The reef front is consistently exposed to the ocean; therefore conditions are consistent and more favorable for coral reef growth.

Many islands in the Caribbean have fringing reefs around their coastline, including Grand Cayman. The reef line that extends across the edge of the North Sound, from Barkers to Rum Point, is a fringing reef.

**Barrier Reefs**

The barrier reef also parallels the coastline but is found much farther from the shore and is separated by a deeper and wider lagoon. Similar to the fringing reef, the barrier reef has a reef front and a reef flat. Corals may grow well in the lagoon, forming inner patch reefs. Small boats often use the quiet, protected waters of the lagoons, but they have to be careful not to run into the reef where it is shallow, and it grows close to the surface. At their shallowest point, they can reach the water's surface forming a "barrier" to navigation.



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The largest barrier reef is the Great Barrier Reef of Australia, which stretches for almost 2,000 km along the eastern coast of Australia, from near New Guinea to just north of Brisbane. The Belize Barrier Reef is the second largest in the world. It is found in the Caribbean Sea, about 20 to 40 km from the coast of Belize and is 200 km long. The Great Barrier Reef in Australia is the largest and most famous barrier reef in the world.

**Atolls**

Atolls are located in deep, clear water through remote areas in the middle of the ocean, far from any shore. They are really small islands of coral. Atolls are usually easily distinguished because they resemble horseshoe-shaped reefs that rise out of very deep water far from land and enclose a lagoon, which may contain lagoon reefs or patch reefs. The majority of formed atolls are found in the Indo-Pacific area and develop on the top of seamounts.

The coral reef forms a circle, and in the middle of the circle is a shallow lagoon. Atoll reefs sometimes get pushed above the sea level in places or get coral sand accumulating and form small islands within the reef. Some of these islands are big enough for palm trees to grow on or even for people to live there.

Atolls usually form when islands surrounded by fringing reefs sink into the sea or the sea level rises around them. A tropical volcanic island furnishes the shallow underwater base on which the coral grows. Eventually, the island becomes surrounded by a fringing reef which is separated in places from the island by only a shallow, narrow strip of water. The fringing reefs continue to grow and eventually form circles with lagoons inside.



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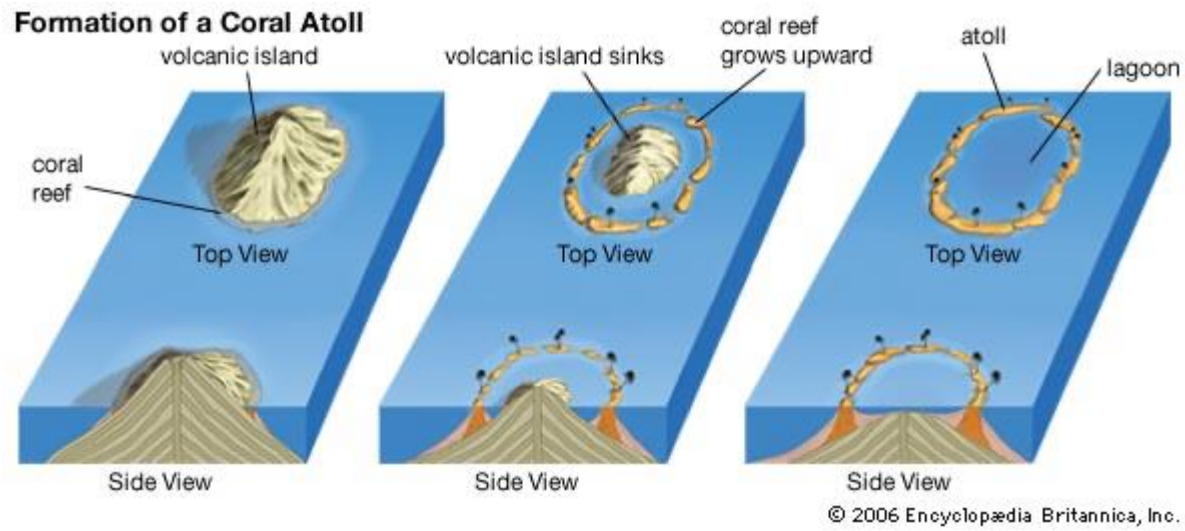


If the island sinks gradually into the water, then a channel develops between the land and the coral forming a barrier reef. A similar process can occur with larger land masses due to the shifting of crustal plates. The Great Barrier Reef is the best example of this.

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

The world's largest atoll, located in the Marshall Islands in the Pacific, Kwajalein is almost 129 km long. There are about fourteen atolls in the Caribbean Basin. Three of these are found on the Belize Barrier Reef. They are the Lighthouse Reef, Turneffe Island and Clovers Reef.

**Patch & Bank Reefs**

Other types of reefs found in the Caribbean are patch reefs and bank reefs. Patch reefs are isolated patches of reef on parts of the seafloor that rise close to the surface. They usually occur between fringing reefs and barrier reefs. Patch reefs may have large areas of sand or beds of seagrasses or algae surrounding the patch and are common in shallow lagoons. If parts of the patch reef are pushed above sea level a white sandy island called a coral cay may form.

Coral cays are made entirely from the sand produced by coral reefs. Small cays are easily shifted by waves because the sand is very loose. But over a period of time, plant growth helps the sand to become fixed. Birds and other animals make their homes on cays. The Cayman Islands have several coral cay islands.

Bank reefs are found offshore on raised parts of the seabed and are usually parallel to the coastline. They may be quite deep as much as 20 m to 40 m below the sea's surface so that their tops are never exposed. However, in some areas they can be quite shallow, causing the waves to break. Where this occurs, the reefs are called bank/barrier reefs. Coral growth occurs mainly at the top of the bank reef. Twelve-mile bank off Cayman is an example of the deep type of area, it is known for its good fishing as the fish are attracted to the coral reef habitat.

**Reefs of the Cayman Islands and the Deep Ocean**

People are commonly unaware of the underwater world that surrounds them and of the dynamic ecological and geological history that is preserved there. The continuing adventure of exploring the ocean, from shore to deepest depths, allows us to increase our knowledge of our entire planet and of ourselves.

The life of a drop of water is constantly changing. At times it moves over the land, it may stay suspended in the air, or it may drop in the deep blue of the ocean. Over geologic time, sea level will rise and fall to influence different areas of the earth. A 'sudden' transformation in the earth's climate or ocean circulation could create these changes



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over thousands or millions of years. People in North America lived along shorelines that are now underwater and once there were coral reefs in Pennsylvania.

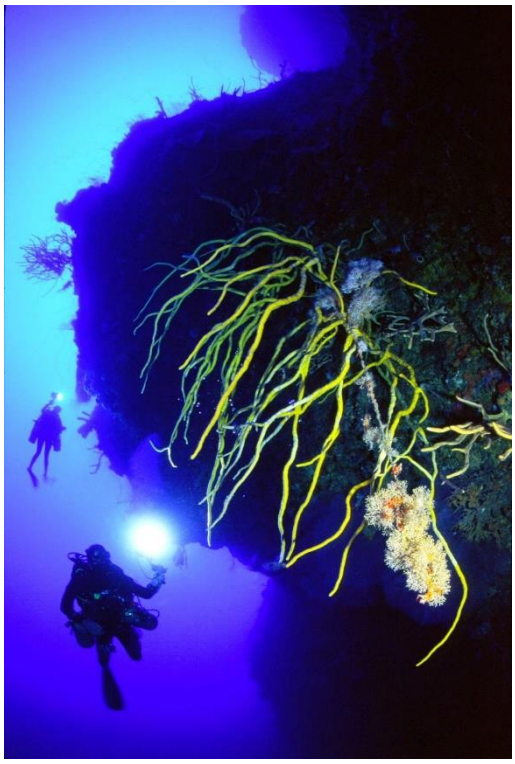

Photo1. Photograph of yellow Aplysina cauliformis at 91m. Photo by Courtney Platt, ©2002 CourtneyPlatt.com

As a student, you can learn and discuss why reefs were once found on tops of mountains and why ancient shorelines are now submerged. By studying geologic records, you can understand and appreciate the dynamic environment of the Earth and ocean. Knowledge of the geologic history of the island allows for an appreciation of the amount of time involved in the evolution of the islands. This history precedes human activities, yet it is our activity now that may most affect it.

The Cayman Islands consists of three small islands situated about 200 km southwest of Cuba. Cayman Brac and Little Cayman are the smaller of the islands, located northeast from Grand Cayman Island. The Cayman Islands are peaks on the Cayman Ridge, a south westward submarine extension or underwater mountain range of the Sierra Maestra Range in Cuba. The Cayman Trench is a submarine trench on the bottom of the western Caribbean Sea between Jamaica and the southeastern tip of Cuba. The Cayman Trench is one of the deepest sections of ocean in the world, reaching depths of 7,686m or 25,216 feet.

The underwater topography around the islands are like mountain slopes. The area along the Wall at approximately 80 m is like a secret garden. Divers term this depth the “Sponge Belt”. It is concentrated at about 75 m to 100 m and seems to continue along the entire northwest portion of the island. Found mainly in the Caribbean, calcified sponges are usually found in caves and crevices of submarine shadows at depths of 5 m and up to 200 m. The group has an extraordinary range of morphologies, textures, and colors and its showcase seems to be



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situated in this sponge belt zone. At 85 m there are large (30 cm) red sponges, tube sponges, barrel sponges, and an increase in lace corals (hydrocorals) and hydroids (cnidarians).

Photo 2. Photograph of a portion of the Wall referred to as the Sponge Belt, including an Orange Elephant Ear sponge (Agelas clathrodes), ~ depth of 90m. Photo by Courtney Platt, ©2002 CourtneyPlatt.com

Rope sponges (Aplysina cauliformis) are the dominant sponge at 91 m (Photo 1) and clusters of luminous white tube sponges extend 3m from the wall. Below 106 m, the wall has a very barren appearance. Demosponges and algae seem to dominate. “Flattened” yellow barrel sponges are observed between 91 m to 121 m. They are tilted toward the sea and two of these sponges are found on the near vertical portion of the wall. Pink encrusting sponge is also observed. Large Orange Elephant ear sponges are also observed at these depths (Photo 2).

We will understand why we need to protect something only when we know there is something to protect. The incredible amount of life that exists in the deep waters displays a beautiful and exotic ecosystem. There are many photographers and explorers in the Cayman Islands who can share with those who can not see it personally.

Explore the Cayman Trough

Sabrina Douglas first Caymanian to explore depths of Cayman Trench

Journey to Challenger Deep with Explorer Victor Vescovo

See Classroom activities on following pages:



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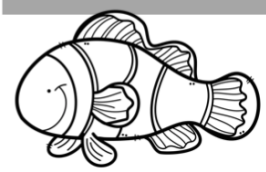

# Coral Reefs
## LABORATORY

## INSTRUCTIONS

I provided you with some samples of corals that I have collected. In the space below draw the coral at you table, write observations about the coral, and answer the questions below.

| Coral Drawing | Observations |
| --- | --- |
| | |

## Analysis Questions ~ Analysis Questions

Why are coral reefs important for the survival of fish? Would fish exist without coral reefs?

Algae depend on coral for survival. Where are algae located in coral? Why do you think they need the coral in order to survive?

How do you think global warming is affecting the coral reefs on the planet? Is this an issue that we should be worried about? Why or why not?



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# Coral Reefs

READING and COMPREHENSION

Read the passage below and write the definitions for each of the following terms. Read the information about the different trophic levels. Answer the questions on the following page about trophic levels

## Biotic Factors: Tropic Levels in a Coral Reef

Coral reefs, like the majority of habitats on the planet, derive their energy from the sun. Solar energy is converted to chemical energy by organisms conducting **photosynthesis**. The **chemical energy** is then passed on to all of the other organisms within the system through **heterotrophic** consumption. To put it simply, plants use sunlight to make their sugar, some animals get this sugar by eating plants, and other animals get this energy by eating plant grazers. This transfer of energy can be tracked in a **trophic level** chart.

**Define** the following terms

PHOTOSYNTHESIS: _____

_____

_____

CHEMICAL ENERGY: _____

_____

HETEROTROPH: _____

_____

_____

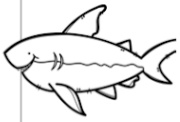
TROPHIC LEVEL: _____

_____

_____

### TERTIARY CONSUMERS

The top-dogs in the coral reef are called tertiary consumers. These organisms eat the organism that each organism that eat the algae. These organisms are completely dependent on all trophic levels below them.

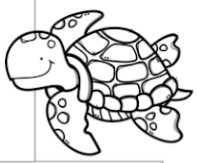


### SECONDARY CONSUMERS

The organisms in this trophic level are carnivores that consume algae-eating organisms. These predators hunt small herbivores fishes hiding within the coral.

### PRIMARY CONSUMERS

Primary consumers are herbivorous organisms that are the first to obtain energy straight from the source: algae making sugars through photosynthesis. Some organisms in this trophic level eat algae, like the filamentous algae that grown on dead coral or rock.



### PRIMARY PRODUCERS

Photosynthetic organisms like phytoplankton, algae, and zooxanthellae found inside coral tissue. These are the most abundant organisms on earth. Some algae work alone, like the fuzzy, filamentous algae found on rocks and dead coral. Other, smaller algae have evolved to live within the cells of coral. Symbiotic algae within the coral are collectively called zooxanthellae.

**Fact** Corals can be categorized as primary producers because they house photosynthetic zooxanthellae, but they can also be categorized as secondary consumers because they actively prey on zooplankton. Scientists call organisms, like coral, that fit into more than one trophic level



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# Biotic factors: TROPHIC LEVELS IN CORAL REEFS

NAME: DATE: PERIOD:

Refer to the previous page with the information on the trophic levels to complete the table below

| Trophic Level | What do they eat? Provide some examples |
|---|---|
| | |
| | |
| | |
| | |

Research the following animals below and determine where they belong on the trophic level chart below based on what they eat.

DUSKY FARMERFISH
ZOOPLANKTON
MORAY EELS
YELLOWLINED GOATFISH
ALGAE
TRUMPET FISH
BLACK JACKS
STRIPED SURGEONFISH
CORALS
SEA STARS
HONEYCOMB GROUPERS
BLACK TIP REEF SHARKS

| | |
|---|---|
| TETIARY CONSUMER | |
| SECONDARY CONSUMER | |
| PRIMARY CONSUMER | |
| PRIMARY PRODUCER | |



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# Abiotic Factors: AFFECTS ON CORAL REEF ECOSYSTEM

Read the table below with the adaptations of corals and abiotic factors

| Abiotic Factors | Effect on Corals |
|---|---|
| SUNLIGHT, CLEAN WATER, & WATER DEPTH | Because of their intimate relationship with zooxanthellae, reef-building corals respond to the environment like plants. Algae need light for photosynthesis, and light best for clear water. Energy from the sun also diminishes with water depth – more water to penetrate means less energy from the light. |
| DISSOLVED OXYGEN AND TEMPERATURE | Oxygen is an element required for respiration in living organisms. There is less oxygen in the water than in air, so coral reef organisms have evolved many adaptations for capturing as much oxygen as possible (such as a high surface area gills in fish). The amount of dissolved oxygen also decreases as water temperature increases. For this reason, organisms that live in areas with high water temperatures (such as coral reefs) need to have adaptations that allow them to function in low oxygen environments. |
| SALINITY | The ocean has a higher concentration of salt than the concentration of salt within bodies of most fishes. Since osmosis dictates a flow of water from high concentration (low salt) to low concentration (high salt), fish within a coral reef tend to lose water from their bodies to their surrounding environment. Many invertebrates (like coral) maintain the same amount of salt within their cells as the surrounding ocean. This is a useful adaptation unless salinity level in the ocean becomes too high that it disrupts protein function within cell, which could lead to death. |

Write adaptations that corals have developed in order to survive in the following conditions

| | |
|---|---|
| DEEP WATER | Corals have adapted to this condition by: |
| LOW OXYGEN CONCENTRATION | Corals have adapted to this condition by: |
| HIGH SALT CONCERTATION | Corals have adapted to this condition by: |



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# Coral Reefs

ASSESSMENT & REFLECTION

Read the scenario below and write how you would handle this situation knowing what you know about coral reefs. Answer the questions in complete sentences. Answer the assessment questions below.

## SCENARIO

You are stranded on a tropical island with the other people at your table, but you are in luck! There are coral reefs in the lagoon around your island. How might you use some of the coral reef abiotic and bioti factors to help you survive? You may draw diagrams and/or write complete sentences to explain your ideas.

## QUIZ

List three biotic factors found coral reefs

Name one secondary consumer you will find in a coral reef

List one adaptation (abiotic factor) that corals have adjusted to in order to survive.



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**CHAPTER 6: Life on a Coral Reef**





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**6: Life on a Coral Reef**

Related ppt presentation: Coral Reef Fish ID: Coastal Lagoon Curriculum
Related Video: Blue Planet Coral Seas

The shallow, warm, crystal-clear waters surrounding the Cayman Islands have provided us with some of nature's most spectacular marine life, none more noteworthy than our breathtaking coral reefs. For hundreds of years, Caymanians have depended on healthy coral reefs to provide food, building materials, medicines, and even decorative objects. To this day, our coral reefs are integral to our island economy thanks to their contribution to tourism and fisheries. In addition, they play a critical role in protecting the shore from storms and hurricanes.

Coral reefs are a vital part of a vast interconnected marine ecosystem that also includes seagrass beds and mangrove wetlands. Each system depends heavily on the others, resulting in a tightly integrated and finely balanced marine environment. It is hard to imagine the massive reef structures and reef walls as fragile, living entities, but coral reefs are extremely sensitive to external pressures and overexploitation.

The coral ecosystem is a community or group of living things, such as coral, fish and marine mammals, that live and interact with their nonliving environment, such as rocks, sand and water. All life interacts with their own species, with other species and with the physical and chemical environments that surround them. In this interactive process, the organisms have effects on each other and on the surrounding environment. Similarly, the different factors in the environment affect the activities of the organisms.

When you snorkel or dive beneath the waves, you may be lucky enough to see turtles, stingrays, colorful parrotfish, angelfish, blue tangs, eels and of course the beautiful coral reef. Life in all its forms swim, dart, lurk and remain motionless. Massive coral structures provide homes for Christmas Tree worms and nudibranchs. The barrel sponge you swim past may have started growing 500 years ago when the first seafarers approached Cayman's shores.



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The 25,000 known species of fish are divided into three main groups. They are the jawless, the cartilaginous and the bony fish. Jawless fish are the last survivors of the world's first vertebrate animals, which means "backboned". They lack both scales and jaws. Dating from over 5000 million years ago, only the hagfish and lampreys remain.

Cartilaginous fish developed about 100 million years later and are ancestors of today's sharks. The skeleton of these fish is made of cartilage, which is not as hard as bone. These fish have jaws, as well as teeth which are usually hard and sharp. Their bodies are covered with hard scales. Bony fish, fish with bony skeletons, appeared at the same time as cartilaginous fish. They are the largest group, with about 20,000 species. These fish have an organ called a swim bladder which gives the animal buoyancy, the ability to float. All fish live in water and breathe with gills. Fish are cold-blooded, which means their internal body temperature changes as the surrounding temperature changes.

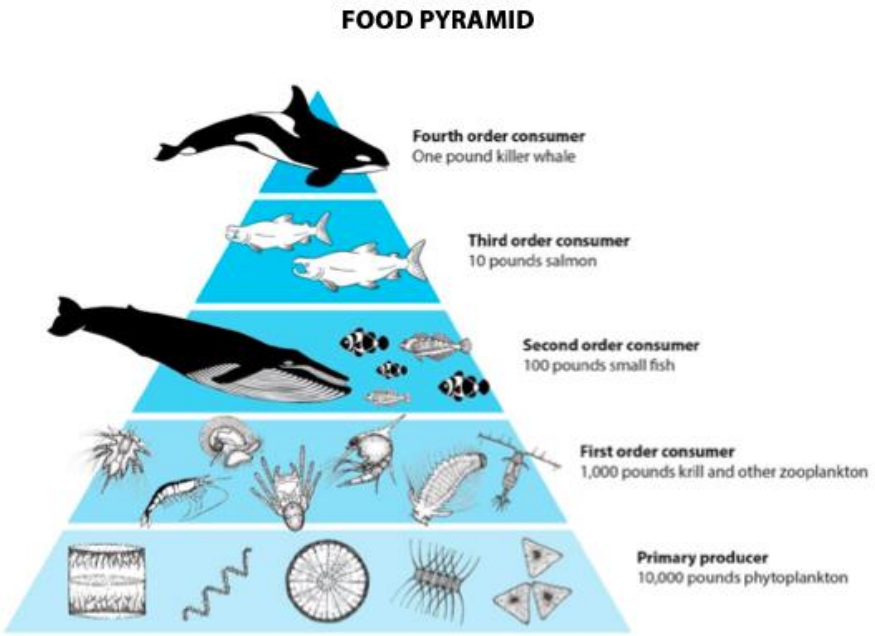
A tremendous variety of life flourishes in the sea. In fact, it is estimated that nine out of every ten organisms on Earth live in the ocean. Tiny one-celled plants floating on the ocean's surface provide the basis for the web of life for water and land animals by making food from the sun's energy. Other plants in the ocean include seaweed and seagrass. Animal life in the ocean can be divided into two categories: vertebrates, animals with backbones and invertebrates, animals without backbones. Invertebrates include animals like oysters, crabs, periwinkles, jellyfish and the octopus. The octopus is believed to be the most intelligent of the invertebrates.

Vertebrates include all fishes, sea turtles and marine mammals. The fish in the sea delight the imagination with a variety of colors, shapes and lifestyles. Sea turtles are reptiles that swim the oceans. The female sea turtle only leaves the ocean to crawl on shore to lay her eggs in a sandy nest. Seals are marine mammals that inhabit all the world's oceans, from the polar areas of Antarctica and Alaska to the beaches of Hawaii. The ocean is also home for the whales, the largest creatures to live on this planet.

**Food Chains and Food Webs**

Food webs are a part of every ecosystem because few animals rely on a single source of food and seldom is any food source consumed by just one kind of animal. The bottom of the food chain is dominated by a great number of very small animals, such as copepods. As the chain grows in length, the size of the animals at each level increases. Link by link, each successive level tends to be made up of larger types of animals.

The flow of energy through such chains is best visualized as a pyramid. The base of the pyramid is formed by vast numbers of microscopic organisms. The top of the pyramid has a few large, predatory animals. From base to top, each succeeding level tends to be dominated by larger organisms which are preying on animals smaller than themselves.




Large size is advantageous in that it is often more difficult to catch and eat a large animal than a small one. However, large animals require large amounts of food to support their size. Special demands are placed on warm blooded animals which live in cold seas, since they must maintain a body temperature well above ambient temperatures. They often must also expend energy to maintain life. Only a little energy is available for growth and reproduction. These limitations help explain why there are a few large animals at the top of the pyramid depending upon billions of minute organisms at the base.

The transfer of energy from the base to peak of the pyramid is governed by the '10%' rule. Simply put, nine-tenths of the food value is lost as heat to the environment at each level of the pyramid. Only about one-tenth of the available energy transfers from one level to the next.

In the following pyramid we see that 10,000 pounds of diatoms are needed to produce 1,000 pounds of zooplankton which produces 100 pounds of fish and squid. The 10 pounds of seal produced by feeding on fish and squid will yield only 1 pound of killer whale. Each pound of whale is supported by 10,000 pounds of phytoplankton. The inefficient transfer of energy limits the number of killer whales which can live and reproduce. It also means killer whales must work hard to obtain the amount of food they may need.

Obviously, it is energetically advantageous to feed on organisms close to the base of the pyramid. Baleen whales (the whale at the third level of the pyramid) exemplify this strategy since they feed directly on zooplankton (krill). The 10,000 pounds of diatoms necessary to support 1 pound of killer whale will produce 100 pounds of baleen whale. This helps to explain why blue whales, the largest animals that ever lived, are plankton

feeding whales. Baleen Whales can afford to be both large and numerous, since they can obtain a large amount of krill with relatively little expenditure of energy.

**Behavior and Special Body Features**
Many animals combine behavior and special body features to ensure their survival. Adaptations are any behavioral or physical characteristics of an animal that help it to survive in its environment. Survival is the name of the game for the animals that live in the sea. Over generations, nature has provided sea creatures with unique characteristics that increase their survival and reproduction chances. It is no coincidence that certain animals exhibit specific color patterns, or live where they do. An animal's shape, behavior , body parts and even its relationships with other animals are all examples of adaptation. In this section, you will discover some ways marine animals have adapted to their water environment.

Adaptations can be either physical or behavioral. A **physical adaptation** is some type of structural modification made to a part of the body. A **behavioral adaptation** is something an animal does - how it acts - usually in response to some type of external stimulus. When you look at an animal, you usually can see some of its adaptations -- like what it is able to eat, how it moves, or how it may protect itself. Different animals have many different ways of trying to stay alive. Their adaptations are matched to their way of surviving.

Anglerfish: A*n example is a Frogfish*
Some slow-swimming bottom dwellers have a special way of capturing their food. They use a fleshy "fishing lure" to attract their prey. When an interested fish swims near, they open their huge mouths to swallow the victim. Add more

Strange Mouths: A*n example is a long-nose Butterflyfish*
The mouths of many animals allow them to feed on foods others cannot catch or eat. The long slender snout of the long-nose butterflyfish allows it to feed on tiny invertebrates that hide in the cracks and crevices of the coral reef.

Bioluminescence: *An example is algae*
Flashlight fish have their own built-in light system. By covering and uncovering pockets of flowing bacteria beneath each eye, the flashlight fish blinks signals to other fish,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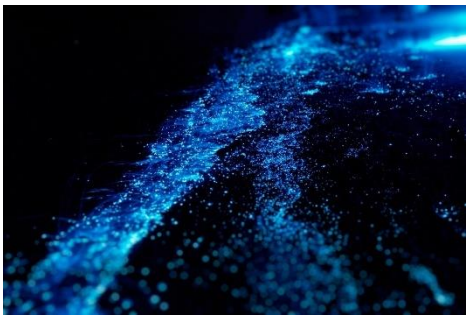
confuses predators and locates food. Flashlight fish live in deep, dark water and hunt only at night.



**Helpful Appendages**

Spines for protection:
Many fish which are not fast swimmers have sharp or poisonous spines for protection. The Lion fish, scorpion fish and stonefish have venomous dorsal spines along their backs. Stingrays have a poisonous barb on their tail.

Some sea urchins and starfish have their upper surfaces protected by sharp spines. The triggerfish have dorsal spines they can erect and lock in place to keep from being swallowed. The Porcupine fish is also covered with spines which it erects by inflating itself like a balloon. When attacked, **porcupinefish** and **pufferfish** protect themselves by drawing water into their abdomen to inflate themselves to more than twice their normal size, thereby making it difficult for predators to swallow them. They also have large protruding eyes that can see in all directions, enabling them to spot predators quickly. Pufferfish produce a powerful poison, tetrodotoxin, which can cause serious illness and even death in humans who eat one that is prepared improperly. Despite this problem, pufferfish are considered a delicacy in Japan.

Arms and tentacles for catching holding:
Some sea animals, like starfish and octopus, have arms equipped with suction tubes or discs for catching and tenaciously holding their food. Some lobster, crabs and shrimp have tentacles equipped with stinging cells to catch their food.

**Helpful Partnerships**
Besides being physically adapted to survive in their environments, marine animals have also evolved some unique social adaptations to improve their chances of survival. Schooling fish join others for their own kind for protection and to find food, but some animals have adapted to some rather strange but beneficial partnerships with other kinds of animals. These relations are called symbiosis.

Cleaners:
A very important type of relationship exists on the coral reef between the brightly colored cleaner fish or the cleaner shrimp and the larger predator fish. Instead of trying to conceal themselves, these animals advertise that they are around because they have a service to offer. They keep other fish clean and healthy by removing bits of dead or infected skin as well as skin parasites and fungus. In return, they obtain food and immunity from being eaten.



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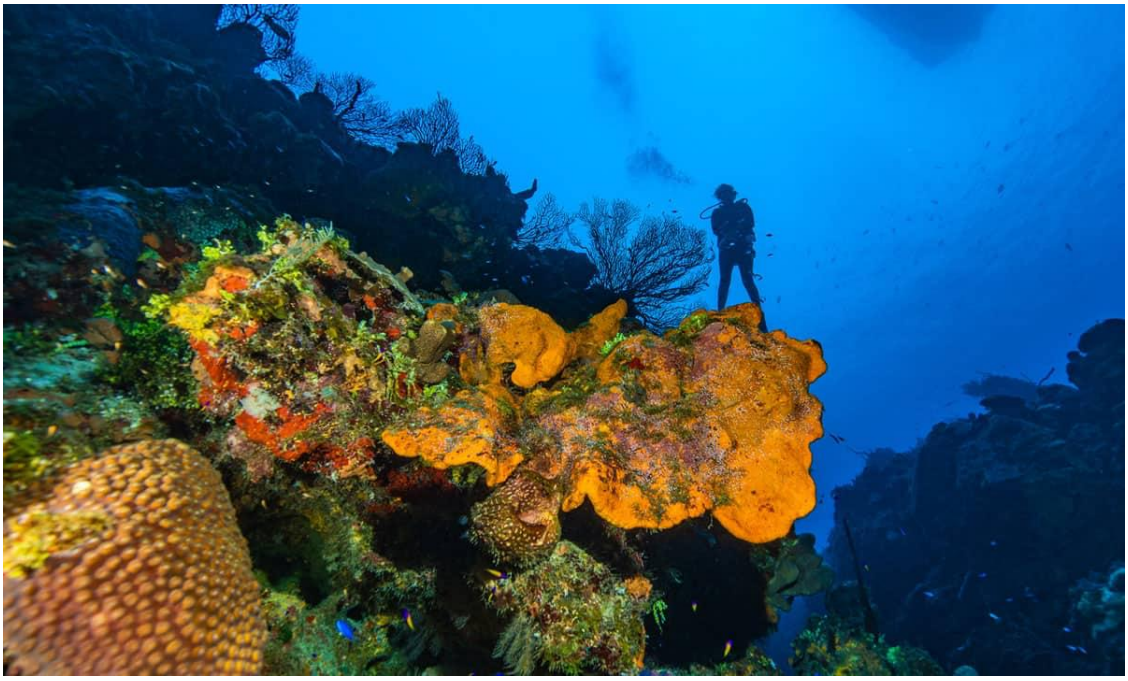
Hermit crabs:
The hermit crab does not have a hard shell of his own, but borrows the empty, discarded shells of others. Sea anemones sometimes grow on these shells providing camouflage for the crab's home and in turn are carried about by the crab to new feeding areas.

Sponges:
A sponge is a marine animal commonly found on the coral reef. They exist in various shoes, sizes and colors. Among the largest types found in the Caribbean is the barrel sponge. Sponges feed by drawing water into tiny chambers and filtering or straining very tiny plants and animals which float in the water. The filtered water is then pushed out through large holes which can be easily seen. The drawing of the sponge shows the path of the



water throughout the sponge. The tiny plants and animals captured by the sponge are plankton (for reference, review Mangrove Section). Most sponges are harmless to human beings. However, some sponges can give a very painful sting. Two such sponges are the fire sponge and the touch-me-not-sponge. It is not difficult to guess how these sponges received their names!

**Importance of Color**
Coloration may help hide an animal or draw attention to its role in an animal community.



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Camouflage: *An example is the Octopus*
Camouflage coloration helps animals blend in with their surroundings. The octopus changes color instantly from black to gray to red to match its background. It can also change the texture of its skin, becoming bumpy or smooth to blend in with rocks and seaweeds.

**Classroom Activity: Watch My Octopus Garden on Netflix**
Accompanying Classroom Activity and Lesson in Appendix

Disruptive coloration: *An example is the juvenile French Angelfish*
Spots and stripes break up the body shape of some fishes and conceal them against their backgrounds. This kind of camouflage, called disruptive coloration, is common in coral reef fishes.

False Eye Spots: *An example is the Butterflyfish*
Unusual color patterns may hide vulnerable parts of an animal's body. The true eyes of a four-eye butterflyfish are hidden in a band of black, but near the tail are two prominent "false eyes." A confused predator may attack these instead of the real eyes, allowing the butterflyfish to escape in the opposite direction.



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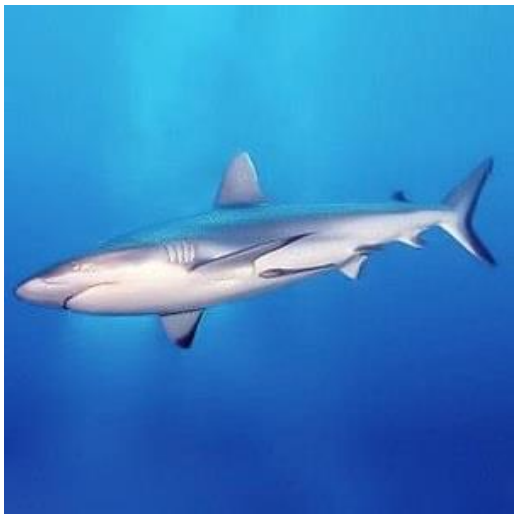
Countershading: *Examples are sharks and rays*



Many open ocean animals have dark backs and light bellies. This protective coloration is called countershading. Viewed from above, dark backs blend with the darkness of the deep ocean. From below, it is difficult for predators to see light bellies against bright sunlit surface waters.

Advertising coloration: *An example is cleaner wrasse and cleaner shrimp*

Some animals have coloration that attracts attention and advertises a special service. Cleaner fish help other fish by removing harmful parasites from their skin. Predators recognize the bright color patterns of cleaners and do not harm them because of the useful service they perform. In turn the cleaner fish gets a meal.

Warning: *An example is a lionfish*
Some animals are so well protected with spines, poisons and armor that their coloration is a warning for other species to stay away. The lionfish has brightly striped fins with poisonous spines that it displays to would-be attackers.

**Cayman Creature Focus**

**Parrotfish**

An example of the important interactions between life and the environment is the relationship between the Parrotfish and the coral reef. ***What is a source of Cayman's beautiful white sand?*** Believe it or not, from a colorful parrotfish and green algae! Reef grazing fish, such as parrotfish, produce a significant amount of sand found on the beaches. From a distance, all sandy beaches look the same. But if you take a closer look, you will find they are all very different. Every grain of sand is unique in color, texture, and shape, depending on what it is made from and where it lives on the beach. Sand is created from either rocks or sea animal remains, such as fragmented shells.

The floury soft coral sand found on the majority of Cayman's beaches comes, almost entirely, from the coral reef community. This type of sand is biogenic – sands made of the skeletal remains of plants and animals. This is the main reason why our sand is so much finer and softer than the sand found on most continental beaches, which comes from terrestrial sources such as weathering rocks. Most of our white sand is largely composed of the sun bleached and eroded calcium carbonate remnants of calcareous green algae, particularly the **Halimeda species**. This calcified sand is deposited from natural expiration and consumption by some marine animals, such as sea urchin and parrotfish.



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Parrotfish get their names from their parrot like mouths, and they have strong teeth that resemble a parrot's bill. These strong, sharp teeth allow parrotfish to scrape algae from rocks and corals. Parrotfish also bite off pieces of coral, grinding up the coral 'skeleton' to eat the tiny coral polyps or algae. But the parrotfish can't digest the ground–up skeleton therefore this passes through their digestive systems to be excreted as 'sand'!

A single parrot fish can produce tons of soft white sand during its lifetime. Parrotfish are not shy and are regularly seen while snorkeling or diving. Often you can hear the sound of their beaks scraping against the coral before you even see them! You may even see them relieving themselves of the indigestible portion of their meal in the form of sand that will settle slowly to the bottom of the sea.

**Blennies**

Visitors to the reef quickly learn to appreciate that these various fish groups do have personalities and different interesting behaviors. Blennies are great subjects for behavioral study. They are easily found in shallow water allowing observation in natural surroundings and they exhibit some interesting conduct!


Blennies are small, shallow water coastal fish with an extensive distribution. They tend to be bold, curious little fish. They dart rapidly around the reef while actively surveying



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their environment. They are openly aggressive and chase other blennies and when they do dare to go forth, it is only to immediately return or travel to another secure location.

The Yellowface Pikeblenny (*Chaenopsis limbaughi)* is a beautiful fish to see while diving or snorkeling. This pikeblenny is extremely elongated and the fore dorsal fin is quite high when extended. It is often found in sea grass areas and inhabits worm tubes. This species feeds mainly on planktonic copepods, but unidentified fish remains, shrimps and worms have also been examined within their stomach content. They are highly territorial, and this territorial aggression involves both real confrontation and mere acts of display by opening their large mouths, erecting the dorsal fin in aggressive threats, and the body is curved as if in a shell. The accompanying photograph illustrates the behavior of the blenny when met with its own reflection!

The Redlip Blenny (Ophioblennius atlanticus) is another pretty little fish to observe. It has a blunt head and large red lips. This blenny is common along the reef off South Sound where it prefers rocky inshore areas and shallow coral reefs. These blennies spend the day nibbling on filamentous algae and detritus within their small territories. It is usually found resting on the bottom and is very territorial. It will come out to meet a diver and dart around the reef until the diver swims away. It is definitely not shy and can be closely approached. Both females and males patrol and defend their territories which average 5 square feet. Nesting sites are prepared by removing sand, rock and debris from gaps or openings in the reef. The small blenny eggs (less than one millimeter) hatch five days after fertilization, one of the shortest incubation periods known for blennies. Blennies that are able to set up a territory have a life expectancy of about one year.

**Giant Caribbean Sea Anemone**

This Sea Anemone is commonly found in the Caribbean, specifically the West Indies and the western Atlantic ranging from southern Florida through the Florida Keys. They are usually found in lagoons or on inner reefs as either individuals or groups, but never as

colonies. In shallow water, this anemone attaches to hard objects and is also seen in turtle grass beds. The shape of this animal's body is related to the habitat in which it lives; it can exhibit a variety of colors: white, light blue, pink, orange, pale red, or light brown. The mouth is surrounded by 100 or more tentacles, each long and tapered with pink-, scarlet-, blue- or green-ringed tips. These tips are usually paler than the body itself. The basal disk, or adhesive foot, is firmly attached to the substrate while the tentacles are the free moving portion.

This anemone primarily likes to sit in one location but is capable of moving from place to place. It moves by using its pedal disk, or attachment point, in a slow, crawling movement. Motion is not used in direct protection from predators; anemones do not run from attackers.

When placed near other anemones, this animal tends to be aggressive toward its similar neighbor. The most effective form of defense for this anemone is the use of nematocysts (stinging cells) which are the defining characteristics of cnidarians, a group that includes anemones, corals and jellyfish. The tips of the anemone's tentacles are packed with nematocysts that contain a toxin. Using their stinging cells as "weapons", the anemone will fire upon other anemones to conserve its space on the ocean floor. The two individuals will fight; one advancing while the other withdraws, but both may suffer tissue damage. The nematocysts are also used in the capturing of prey. The toxin, in the concentrations found in C. gigantea, is not harmful to humans.

The Giant Caribbean Sea Anemone has many symbiotic relationships with fish and crustaceans. Some of the most common relationships include cleaner shrimp (Periclimenes anthophilous), and arrow crabs (Stenorhynchus seticornis). Animals that have a symbiotic relationship with this anemone require a period of adaptation in which the animals acclimatize to each other. This adaptation allows the anemone to recognize that the other animal is not prey or a predator.



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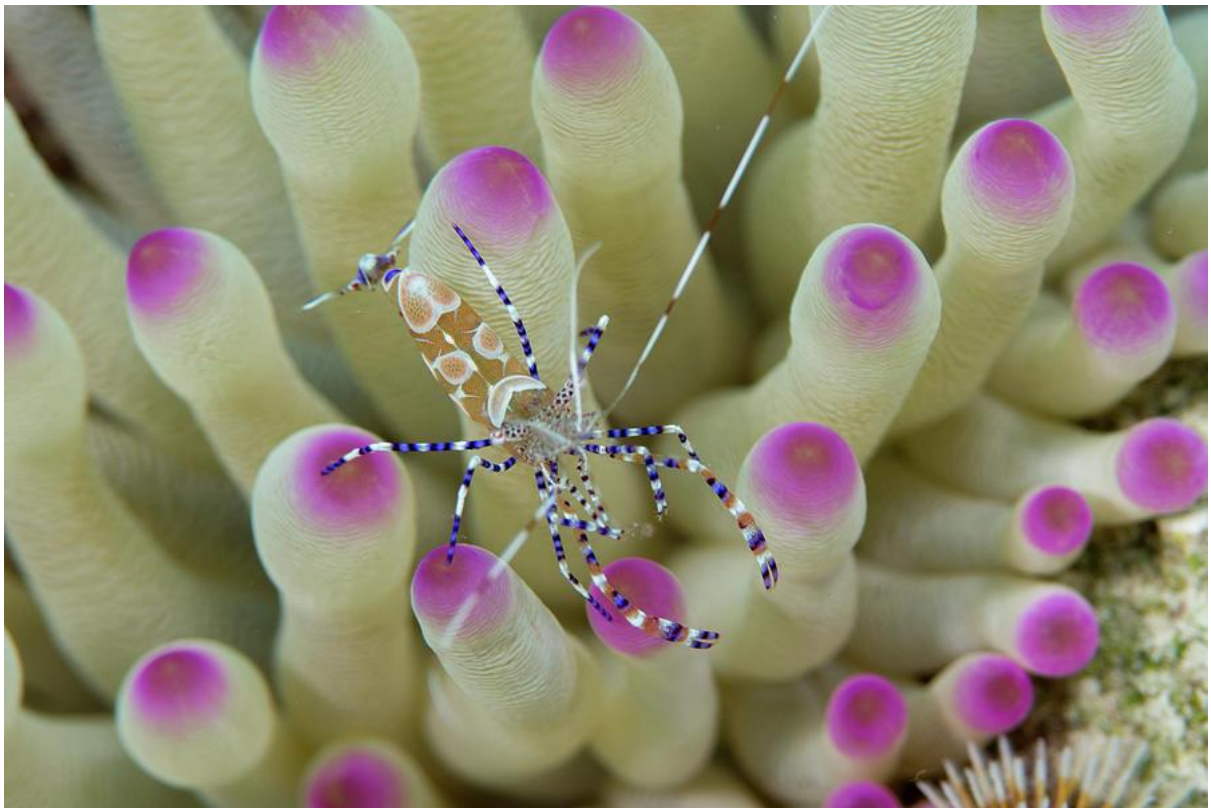

The Giant Caribbean Sea Anemone's most important symbiotic relationship is not with another animal but a plant. Single celled algae called zooxanthellae are found living within the tissues of the anemone. They are also found living in reef-building corals and are important to their hosts because they provide nutrients.

This anemone feeds upon fish, mussels, shrimp and other similar organisms. It will not, however, go near any of its natural predators, such as nudibranchs (sea slugs). The anemone eats food that is large in relation to its own size; for example, it will ingest prey such as adult sea urchins. With the low frequency of large prey available, it is suggested that, like other anemones, it is not selective about what it ingests but rather eats whatever prey it encounters.

**Caribbean Reef Squid**

Reef squid live in the ocean waters of Florida, Bahamas, and the Caribbean. Squid are commonly found in groups of about 4 -30 in the shallows associated with reefs. It lives in water depths of approximately 100 meters. The habitat of reef squid changes according to the squid's stage of life and size. The small squid typically gather together in shallow turtle grass near islands and remain within two meters from the surface to avoid bird predators. They also do not dwell on the ocean floor because of possible snapper predation. At night however, they often will swim to deeper waters and hunt with older, larger squid. When mating, adults are found near coral reefs in shallower depths.



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Squid are in the Class Cephalopoda and are mollusks: they are closely related to the cuttlefish and octopus and more distantly to the snails, clams, oysters, and sea slugs. Like all squid, Caribbean Reef Squid have eight arms and two longer tentacles that flow behind their body as they swim by expelling water from a mantle cavity with a water-jet action. All 10 appendages of the squid are "fixed to its head" and are arranged in a circle around the mouth. Compared to the overall body, squid's eyes are strikingly large. They have the largest eye to body ratio in the entire animal kingdom.

All are carnivores that have a pair of powerful, beaklike jaws to crush or tear food. Squid are voracious eaters typically consuming 30-60% of their body weight daily. Prey is caught using the end of the long tentacles which are then pulled towards the mouth supported by the shorter arms. They consume small fish, other mollusks, and crustaceans.
The coloring of a Caribbean reef squid is generally a mottled medium green to brown on the dorsal side and clear, light brown, or whitish on the ventral side. A distinct white line runs longitudinally on the dorsal side. These animals are social creatures often found in small groups that communicate through a variety of complex signals. Both cuttlefish and squid communicate by controlling the pigment in their skin. This strategy is used as a defense to confuse predators and to communicate between members of a shoal. Caribbean Reef Squid are believed to display nearly 40 different patterns. Colors are produced by chromatophore organs, part of the muscular system, controlled directly by the brain. Retreating squid near the protection of the reef will often turn dark brown or reddish in color to match their surroundings.



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On average, squid shoals are attacked several times during the daytime, by such predators as Bar and Yellow Jacks, Cero Mackerels and groupers. Members of a shoal typically form a line with larger individuals, acting as sentinels, stationed at each end and near the middle. When approaching danger is detected, the shoal typically forms into a tight semelparous; that is, they die after reproducing. Females lay their eggs then die immediately after. The males, however, can fertilize many females in a short period of time before they die. Females lay the eggs in well-protected areas scattered around the reefs.

In terms of conservation, there are several reasons that Cephalopods are rarely listed as threatened or endangered (nationally or internationally). The primary reason squids, octopuses, and cuttlefish have not received much attention for conservation issues is because not enough is known about the species to know whether or not they are threatened. Cephalopods have no conservation status under The United States Endangered Species Act, IUCN, or CITES.

**Butterflyfish**

Butterflyfish are a group of tropical marine fish of the family Chaetodontidae. Butterflyfish are fairly small, most from 12-22 cm in length. Butterflyfish are one of the most noticeable groups of fish observed by divers. There are about 120 species of Butterflyfish found worldwide, only seven are found in the Caribbean. Of these there are five well-known and striking members within Cayman's reef community. These include the Banded Butterflyfish, the Spotfin Butterflyfish, the Foureye Butterflyfish, the Reef Butterflyfish, and the Longsnout Butterflyfish.

Butterflyfish generally travel singly or in pairs within a rather limited home-range. At dusk they find shelter in the reef and become less active. At night when they are resting, the colors of butterflyfish become dull, helping them hide within the reef, caves, and crevices. Butterflyfish are pelagic spawners; this means they release many buoyant eggs into the water which then become part of the plankton, floating with the currents until hatching. The typical food of Butterflyfish includes tiny worms, exposed coral polyps, tiny shrimp, crabs, and algae (from scraping the reef with their bristly teeth).



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Butterflyfish are preyed upon by nocturnal predators such as moray eels, sharks, snappers, and groupers. In order to avoid predators and live on the reef, butterflyfish have evolved certain adaptations to maneuver along the reef relatively easily. Because of their small size and shape they are also able to lodge themselves between pieces of coral preventing predators from attacking them. They also erect fin spines which make it almost impossible for them to be removed.

*Foureye Butterflyfish*

*Spotfin Butterflyfish*

Some Butterflyfish make fish identification easy as their distinctive features make up part of its common name. The Banded Butterflyfish first has two dark midbody bands making them easy to identify by simply associating the bands with the species' name. Note the dark band running through the eye; this is not a distinctive feature only to this species as you will notice similar markings are present in all five species. Eye-bands, believed to be a survival adaptation of several fish species, including butterflyfish, help camouflage the location of their true eyes. This characteristic helps confuse potential predators as to the direction the little fish will dart when attacked.

Foureye Butterflyfish are also easy to recognize and remember. Their distinctive feature is the black spot, ringed in white, on the rear body. This characteristic, known as a false eyespot false eye spot fool predators into lunging the wrong way, also eye bands help camouflage the location of their true eyes to confuse predators as to the direction the little fish will dart when. Predators don't know whether to attack the front end—or the back!
The eyespots misdirect the predator allowing less vulnerable areas to be attacked first. Most juvenile butterflyfish are usually seen in shallow habitats, such as sandy areas, isolated coral and sponge formations, seagrass beds and around mangrove roots. Juvenile butterflyfish are also sighted hovering close to the openings of discarded conch shells. They lead solitary lives until they reach sexual maturity after a year. In many instances juvenile butterflyfish look completely different from their adult form. The juvenile Foureye has an extra set of ocellated spots and pale bands, and these markings disappear as the fish matures.



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*Banded Butterflyfish*

Butterflyfish may be used as an indicator of the health of a coral reef. Since they feed on coral polyps, an abundance of butterflyfish on a reef indicates a healthy reef or the amount of food available for them to eat (coral polyps). Also, when there is a decline in coral quality and abundance, butterflyfish respond with behavioral and distribution changes which are easy to observe. These species can therefore be used to help monitor changes in the health of a coral reef ecosystem and can allow for the rapid implementation of measures that might improve the health of the reef.

Classroom Activities:
See following pages for activity sheet



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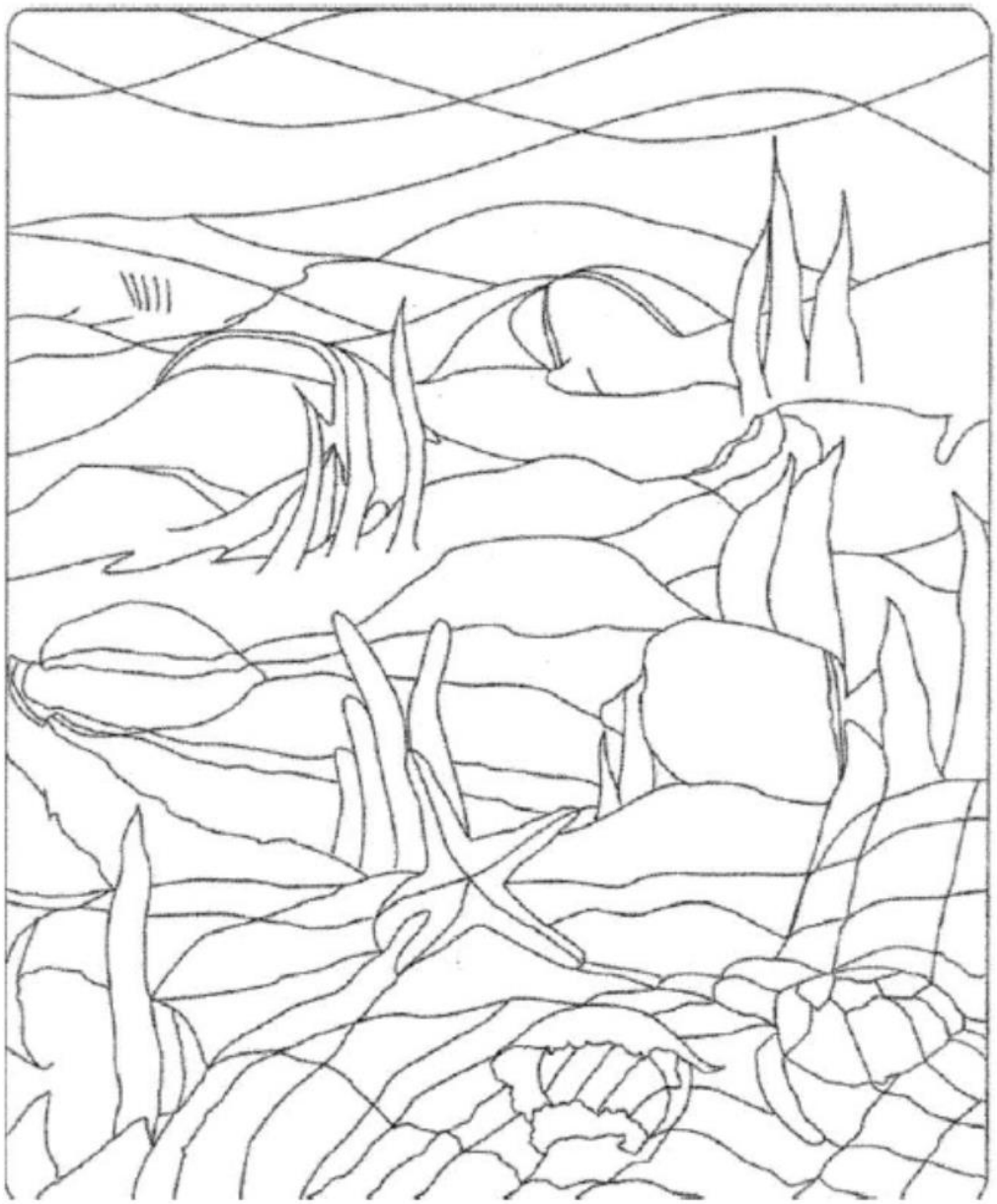
# Hidden animals

## Can you find the ten animals in this picture?





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# Camouflage

Find and color the fishes hidden in this drawing.

Courtesy of Shedd Aquarium



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# Coral Reef and Fish Identification



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# Catching Food Crossword Puzzle

Marine animals have many adaptations that help them attract, catch and eat food. They have claws and spines, teeth and tentacles, and disguises that help them hide from their prey.

**ACROSS**

3. The dolphin's sharp _____ help it to catch fish.
6. This kind of snail smothers other shell fish with its one large foot.
7. Lizards catch insects with a flick of their _____.
8. Another word for prey.
9. Predators have many adaptations that help them _____ their prey.
11. This animal stuns its prey with an electric shock.
12. The poisonous _____ displayed by a lionfish keep it from being eaten by other fish.
13. A _____ is an animal that is hunting for another animal to eat.
15. An oyster eats by collecting small particles of food from the water. Animals that eat this way are called _____ _____.
16. A crab can catch food with its _____.

**DOWN**

1. A jellyfish has tentacles that _____ its prey.
2. A flounder changes its color to match the ocean floor. This hides it and enables it to catch other fish that don't see it. This kind of coloring is called _____.
4. An octopus uses these to catch fish.
5. Anemones have rings of tentacles that circle their _____.
10. A moray eel hides in a dark _____ and waits for fish to go by.
12. This invertebrate prys open clams with its arms.
14. Birds that eat fish usually have a long, sharp _____.

**WORDS USED IN THE PUZZLE**

| | | | |
|---|---|---|---|
| beak | claws | mouth | sting |
| camouflage | eel | predator | teeth |
| catch | filter feeders | spines | tentacles |
| cave | food | starfish | tongue |
| | moon | | |

**Courtesy of National Aquarium in Baltimore**



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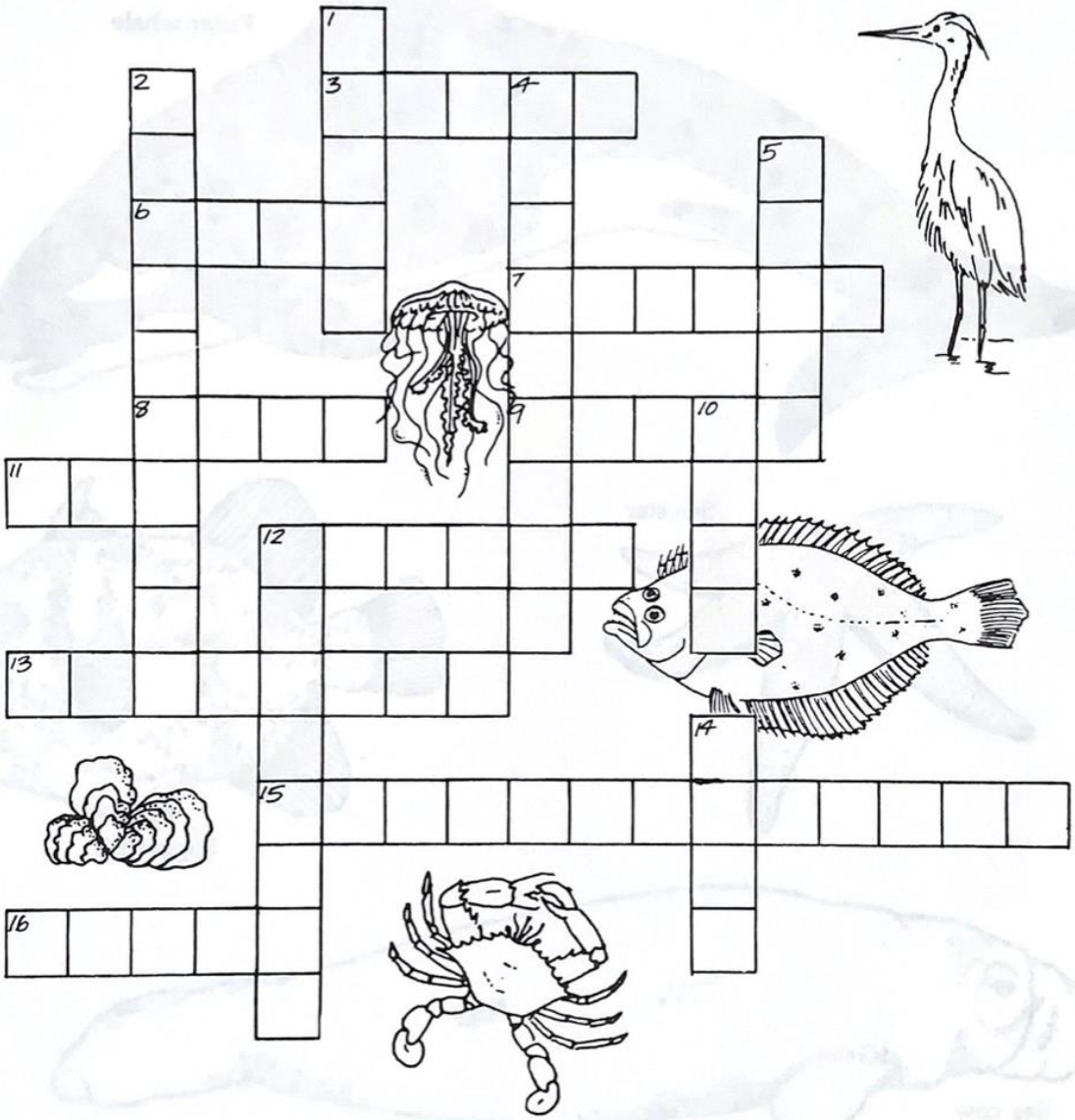
# Catching Food Crossword Puzzle



Courtesy of National Aquarium in Baltimore



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# Ocean Fun

## Language Arts—Ocean Alphabet

Two or more students may play. The first person names a fish. The second person must now name a fish whose name begins with the last letter of the previous name given. For example, 1st person—"sailfish" (H); 2nd person—"halibut" (T); 3rd person—"tuna" (A); etc. If a name cannot be found that begins with a certain letter, that person is eliminated and the next person begins the game with another name. No name may be repeated. Variation: This may encompass *all* forms of marine life including marine mammals, invertebrates, marine plants, etc.

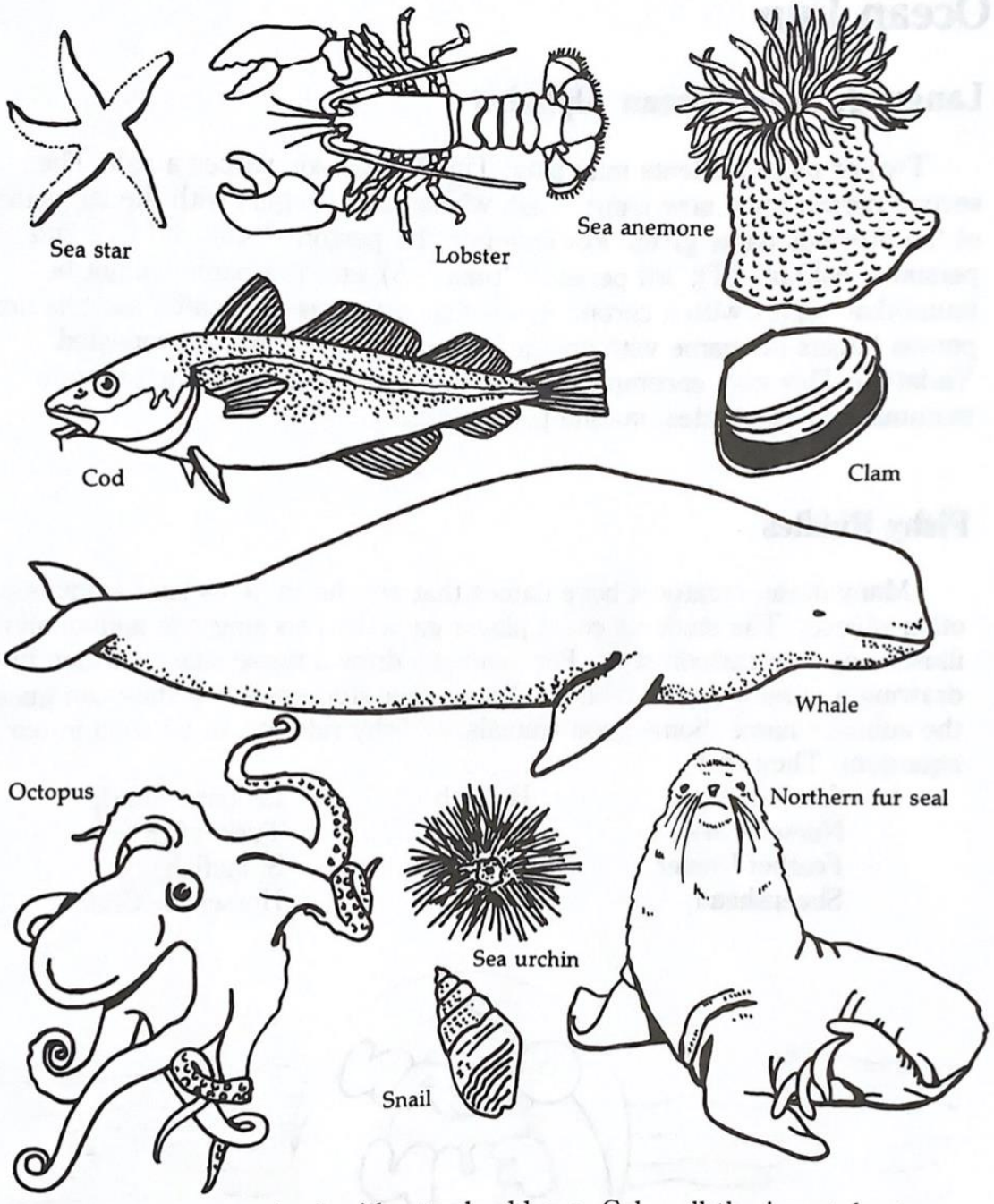
## Fishy Riddles

Many ocean creatures have names that are the same as land animals or other objects. The students could play a game by choosing one animal and illustrating it in cartoon style. For example, draw a nurse shark cartoon by drawing a nurse's cap on a shark. Have other students see if they can guess the animal's name. Some good animals for fishy riddles can be seen in our aquarium. They are:

| | | |
|---|---|---|
| Sea Horse | Hogfish | Leopard Shark |
| Nurse Shark | Starfish | Turkeyfish |
| Feather Duster | Angelfish | Stonefish |
| Sheepshead | Fan Coral | Horseshoe Crab |


Courtesy of Sea World Ohio

# Invertebrate



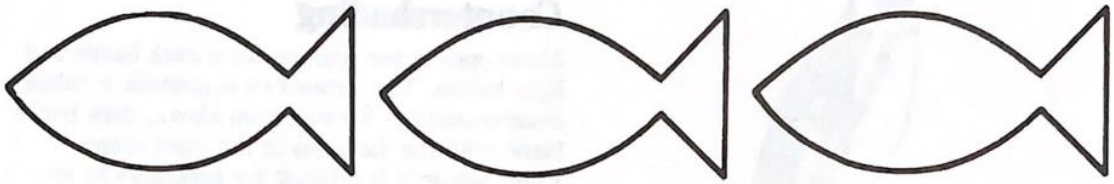

An invertebrate is an animal without a backbone. Color all the invertebrates in the picture. Name the three animals that are not invertebrates.

1. _____
2. _____
3. _____

Courtesy of Mystic Marinelife Aquarium

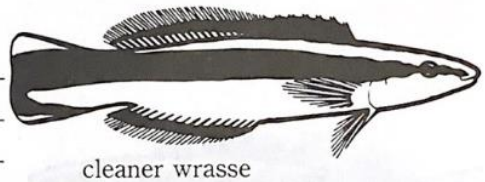
# Worksheet: Coloration

1. **Protective Coloration** helps animals survive in their natural habitats. Protect the fish below by giving them the proper coloration:



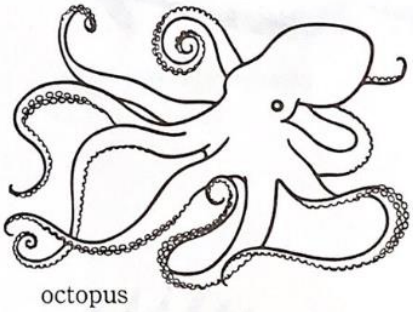
**Countershading** **Disruptive Coloration** **False Eye Spots**

2. What is **Advertising Coloration** and how does it help an animal survive?



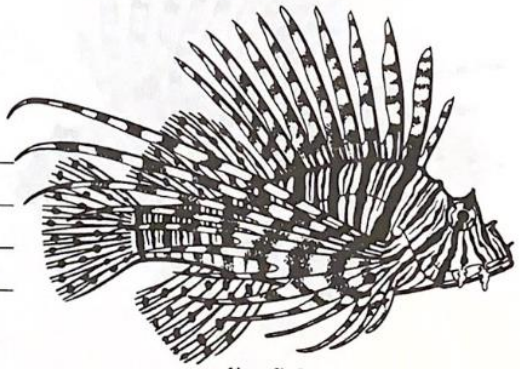
cleaner wrasse

3. What is **Camouflage** and how does it help an animal survive?



octopus

4. What is **Warning Coloration** and how does it help an animal survive?



lionfish

**Courtesy of New England Aquarium**



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# Adaptation Code

A. _ _ _ _ _ _ _ _ _ _ _
3 1 13 15 21 6 12 1 7 5
An animal blends with its background to hide from its enemies.

B. _ _ _ _ _ _ _ _ _
19 25 13 2 9 15 19 9 19
Two kinds of animals living together to survive.

C. _ _ _ _ _ _ _ _ _
20 5 18 18 9 20 15 18 25
A certain place an animal lives and defends.

D. _ _ _ _ _ _ _ _ _
19 3 8 15 15 12 9 14 7
Many of the same fish swimming together.

E. _ _ _ _ _ _ _ _ _
18 8 5 15 20 1 24 9 19
Fishes swimming into a current.

F. _ _ _ _ _ _ _ _ _
1 20 20 1 3 8 13 5 14 20
The way in which sea star tube feet hold on to a surface.

| Alphabet | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |

Look at the alphabet code. Place the correct letter in the space above its matching number to decode the adaptation word that is opposite its meaning.

Courtesy of Mystic Aquarium



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## CHAPTER 7: Cycle of Water & Hurricanes





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**Chapter 7- Cycle of Water & Hurricanes**

Related Video: Elements of the Water Cycle
NASA Earth Water Cycle
Related PPT Presentation

**Elements of the Water Cycle**

The ocean is a fundamental part of the water cycle that sustains all of life on Earth. The water cycle is connected to all of the Earth's water reservoirs through evaporation and precipitation processes. As scientists seek to better understand the ocean and the Earth's processes, the water cycle is an essential piece of their work. Water is one of the most powerful forces that shape our Earth, moving over the surface of the Earth creating wonders such as the Grand Canyon. Along with temperature, the water cycle shapes the Earth's climates.

*Photo by Courtney Platt*

**Where is water found and how long has it been around?**

Water, water everywhere! The most common places to find water include oceans, rivers, streams, and lakes. Water can also be found in abundance in glaciers, underground aquifers, and in the air as water vapor. Planet Earth is called the water planet because roughly 71% of the surface of earth is covered in water. About 97% of that water is found in the salty oceans and is therefore undrinkable. Freshwater makes up the remaining 3% and of that, 68% is locked up in glaciers, 32% exists in underground aquifers and <1% can be found in our freshwater lakes, rivers, and streams. The water that exists today is the same water that existed when the Earth first had water, about 4 billion years ago. This water is continually recycled over and over throughout time by a process called the hydrologic cycle, or the water cycle.



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**States of Water**

Water exists in three different physical states. Most water on Earth is in the liquid form and can be found in oceans, lakes, streams, and rivers. Water can be in the solid form, ice, and is found in higher elevations where it is cold, like on mountaintops and in the form of glaciers. When water gets heated, it is transformed into its gaseous state and turns into water vapor, steam, or fog. Water vapor forms when the sun heats the surface of a body of water. The water at the surface evaporates and rises into the atmosphere. When this happens on large bodies of water like lakes or oceans, so much water vapor is produced that it eventually condenses, forming clouds in the atmosphere. Steam forms when a body of water is heated to its boiling point, 100°C or 212°F, transforming liquid water into gaseous water that rises into the air. Fog forms from water vapor in the air and condenses when it comes in contact with the ground. Therefore, fog is a cloud that comes in contact with the ground.

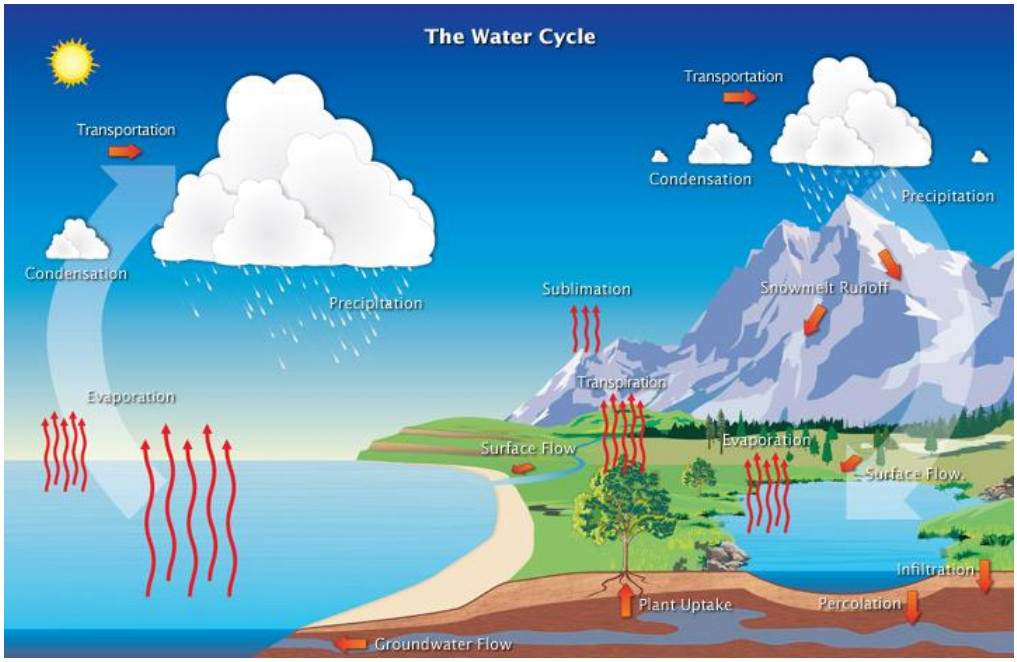
**The Water Cycle**

The water cycle is the continuous recycling of water on Earth; from the oceans, up to the sky and down to land to be transported back to the oceans and sky again. Water is constantly changing states due to the energy of the sun transforming surface water into water vapor.

The water vapor eventually attaches to a solid, such as dust or salt, and forms clouds, and clouds condense back into water droplets. When the droplets become very dense in the clouds, the force of gravity pulls the water drops back down to the Earth where the cycle begins all over again. To demonstrate this concept, start with a drop of water in the ocean, since the ocean is where most of the Earth's water is found. This drop of ocean water gets heated by the sun and turns into water vapor. When many drops of water turn into vapor and rise up into the higher altitudes where air pressure is lower, clouds form. Many different types of clouds exist and depending on what they look like and where they are in the sky, one can try to predict whether rain will occur or not.

For types of clouds see:
https://scied.ucar.edu/learning-zone/clouds/cloud-types and
https://www.nature.com/scitable/knowledge/library/tropical-weather-84224797/

When the clouds cool, the water vapor turns back into liquid water, forming droplets through a process called condensation. When too much of the water vapor condenses into liquid water, the clouds get so heavy that they release water in the form of rain or snow called precipitation. The water that falls from clouds can take many paths. It can flow into rivers and streams and eventually back into the oceans. Water on the surface of the ground can evaporate back into the air. The water can also seep through the surface into the ground where it may become trapped in aquifers. Plants need water to survive, and they obtain it from groundwater in the soil and to a lesser extent via absorption of water through their leaves, but plants can also 'sweat' water out through their leaves during really hot days; this is called transpiration.




**Weather and Climate and How They Relate to the Water Cycle**

The weather is all around us and has a profound influence on our day to day lives, like how and where we live, what we do each day, what we wear, and what we eat. Weather is made up of many different atmospheric factors like wind, precipitation, humidity, temperature, pressure, sunshine, clouds, and visibility. Someone who studies the weather is called a meteorologist. Meteorologists make predictions of the weather based on what is known about how the different things that make up weather interact with each other. The climate is the common, average weather conditions at a particular place over a long period of time. We learn about different climates around the world; deserts have a hot and dry climate while the Antarctic has a very cold and dry climate. Tropical places like the Cayman Islands have warm, humid climates. While the weather in a particular place can change from day to day, climate changes typically take place over many years (for example, more than 30 years). Evaporation and precipitation are ways in which water moves through the water cycle on any given day during a weather event. During certain times of the year, it might rain often causing plants, soils, rivers, and lakes to absorb more water. During other times of the year, hot, dry weather can lead to water evaporation causing plants and soil to dry out and streams and rivers to have lower elevations, but over the course of a year or several years, a balance occurs in the water cycle so the amount of water entering the system is equal to the amount exiting. This balance or equilibrium in the water cycle helps stabilize the climate. Climate is affected by the natural fluctuation of the balance of water entering and exiting the system on a global scale. It depends on whether water is available in the ocean, in the atmosphere, or in large freshwater lakes and glaciers. Natural hazards like floods, droughts, sea level rise, and elevated sea surface temperature can be isolated weather events or related to climatic changes that impact the water cycle over a longer time scale.

Scientists study factors that impact climate, both on a global scale and local small scale local weather patterns. The majority of climate scientists agree that one of the biggest threats to our Earth is the rapid global climate change taking place as a result of human

influence. The energy and resources we use are converted into gases that change the chemistry of the atmosphere. Climate change can alter the water cycle by increasing the likelihood of floods in usually dry regions and droughts in historically wet regions. As a result, many of the Earth's glaciers are melting and can contribute significantly to a rise in sea level. It also changes weather patterns in some areas making them harder to predict, ultimately producing more severe weather as a result. In tropical regions, global climate change can contribute to a rise in sea surface temperatures. As previously discussed, even small increases can have big effects on coral reefs, causing coral reef bleaching that could eventually lead to the destruction of the corals.

**Description of a Watershed**

A watershed describes an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake, or an ocean. A watershed may be only a few hectares as in small ponds or hundreds of square kilometers. Watersheds are often valleys bounded by higher elevation lands such as mountains. In the middle of the valley, a stream or river often collects the rainwater and transports it to the ocean. In other places, there may be many watersheds that empty into a major river which flows for many miles before reaching the ocean. An example of this is the Mississippi River that flows into the Gulf of Mexico after traveling 2,300 miles. The watershed of the Mississippi covers 41% of the continental U.S. and encompasses about 1.1 million square miles.

**Cayman Watersheds**

Three things can happen to water that falls as rain. Some are absorbed by plants. More hits the ground and flows away, forming rivers and streams and filling lakes and wetlands. In the Cayman Islands there are no rivers or streams as there are no mountains, and so the majority of the rain filters into the ground, filling underground reservoirs or lenses that sit above brackish water, which in turn sits above sea water that has permeated the limestone rock that makes up the islands. This is the ground-water. Every river, stream, and underground reservoir is supplied with water by its own area of land. This area is called a watershed.

All the water in a watershed is connected. Any activity in a watershed that affects the water will affect the other water bodies. For example, if the rivers in the mountains become clogged with silt because too many trees are cut down, less water will evaporate from the rivers, less rain will fall in the mountains, and less water will enter the rivers and streams. The wetlands by the sea will dry up. In order to protect a coastal wetland, it is necessary to protect the whole watershed.

With the flow of water to the mangrove wetlands comes a steady supply of nutrients from the sur- rounding land. The organic silts and sediments settle and warmed by the sun, provide ideal conditions for the growth of microscopic plants and animals—the base of aquatic food chains. The abundance of food materials leads to some mangrove wetlands' being called the most productive systems (in terms of gross plant material) on Earth. A well-established marsh is estimated to be as much as 50 times as productive as a similar area of grassland, and about eight times as productive as cultivated land. The contribution of plant material to climate is one reason it is so important to protect mangrove wetlands.



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On mountainous islands, the climate is often very predictable, with hot, sunny mornings followed by heavy afternoon showers. Wetlands play an important role in maintaining this pattern. In the Cay- mans, especially in Grand Cayman, the Central Mangrove Wetlands perform a function similar to that of mountains, with prevailing winds moving more than 40 million gallons of water a day from east to west, where the water falls as heavy rain. Cayman Brac is much drier because it has few wetlands, whereas Little Cayman, which has extensive mangroves, has more rainfall than the Brac but not nearly as much as Grand Cayman.
Most Caribbean wetlands are densely covered by plants. A plant, because of its spreading leaves, has much greater surface area than the area of soil it covers. Plants, like the mangroves that cover the Central Mangrove Wetland, lose water through their leaves by a process called transpiration. Therefo*re, a wetland contributes much more water to the water cycle than the same area of land if the* wetland were not there.
Here is how the climatic pattern works in mountainous islands. After sunrise, the land heats up and water evaporates from the sea and from coastal and wetland plants. Prevailing winds carry this moist air inland, toward the mountains. The mountains force the warm, moist air to rise; as it reaches colder air at higher altitudes, it condenses and falls as rain, filling up both upland and lowland wetlands. In this way, wetlands help to maintain local climates.

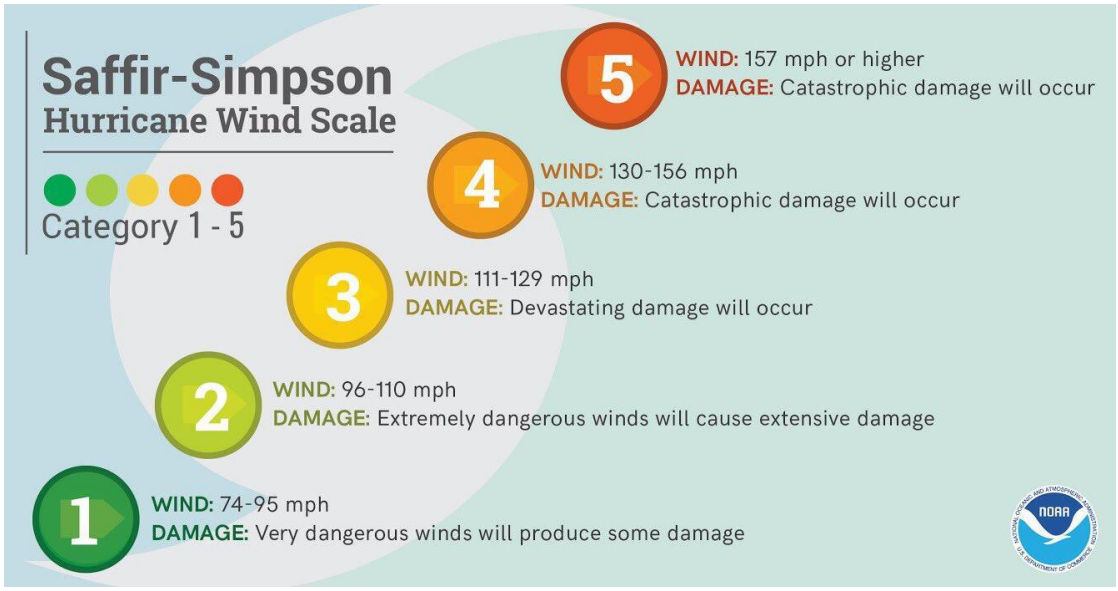
**Hurricane Awareness**
Hurricanes are tropical cyclones that form over tropical oceans, often causing considerable onshore damage, and flooding. Tropical cyclones are characterized by the magnitude of sustained wind speeds as they transition from tropical depressions to tropical storms, and finally hurricanes. The tropical cyclone, typhoon, and hurricane are all the same type of storm, but they are called by different names depending on where in the world they occur.
Tropical storms become hurricanes only when certain conditions exist over warm tropical oceans. Tropical storms, warm ocean waters, moisture, and winds are prerequisites in the formation of hurricanes. Once formed, hurricanes are further categorized based on sustained wind speeds.

What is a hurricane?
Though named for the wind, hurricanes are generated from the sea. They emerge in late summer, when the sea is at its warmest and winds begin to spiral around areas of low pressure. Water evaporates, rises with the wind and condenses. The rain releases heat, powering more wind that captures more water, then rises, rains and releases more energy. The hurricane or typhoon feeds itself, wreaking havoc as it makes landfall.

Hurricanes occur in the North Atlantic, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean east of 160E longitude. In other parts of the world, these types of storms have different names: typhoons (the Northwest Pacific Ocean west of the dateline), severe tropical cyclone (the Southwest Pacific Ocean west of 160E or Southeast Indian Ocean east of 90E), severe cyclonic storm (the North Indian Ocean),

and tropical cyclone (the Southwest Indian Ocean). Although different names are used, they all mean the same thing. The definition of hurricane in the glossary applies to all these names.

Hurricanes are a type of tropical cyclone which is accompanied by thunderstorms and, in the Northern Hemisphere, a counterclockwise circulation of winds near the earth's surface that revolve around an eye. There are three types of tropical cyclones which are characterized by the magnitude of their sustained wind speeds: tropical depressions, tropical storms, and hurricanes.




A tropical cyclone is a rotating low-pressure weather system that has organized thunderstorms but no fronts (a boundary separating two air masses of different densities). Tropical cyclones with maximum sustained surface winds of less than 39 miles per hour (mph) are called tropical depressions. Those with maximum sustained winds of 39 mph or higher are called tropical storms.

When a storm's maximum sustained winds reach 74 mph, it is called a hurricane. The Saffir-Simpson Hurricane Wind Scale is a 1 to 5 rating, or category, based on a hurricane's maximum sustained winds. The higher the category, the greater the hurricane's potential for property damage.

Hurricanes originate in the Atlantic basin, which includes the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico, the eastern North Pacific Ocean, and, less frequently, the central North Pacific Ocean. A six-year rotating list of names, updated and maintained by the NOAA, is used to identify these storms. "Hurricane Season" begins on June 1 and ends on November 30, although hurricanes can, and have, occurred outside of this time frame. NOAA's National Hurricane Center predicts and tracks these massive storm systems, which occur, on average, 12 times a year in the Atlantic basin.

Heat and energy for the storm are gathered by the disturbance through contact with warm ocean waters. The winds near the ocean surface spiral into the disturbance's low-pressure area. The warm ocean waters add moisture and heat to the air which rises. As the moisture condenses into drops, more heat is released, contributing additional energy to power the storm. Bands of thunderstorms form, and the storm's cloud tops rise higher into the atmosphere. If the winds at these high levels remain relatively light (little or no wind shear) the storm can remain intact and continue to strengthen.

In these early stages, the system appears on the satellite image as a relatively unorganized cluster of thunderstorms. If weather and ocean conditions continue to be favorable, the system can strengthen and become a tropical depression (winds less than 39 mph or 33 kt). At this point, the storm begins to take on the familiar spiral appearance due to the flow of the winds and the rotation of the earth.

If the storm continues to strengthen to Tropical Storm status, (winds 39-73 mph) the bands of thunderstorms contribute additional heat and moisture to the storm. The storm becomes a hurricane when winds reach a minimum of 74 mph. The center, or eye, of the storm forms a calm region of low pressure, while the dense walls of cumulus-type clouds which encircle the eye make up the regions of highest wind speeds and extremely dense precipitation. Wind speeds in such tropical storms are inversely related to the air pressure at the center - the lower the pressure, the higher the wind speed.

Once a hurricane or typhoon passes over land it begins to lose its power, since the energy from the warmer ocean is cut off and the increased friction from the land upsets the pattern of air circulation. Sea surges and torrential rain are associated with such storms.


*Photo by Julie Corsetti*

**Hurricane Ivan** was the strongest hurricane of the 2004 Atlantic hurricane season. The storm formed as a Cape Verde-type hurricane in early September, and became the ninth named storm, the sixth hurricane, and the fourth major hurricane of the year. Ivan reached Category 5 strength on the Saffir-Simpson Hurricane Scale, the highest possible category and the only one of the season. At the time it was the sixth most intense Atlantic hurricane on record.
Ivan caused great damage to Grenada, which struck directly at Category 3 strength, and heavy damage to Jamaica, Grand Cayman, and the western tip of Cuba. After peaking in strength, it moved north-northwest across the Gulf of Mexico to make landfall as a strong Category 3 storm in the United States, in Orange Beach, Alabama, causing very heavy damage there. Ivan dropped heavy rains on the southeastern United States as it looped across Florida and back into the Gulf of Mexico.

See Video: Remembering Ivan - National Gallery

In the days and weeks following Hurricane Ivan, Courtney Platt documented the destruction wrought by the storm in a series of powerful images that ultimately became a book, “Paradise Interrupted: Hurricane Ivan.”



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Classroom Activities and Field Trips:

**Salty Currents**

**Summary:** This activity demonstrates the mixing of fresh and salt water

**Learning Objectives:**

Students will be able to:

1. a) observe what happens when fresh and saltwater meet and mix; and
2. b) observe how water temperature influences plant and animal habitat.

**Age levels:** 13 and up

**Subject Areas:** Science

**Time:** 30-60 minutes

**Materials**

Two 5 or 10 gallon aquariums or clear plastic containers of similar size and shape (if using aquariums, make sure the one that contains salt water will not be used later for freshwater fish) Two small (6 or 8 oz) glass bottles, such as soda or mineral-water bottles, with caps

Salt (coarse or table salt) Food coloring Paper and pencil for recording results Easel paper or flip chart Labels or permanent marker for labelling bottles

**Background**

Many kinds of wetlands (including mangroves) are located where fresh water from the land meets salt water from the ocean. The most obvious characteristic of sea water is its

saltiness, or salinity. But most kinds of wetlands, from salt ponds to estuaries, are less salty than the ocean, and organisms face a constant fluctuation in salinity as both tides and freshwater flow interact. Salt water is denser than freshwater and tends to sink to the bottom, so the organisms often have to deal with "layers" of different salinities. Freshwater, being lighter than salt water, floats to the top of ocean water. Wind, waves and tides can stir up the layers, so wetland animals must be prepared for quick changes in salinity. On a secondary school level, this activity works with Chemistry and Physics classes as it demonstrates density through the movement of saltwater and freshwater currents.

**Procedure**

1: Ask two students to half-fill both aquariums with cold fresh water. Also fill the two small bottles with water. Cap and label one of the bottles "fresh water". To the other one, have a student add enough salt to make a very salty mix (approximately two teaspoons, which is much saltier than sea water). Cap the second bottle and have a student shake it up until the salt is completely dissolved. Label the bottle "salt water".

2. Lead the class in a discussion to predict what will happen when the two bottles are placed at the bottom of the aquarium uncapped to let the water escape. Record students' predictions on easel paper or a chalkboard and encourage them to give reasons for their predictions.

3. Ask students to suggest how we might observe what the water in each bottle will do when it comes into contact with the water in the aquarium or basin, if the waters all look the same. Teacher direction may be required to lead the students to think of adding food coloring to the water in the bottles as a solution to the problem.

4. Add food coloring to both small bottles of water. Have a student shake up each of the bottles to make sure the food coloring is completely dissolved. (Note: If you do the saltwater demonstration first, the results are more surprising to the students and usually give a clue to whether their predictions are correct for the second demonstration.)

5. Have a student lay one bottle on its side on the bottom of one of the aquariums and then uncap it. Observe what happens as the bottled water leaks into the basin. Discuss the reasons for what happened. Compare the predictions to the actual event. Leave the basin undisturbed to see what will happen to the water over time. Follow the same procedure with the second bottle of water.

6. (Alternative) If you have only one aquarium or container, follow the same procedure, but use two different colors to distinguish the saltwater mix from the fresh water.



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**Discussion/Reflection**:

Culminate the activity with a discussion of wetlands and estuarine areas. Deep ocean water is always colder than the water in a shallow estuary. Water entering both the estuary and wetlands as run-off from streams and rivers is usually colder than the water already in the estuary and wetland areas, which has been warmed by the sun. How do differences in water temperature influence the plants and animals that live there? Plant growth is faster in warm temperatures, and this is one reason that wetlands and estuaries are so productive.

**Extensions**: Students may draw or write about the experiments on paper or in a science lab book as a follow up



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**Water Cycle Relay**

**Summary:** Students will be able to understand the process of the water cycle.

**Age levels:** 4-11

**Subject Areas**: Science

**Time:** 30-14 minutes

**Materials**

Four or more buckets

Two cups

**Handout:** Water Cycle Process

**Background:** Same as for Water Cycle Rap

**Procedure**

1. Divide the students into two or more teams.

2. For each team, set up two sets of buckets (two buckets per team), with one set approximately one-third full of water. Place the ones containing water about 10 m (30 ft) away from the empty ones. Line the two teams up behind the buckets containing water.

3. Students must fill a cup with water and "precipitate" by running the water (without spilling) to the other (empty) bucket, which represents a wetland or stream. When the race begins, the first student from each team runs with his or her cup of water and empties it into the bucket at the other end. When they



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return to the other side, they hand off the cup to the next person in line on their team. The first team that empties its bucket and spills the least is the winner.

4. Play the game again, this time having the students “evaporate” the water from the wetland or stream back to the clouds.

**Discussion/ Reflection**: Use the water cycle chart on pages to go through the water cycle process with the students, and then lead them into a discussion of the importance of water.



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**Condensation Demonstration**

**Summary**: By creating condensation in a glass jar, students observe how water condenses to form precipitation.

**Learning Objectives:** Students will be able to:

a) define condensation; and

b) explain how clouds are formed.

**Age levels**: 7-14

**Subject Areas:** Science, Language Arts

**Time:** 30–60 minutes

**Materials**

A large Pyrex glass jar

An extra-large jar lid

A small tin can containing ice cubes Salt (coarse or table salt)

**Background**

When water vapor rises, it meets cool air and begins to change form into tiny droplets of liquid water, forming clouds. If the air around a cloud becomes cooler, water vapor condenses further and the tiny droplets join up, forming larger droplets. This process is called condensation. When the droplets can no longer float in the air, they fall to Earth as rain or, in northern climes (regions), snow, sleet, or hail. Sometimes condensation happens close to the surface of the ground or water. Then the water droplets create a



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low cloud called mist, fog, or steam. When this happens, water purifies itself of salts or pollutants. The purpose of this activity is to show how water condenses to form precipitation.

**Procedure**

1. Pour half a cup of very hot water into the large Pyrex glass jar.

2. Cover the jar with an extra-large jar lid turned upside down.

3. Place a small tin can containing ice cubes on top of the jar lid. Water vapor will form a cloud of steam in the air. Large water droplets will form on the inside of the glass jar as the steam cloud meets the lid, which has been cooled by the ice. Condensed water drops will roll down the side of the lid or just drop.

4. Repeat the experiment, only this time have a student add enough salt to make a very salty mix in the Pyrex jar. This represents a saltwater pond or the ocean.

5. After several minutes, ask the students if the water in the drops is different from the hot salt water. Have them taste the drops.

**Discussion/ Reflection**

Culminate the activity with a discussion of what happened to the salt in the water. Ask if any students have ever tasted water from the ocean or an inland salt pond, and if they know why it is salty. Discuss why rainwater does not contain salt. Ask students if they have ever exhaled on a mirror or in a glass before. Discuss what happens.

Extensions Learn all the words of the water cycle.

**WATER CYCLE WORDS**

Match each word in column 1 with its definition in column 2 by writing the appropriate letter in each blank. Using your answers, label the diagram below.

**Column 1**

1. a) Precipitation
2. b) Evaporation
3. c) Condensation



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4. d) Run-off

5. e) Groundwater

6. f) Infiltration

7. g) Transpiration

8. h) The water cycle

9. i) Transportation

**Column 2**

___ the change of water vapor to liquid.

___ the process whereby water travels from the Earth to the air and back to the Earth.

___ the release of moisture by living things.

___ water collected below the soil on the bedrock.

___ the change of water from liquid to gas.

___ any type of moisture that falls to Earth.

___ the flow of water from land into lake, river, wetland or ocean. ___ the penetration of water into the ground.

___ the phase in which clouds carry water from the point of evaporation to the point of precipitation.



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## Evaporation Demonstration

**Summary**: Students observe under what conditions water evaporates fastest, and how salts are left behind in the process of evaporation.

### Learning Objectives

Students will be able to:

a) define evaporation;

b) explain how seasonal wetlands dry up and how tidal pools become smaller; and

c) describe how salt is extracted from sea water.

**Age levels:** 7-14

**Subject Areas:** Science, Language Arts

**Time**: Long (2–3 lessons)

### Materials

Four same-size glass containers with tops (such as jars formerly containing jam, mayonnaise, etc.)

Salt (coarse or table salt)

Food coloring

Labels

Handout: Water cycle chart

### Background



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Heat from the sun and air causes water to evaporate. Water that evaporates turns into a gas called water vapor and rises into the air. This is how puddles dry up and disappear after the rain, how seasonal wetlands dry up, and how tidal pools become smaller (hotter and saltier) very quickly. When it evaporates quickly and in large amounts, as it does in tropical and sub- tropical areas, water leaves behind salts that have previously been absorbed from the rock and soils that surround the wetland.

**Procedure**

1. Ask two students to fill all four glass containers with fresh water. To two of them, have a student add enough salt to make a very salty mix (approximately two teaspoons, which is much saltier than the ocean). Cap and label the containers “salt water”.

2. Select four places in the school grounds or classroom and place each container in one of them; leave the tops off. Label each container with a description of where it has been placed. The locations will be:

    a. cool, shady place

    b. a hot, sunny place

    c. a hot, sunny, but drafty (windy) place d. a drafty, cool, and shady place

3. Leave the containers in their locations for a week.

Discuss where water vapor comes from. Most of it comes from the oceans, including the Caribbean Sea. It also comes from the surfaces of lakes, ponds, and wetlands; from the transpiration of breathing plants; the perspiration, or sweating, of humans and animals; and the respiration, or breathing, of humans and animals. Ask the students to predict what will happen in the various containers.

4. Collect the containers and observe each one, noting its condition in science lab books or on an observation sheet.

Culminate the activity with a discussion of why the container that was in a hot place has little or no water left and has salt crystals around its edges. Ask if any students have ever tasted water from the ocean or an inland salt pond, and if they know why it is salty. Discuss why water in cool, shady places evaporates more slowly and is therefore better habitat for wildlife.

Following a field trip to a local wetland, students can bring back small containers of water and place them in the same locations for a week and observe what happens to the water samples.



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**Discussion:**

Culminate the activity with a discussion of why the container that was in a hot place has little or no water left and has salt crystals around its edges. Ask if any students have ever tasted water from the ocean or an inland salt pond, and if they know why it is salty. Discuss why water in cool, shady places evaporates more slowly and is therefore better habitat for wildlife.

**Extensions:** Following a field trip to a local wetland, students can bring back small containers of water and place them in the same locations for a week and observe what happens to the water samples.



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## MANGROVES AND THE WATER CYCLE

The amount of the water in the world never diminishes, but constantly changes its form: it goes from the liquid state to the gaseous, or to solid, and then the chain repeats itself. The movement of water from land to sea, to the air and then to the land again is called the water cycle or hydrologic cycle which is driven by solar heat (Figure 8).

A part of the water that falls in the form of rain is absorbed by plants, some flows to form rivers and streams of water, thus filling lakes and wetlands. In some regions there are no rives nor streams of water as a result the greater part of the rainwater seeps into the ground (infiltration) and fills subterranean deposits (aquifers). This is the underground water.

All the rivers, streams and subterranean deposits are replenished with water from their own geographical area. This area is known as a basin or watershed. All the water inside a basin or watershed is interconnected. Any activity in one basin that has an effect on the water will likewise affect other bodies of water in the area. For example, the falling or cutting down of trees on a mountain will result in erosion which leads to sedimentation in the rivers that source their water there; thus, the volume of evaporation will decrease, so that less rain will fall on the mountains and less water will enter the rivers and streams, and the wetlands near the sea will dry up. In order to preserve coastal wetlands, it is necessary to protect the whole basin.

### Water Cycle Rap

**Summary:** Students will learn the process of the water cycle through doing a rap

**Learning Objectives:** Students will understand the process of the water cycle.

**Subject Areas:** Science, Music

**Time:** 10-30 minutes



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**Materials:** Copy of Water Cycle

**Background:**

Most of the Earth is covered with water and every living thing needs it to survive. That's why we need to keep it clean. The water that exists today is the same water that the dinosaurs drank-because of the process of the water cycle. Many different types of rain or moisture come from the atmosphere-snow, hail, mist, fog and rain in a process known as precipitation. When rain falls, it soaks into the ground, filling up lakes, rivers, and wetlands. This process is called saturation. Water then returns to the atmosphere as an invisible vapor. Some water infiltrates the permeable soil and enters the groundwater. When it is emitted from plant leaves, the process is called transpiration. Water vapor rises from the Earth's surface when heated by the sun in the process known as evaporation. As the water vapor cools it condenses, usually on tiny particles of dust in the air and collects to form clouds. We call this process condensation.

**Procedure**

1. Review the water cycle with the students.

2. Have the students stand up and reach high above their heads, then bring their arms down as they say "precipitation". They should then touch the ground saying "saturation". Then have them wiggle their fingers on the ground saying "infiltration". Next have them raise their arms partway up as they say "transpiration" and the rest of the way up as they say "evaporation". Finally, they should form a circle with both arms raised overhead, saying "condensation". Do this slowly first, then have them continue to do the cycle, gradually speeding up.

**Discussion/ Reflection**

Refer to the handout and lead the students into a discussion of the process.



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**CHAPTER 8: Human Impacts: Benefits, Threats, and Solutions**



**Classroom and Field Trip Activities for Chapter 8**





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**Chapter 8: Human Impacts: Benefits, Threats, and Solutions**
Related PPT Presentation: Ecosystem Threats: Coastal Lagoon Curriculum
Related Videos:

**Importance of Coral Reef and Coastal Ecosystems**
The Cayman Islands is the coastal home to 119,605 square-km of national waters that includes the deepest area of the Caribbean Sea, the Cayman Trench which reaches a depth of approximately 25,000 feet below sea level, 365 dive sites, 60 species of coral and more than 500 fish species. The warm, clear water, spectacular colors and multitude of living things captivate almost everyone who sees a coral reef. Few things in the world can connect people as well as sharing stories of experiences in the oceans and discoveries on the coral reef.

Although sometimes viewed as a separate entity, the coral reef ecosystem contains delicate and complex interconnected relationships between many organisms. They are intimately connected to other marine communities such as mangrove forests, seagrass beds, and the open seas as water currents transport larvae, plants, animals, nutrients, and organic material. Each system depends heavily on the others, resulting in a tightly integrated and finely balanced marine environment. It is hard to imagine the massive reef structures and reef walls as fragile, living entities, but coral reefs are extremely sensitive to external pressures and over-exploitation.



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The world ocean provides so many benefits. Here are seven things the ocean does for humans and the planet:

1. The air we breathe: The ocean produces over half of the world's oxygen and absorbs 50 times more carbon dioxide than our atmosphere.

2. Climate regulation: Covering 70 percent of the Earth's surface, the ocean transports heat from the equator to the poles, regulating our climate and weather patterns.

3. Transportation: The majority of global trade involves some form of marine transportation.

4. Recreation: There are a multitude of activities from boating to SCUBA diving to kayaking and fishing, the ocean provides us with many unique recreational opportunities.

5. Economic benefits: the ocean economy produces billions in goods and services and ocean-dependent businesses employ millions of people. Locally, the beauty and diversity of the three islands' marine environment has earned it multiple awards for Best Overall Dive Destination in the Caribbean and more than millions of dollars in marine-related tourism income. Not surprisingly, the local government— prompted by an 80% decline in Caribbean reefs over the past 25 years— has enacted legislation placing the three-island archipelago at the forefront of Caribbean marine conservation. This push has also resulted in the growth of a diverse marine conservation business sector, with a multitude of activities and opportunities for both locals and visitors.

6. Food: The ocean provides more than just seafood; ingredients from the sea are found in surprising foods such as peanut butter and soy milk.

7. Medicine: Many medicinal products come from the ocean, including ingredients that help fight cancer, arthritis, Alzheimer's disease, and heart disease

**Threats to the Coastal Ecosystems**

The biodiversity of the reef system supports a vast interdependent food web, from microscopic plants and animals to humans. However, this life sustaining resource is now seriously threatened by human impact. The possible warming of our climate with associated warming of ocean temperatures, increased sedimentation from development along coastal areas, pollution, and unsustainable fishing methods are only some of the threats to reefs worldwide. As humans change the environment on the surface of the Earth, the conditions underneath the surface of our oceans change accordingly.



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The present degradation of the marine and coastal environment presents an urgent need to initiate a new regime that adopts a more precautionary ecosystem approach to sustaining the health of these systems and restricts adverse man-made impacts upon these related habitats. Environmental education has been promoted as a method for increasing awareness and understanding of environmental issues such as coastal and marine resource management. Interactive environmental education programs may initiate stewardship through participation, discussions, and action, within communities. A central idea in this process involves the issue of sustainability.

**Mangrove Threats**

The mangroves of Grand Cayman provide many functions crucial to the health of Cayman's environment. The tangled roots of the mangroves are a nursery for juvenile fish, turtles and lobsters. A diverse range of invertebrate species make their homes on the mangrove trees as well as roots submerged beneath the water, while birds such as the Cayman parrot nest in the mangrove branches above. Essential functions of the mangroves include protection from the storm surges and large waves of hurricanes, prevention of shoreline erosion, and as a filtration system for fresh water entering the marine environment. Mangroves also provide important nutrients to the surrounding ecosystem, thereby increasing the productivity of the area.

The major challenges facing healthy mangrove environments include commercial and industrial developments. During the last three decades, the expansion of Cayman's population and tourism industry has intensified land development particularly on Grand Cayman. One of the most significant problems is the destruction of mangrove swamps attributable to canal and waterfront real estate development.

**Coral Reef Threats**

Coral reefs face multiple threats at different scales. Global threats like warming waters combined with direct threats like overfishing and water pollution, will severely inhibit the ability of corals to grow, reproduce and thrive. As much as one-third of all reef-building corals are at risk of extinction. Scientists predict that all corals will be threatened by 2050, with 75 percent facing high to critical threat levels. (see link PDF WDI Reefs at RISK)

However, there is a reason for hope. There are many clear-cut actions that can help coral reef ecosystems. At a local level, when we reduce direct threats to reefs—such as pollution, overfishing or unsustainable tourism—reefs are healthier and more capable of withstanding the effects of climate change, like bleaching and ocean acidification. At a regional and global level, policy and projects to help restore the ecosystem will aid in providing networks of healthy reefs that enable corals to adapt to climate change because they are diverse, connected and large.

**Direct Threats**

**Unsustainable fishing**

Overfishing is thought to affect more than 55 percent of the world's coral reefs. When people overharvest fish on a reef, the entire food web is affected. Intense grazing by herbivorous fish, such as parrotfish, on healthy reefs keeps algae at low levels. When



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these fish disappear, the delicate balance of the coral reef ecosystem is disrupted, and seaweed-like algae (called macroalgae) can grow unchecked, eventually smothering reefs.

Globally, there is a shift away from sustainable small-scale fishing methods towards ones that use indiscriminate fishing methods, such as gill and trammel nets, to remove large quantities of fish populations, regardless of size or species. When reefs are overfished, fish populations decline, and fishers respond by intensifying their effort in an attempt to catch something. Their increased efforts can lead to the collapse or near-collapse of fish stocks, which not only threatens the economic stability and food security of local communities but puts coral reefs at significant risk. According to the 2018 WWF Living Planet Report, almost 6 billion tons of fish and invertebrates have been taken from the world's oceans since 1950.

**Water pollution**

Land-based sources of pollution: clean water is vital for both human communities and coral reefs. Around the world, water pollution from land causes severe damage to coral reefs, poses risks to human health and threatens the tourism industry. Directly discharged sewage and inadequately treated wastewater from cesspools and septic tanks allow high levels of nutrients, bacteria, chemicals, and pathogens to enter the marine environment. Other land-based activities—like farming, logging, road construction, animal husbandry and mining—produce pollutants such as sediments, fertilizers and pesticides which run off the landscape when it rains and end up in the ocean. An overabundance of nutrients in marine environments upsets the delicate balance of coral reef ecosystems. Excess nutrients promote the growth of algae, which can kill corals by smothering them, blocking their access to sunlight, and promoting the growth of harmful bacteria. Likewise, sediments can harm corals by blocking their access to sunlight, which the algae that lives inside them depends on in order to photosynthesize effectively.

**Marine debris:** Marine debris, also known as human trash, can harm or kill coral reefs and the many animals that live in them. Marine debris can get to the ocean from land or from boats and ships. Floating trash hooked on reefs can block the sunlight reefs need for their symbiotic algae to photosynthesize. Lost or discarded fishing nets (called "ghost" fishing gear) can get caught on reefs and entangle fish, sea turtles and marine mammals. Sea turtles often mistake plastic bags for jellyfish and eat them, causing harm to their digestive tracts and even death.

**Habitat destruction**

Like trees, coral reefs are living structures that can take many years to regenerate once destroyed. Since most coral species grow less than an inch per year, reef destruction can have long-lasting consequences. Unfortunately, many human activities directly damage

or destroy coral reefs and associated habitats. This includes habitat destruction of interrelated coastal ecosystems such as mangroves and lagoons.

Examples include:
Coral mining: Coral pieces are removed in large quantities for use as bricks or road-fill. Sand and limestone derived from coral reefs are used to make cement for new buildings. In some places where coral reefs were heavily mined, the reefs have still not made a comeback.

Construction: In many places, developers have constructed piers and other structures directly on top of coral reefs, destroying them and any possibility of regeneration.

Coral collecting: Particularly beautiful coral species, like black and red coral, which are used to make jewelry, are heavily harvested. Branching corals are often broken off and sold as souvenirs or beachy home décor. As is the case with sea stars and sand dollars, this type of harvesting can cause rapid declines in target species. By purchasing jewelry or other souvenirs made from coral or other once-living marine life, tourists and other consumers often unknowingly contribute to the destruction of reefs.

Destructive fishing methods: Blast fishing and cyanide fishing use dynamite and poison, respectively, to stun and trap fish. Blast fishing can destroy an entire reef in one act. Fishermen use cyanide to stun fish and capture them for the live aquarium trade. While large fish can metabolize cyanide, smaller fish and other marine animals, including coral polyps, are poisoned by the chemical cloud created by this activity. Bottom trawling, a fishing method that drags a weighted net along the seafloor, destroys virtually everything in its wake during a single fishing event.

Boat anchors: Boat anchors are often dropped directly onto reefs, causing significant damage to reef and disturbing marine life. One solution is to install permanent mooring buoys which float on the water and can be used by fishermen or tourist operators as a place to safely anchor their boats. The Cayman Islands employs an extensive permanent mooring buoy system around all three islands.

Unsustainable tourism: When tourism is not carried out responsibly, it can harm reefs. Snorkelers or divers who grab, walk on or kick their fins on coral, can destroy coral reefs and stir up sediment on the sea-floor bottom (which affects water quality). In places where tourism is high, tourists can unwittingly cause additional damage by wearing sunscreen, which leaves chemicals in the water that are harmful to reefs.

Mangrove destruction: Throughout the tropics, mangrove forests are destroyed by industrial agriculture, aquaculture and harvesting of wood to approximately 1 to 2 percent globally per year. Tens of millions of tons of the carbon that was once locked away in these forests' meters-deep, oxygen-poor soils is now in the atmosphere, contributing to climate change. These ecosystems normally filter the amount of sediment reaching the ocean; therefore, their disappearance has also led to an increase

in the amount of sediment reaching coral reefs. In addition, mangroves serve as important nursery habitat for reef species.

## Global Threats

**Climate Change:** Ninety-seven percent of publishing climate scientists agree that global climate change is real and a result of human activity. Our world is getting warmer, and our oceans are growing more acidic. By reducing the human use of fossil fuels, we can curb carbon dioxide emissions (CO2), slow the pace of climate change, and give coral reefs the critical time they need to adapt.

**Coral Bleaching**: Coral bleaching happens when corals lose their vibrant colors and turn white. The symbiotic algae, zooxanthellae, that live in corals are what give healthy corals their variety of different colors. Most corals have a narrow temperature tolerance. Coral bleaching occurs when corals become stressed, most often when ocean water gets too warm. Corals will "eject" the zooxanthellae or algae that live inside them. When corals lose their algae, they not only lose their color, therefore turning white, but also their built-in food source. Severe bleaching is usually associated with environmental stress, such as unusually warm (or cold) water temperatures, increased light or solar radiation, changes in salinity, sedimentation, or other pollution from land. The leading cause of coral bleaching is climate change. A warming planet means a warming ocean, and a change in water temperature—as little as 2 degrees Fahrenheit—can cause coral to drive out algae. Coral may bleach for other reasons, like extremely low tides, pollution, or too much sunlight.




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Though bleaching does not mean the coral is immediately dead, they will eventually die if they are under repeated stress, which has devastating impacts on the ecosystem. After an intense El Niño in 2015–2016 led to the longest global coral bleaching event on record, causing significant coral mortality in the Pacific Remote Islands in 2016 and 2017. This even destroyed as much as two-thirds of the corals in the northern part of Australia's Great Barrier Reef. Outbreaks of coral disease typically follow bleaching events since stressed corals are more susceptible to infection. A recent special report from the Intergovernmental Panel on Climate Change (IPCC) states that with an additional half-degree of warming above today's levels, tropical coral reefs will face "very frequent mass mortalities," although coral adaptation is possible. If temperatures rise an additional degree to 2 degrees above pre-industrial levels, coral reefs are in danger of vanishing entirely.

**Sea level rise**: As the planet gets warmer, glaciers melt, causing sea level to rise. As a result, corals are predicted to end up deeper underwater, receive less sunlight and grow more slowly. The IPCC has found that sea level is rising at a rate of 0.12 inches per year—60 percent faster than the 0.08 inches per year that were predicted in 2007. Stronger storms: Another predicted climate change impact is an increase in the frequency and intensity of tropical storms. Hurricanes, cyclones and typhoons gain their speed and strength from warm ocean temperatures. These storms cause larger and more powerful waves than normal and can break coral branches and overturn coral colonies. Heavy rainfall from a storm can also cause an increase in runoff from land-based sources, leading to increases in nutrients and sediments flowing to the coral reef causing additional stressors.

Ocean Acidification: The amount of carbon dioxide (CO2) in the air has increased by one-third since the beginning of the Industrial Revolution, about 150 years ago. About 25 percent of all of the CO2 emitted is absorbed by the oceans, another 25 percent is absorbed by plants and trees, and the remaining 50 percent stays in the atmosphere. As the oceans absorb CO2, their chemistry changes and they become more acidic. This makes it difficult for corals and other marine organisms to grow their skeletons and shells. The calcification rates of corals and other reef organisms have already begun to decrease. With increased CO2 in the water, coral may form weaker skeletons, making them more vulnerable to disease and destruction by storms.

## Local Threats

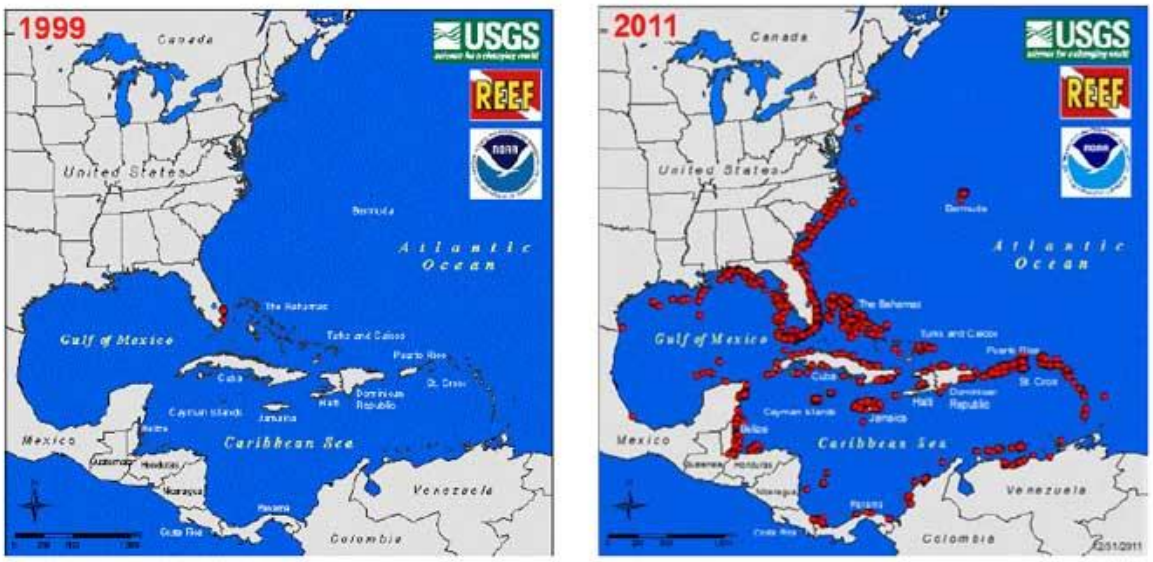
An important local issue is the **Stony Coral Tissue Loss Disease (SCTLD)**
Since the discovery of Stony Coral Tissue Loss Disease (SCTLD) on the north wall of Grand Cayman in June 2020, the Department of Environment (DoE) continues to battle with this deadly coral disease which has devastated reefs in Florida and around the Caribbean.
The Department of Environment (DoE) held a meeting with watersports and dive operators on the 16th October 2020 to update persons in the industry about the nature of this disease and DoE's response, to request the public's assistance in reporting any possible disease sightings, and to request that dive sites in diseased areas be avoided.

This meeting can be viewed on CIG television here:
https://www.youtube.com/watch?v=97ItvlR22T4&t=2628s

The DoE held an update meeting on the 26th February 2021 for all watersports and dive operators given that the disease had progressed beyond the DoE's managed firebreak. The full meeting can be viewed on CIG television:
https://www.youtube.com/watch?v=Tq14ka1Jaf0.

**Lionfish Invasion**
*Information from the Cayman Islands Department of Environment:*

In February 2008 a juvenile Red Lionfish was removed from a dive site in Little Cayman and since then many others have been removed from Grand Cayman, Little Cayman and Cayman Brac. While it may seem exciting to see this fish on a dive it is quite disturbing when you realize that this species was only supposed to be found in the Indian and Pacific Oceans.
So what's it doing in the Atlantic Ocean? While no one knows exactly how they arrived in the Atlantic, the most accepted method is the accidental or intentional release of aquarium fish into the marine environment. Lionfish are now established along the entire US East Coast from Florida through Massachusetts, east to Bermuda and throughout the Caribbean and Gulf of Mexico in depths ranging from 1 to 1,000 feet!




**Red dots show locations of lionfish**

Allowing lionfish to establish themselves in our waters can lead to serious problems because they are:

- Ravenous predators are known to eat juvenile fish and crustaceans (shrimps, crabs, etc.) in large quantities.
- Not known to have many native predators
- Equipped with venomous spines which deter predators and can cause painful wounds in humans.
- Capable of reproducing at a rate of 30,000 eggs every four days
- Able to reproduce at less than 1 year old.
- Relatively resistant to parasites, giving them another advantage over native species.
- Fast in their growth, able to outgrow most native species with whom they compete for food and space.

It is well established that red lionfish will stand their ground when harassed and, when threatened, can arch their backs, pointing their dorsal spines at the aggressor, and swim forward rapidly in order to inflict a sting. Poisoning of the hand from the venomous sting has been the most common injury. **It should also be stressed that serious wounds have also resulted from the careless handling of recently dead specimens.**



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The lionfish has 18 venomous spines. 13 are on the top of the fish and the remaining 5 are on the bottom. The sting of the red lionfish causes intense pain immediately and leads to several hours of extreme pain, depending upon the amount of venom received. To treat lionfish stings you should immerse the affected area in hot but non-scalding water for two to three hours and seek medical attention immediately!

When diving, especially in a wreck, cave or swim-through, be aware of the areas above you as lionfish are able to rest, upside down, on the ceilings and walls of these features. Divers have been stung by lionfish they were not aware of. If they are caught while fishing do not release them back into the ocean.

For these reasons the Department of Environment (DoE) has taken the stand that these fish must be removed from our waters, however, due to the venomous nature of the fish we ask that only licensed individuals attempt to cull them. If you are interested in being licensed, or learning more about the lionfish, please attend one of the DoE trainings courses which are offered monthly. Contact DoE for more information or email to be added to the notification list for future courses. Phone: 345-949-8469, Email: DoE@gov.ky

**Plastic Pollution:**

Plastic pollution is one of the greatest threats to ocean health worldwide. With skyrocketing plastic production, low levels of recycling, and poor waste management, between 4 and 12 million metric tons of plastic enter the ocean each year—enough to cover every foot of coastline on the planet! And that amount is projected to triple in the next 20 years.



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In the ocean, plastic pollution impacts sea turtles, whales, seabirds, fish, coral reefs, and countless other marine species and habitats. In fact, scientists estimate that more than half of the world's sea turtles and nearly every seabird on Earth have eaten plastic in their lifetimes. Plastic pollution also damages beautiful beaches, coastlines, and snorkel and dive sites worldwide, even in remote areas such as Midway Atoll. One of the reasons that plastic pollution is such a problem is that it doesn't go away: "plastics are forever." Instead, plastic debris simply breaks down into ever-smaller particles, known as microplastics, whose environmental impacts are still being determined.

A great resource for additional information is https://www.5gyres.org

**Balloons Blow!**

Balloons are often seen as fun, harmless decorations. But they become deadly litter as soon as they are released into the air and forgotten. What goes up must come down. Balloons are hazards when they enter the environment. All released balloons, whether they are released intentionally or not, return to Earth as ugly litter, including those marketed as "biodegradable latex". Balloons kill countless animals and cause dangerous power outages. They can travel thousands of miles and pollute the most remote and pristine places. Inflated balloons that make their way back to earth or water, pose a risk for wildlife due to their probability of becoming ingested due to attractive color or their ribbons and tassels forming the perfect trap for animals to become entangled. Balloons return to the land and sea where they can be mistaken for food and eaten by animals.



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Sea turtles, dolphins, whales, fish and birds have been reported with balloons in their stomachs and ribbons and strings can lead to entanglement, causing death.

**Balloons and their biodegradable nature**

There are two types of balloons in general use, latex and mylar. Although latex balloons are considered biodegradable, this will take anywhere from 6 months to 4 years to decompose and they can wreak a lot of havoc before they do. In one experiment researchers observed that balloons floating in seawater deteriorated much slower, and even after 12 months, still retained their elasticity.

*"Latex balloons float for just 10 hours, but can take a year or more to degrade, long enough to repeatedly wrap around or be ingested by turtles, seabirds and marine mammals. Scientists who work with stranded whales, dolphins, seals and sea turtles have found balloons, parts of balloons and balloon string in the stomachs of many of these dead animals. In 2003, volunteers collected 4,228 mylar and latex balloons just from New Jersey beaches."* Patricia Sullivan, Honolulu Environmental Policy Examiner 2010

*See activity for alternatives to balloon releases.*

**Solutions**

Environmental education is an important component of marine and coastal resource management for creating awareness of environmental concerns. To recognize the significance of global environmental changes, we must appreciate the intimate and fragile interactions between humans and the ecological systems of the planet. Too often we acknowledge the degradation of a species or habitat when it is almost too late for reparation. Management of marine resources will continue to be unsuccessful if the public remains uneducated with little or no access to the issues and science behind the policies.

Environmental education aims to enhance a community's recognition of not only the economic value of resources, but also their awareness of how their actions may influence the environment. Through environmental education programs, communities may become reinvigorated, therefore reinforcing the importance of a shared voice. Environmental education may sustain the community's interest in its environment and its resources and promote responsible stewardship initiatives.

The diverse shorelines of Grand Cayman are an excellent setting for environmental education opportunities. Exploration and discovery have the capability to inspire curiosity and encourage initiatives in marine conservation. Interactive environmental education programs for children may enhance the knowledge of the ecology of the island, and therefore the community's awareness of the significance for environmental protection. The dynamic features contributing to the vitality of the islands can be discovered through interactive environmental education and may allow the children to gain increased appreciation of their environment.

Environmental education goes beyond the presentation of information to inspiring positive attitudes toward the environment, and to enhancing the capability for community action skills.



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**Restoring coral reefs**
Corals are able to recover from bleaching events if conditions improve before they die, though it can take many years for the ecosystems to fully heal. Scientists are also testing new ways to help coral reef ecosystems, such as growing coral in a nursery and then transplanting it to damaged areas.

Grand Cayman Eco Divers in collaboration with the Cayman Islands Department of Environment and local dive establishments are working together to maintain coral nurseries and aid in conservation, sustainability and restoration of Cayman's coral reefs. The program develops effective strategies for protecting and restoring damaged areas of coral reef with an emphasis on growing Staghorn coral in nurseries. Coral fragments are grown on structures referred to as coral trees. These "trees" are made from PVC and fiberglass rods.

The fragments of coral grow into colonies and after significant growth, they are removed from the tree and planted onto damaged coral reef areas to aid in their recovery. The fragments are proven to provide a sustainable method in maintaining healthy reefs for the long run. The successful transplantation and growth of the coral fragments help create diversity in the ecosystem and resilient reefs.

https://mission-blue.org/2017/03/cayman-islands-coral-nursery-conservation-program/

**Grouper Moon Project**
The Grouper Moon Project is a conservation science partnership between Reef Environmental Education Foundation (REEF) and the Cayman Islands Department of

Environment (DoE) with scientists from Scripps Institution of Oceanography at UC San Diego and Oregon State University, aimed at studying Nassau grouper (Epinephelus striatus) - a social and ecological cornerstone of Caribbean's coral reefs.


January 2020 - Scientific paper from the Grouper Moon team that documents a successful recovery of Nassau Grouper populations in the Cayman Islands. It also highlights the value of collaborative efforts for conservation success. The study, published in Proceedings of the National Academy of Sciences, is available here. Read more here. All publications from the project are listed below.

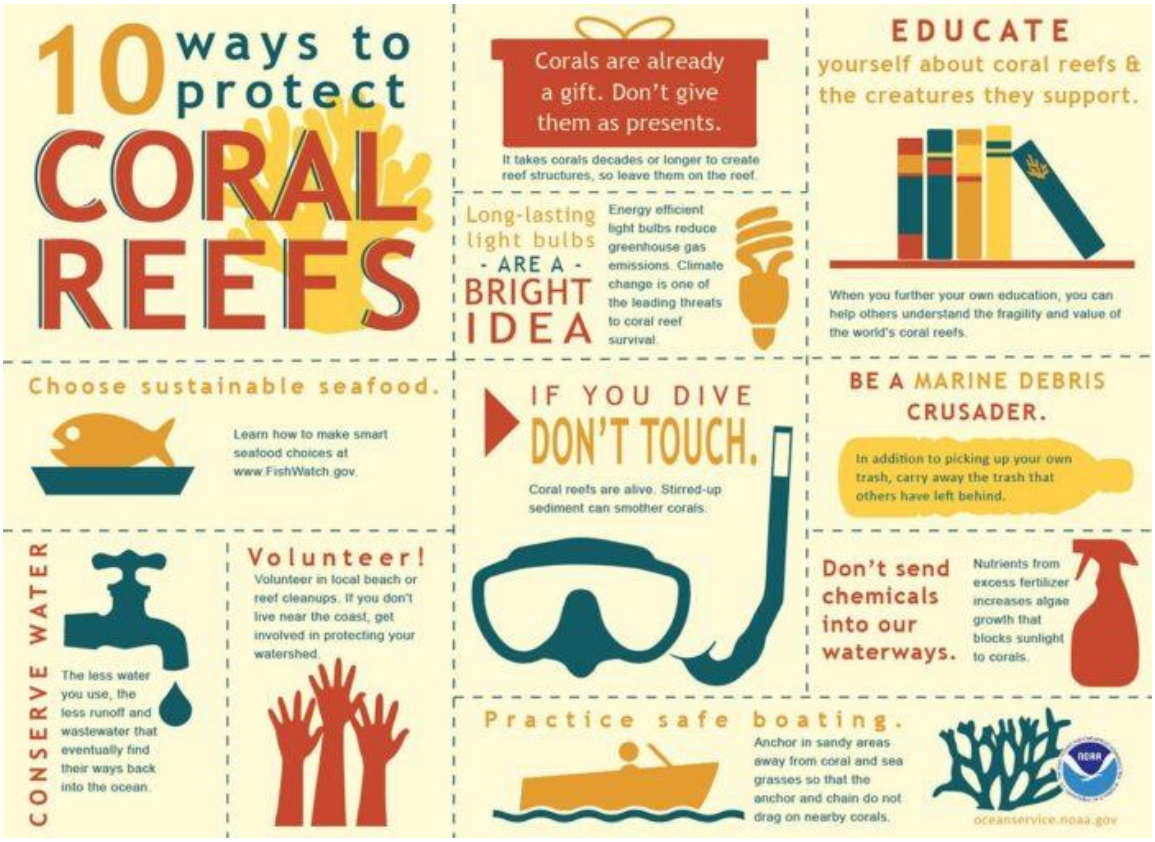
August 2016 - Grouper Moon findings led to sweeping science-based legislative protections for Nassau Grouper in the Cayman Islands! Read More Here.

Grouper Moon 2013
https://www.youtube.com/watch?v=W9tYkdK233Q
Grouper Moon 2020
https://www.youtube.com/watch?v=FhQzEGc1_bk

**Live Sustainably**
Conserving energy to reduce your carbon footprint is one way to fight the effects of global warming and lessen large-scale threats to reef ecosystems. Take small but powerful steps like switching to compact fluorescent light bulbs, planting native trees, buying energy-efficient cars, avoiding pesticides, and teleconferencing instead of flying when possible.

Follow the “3 R’s” whenever and wherever you can, reduce, reuse, recycle, to decrease the negative impacts of pollution and landfills on the health of our oceans. We can change our behavior in simple ways such as using reusable bags when shopping, taking lunch in reusable containers rather than wasting take-out boxes, or starting your own compost bin for kitchen and yard waste.

Use water wisely. When you use less water, less runoff and wastewater will end up in the ocean. Try to prevent polluted runoff from oil, grease, and heavy metals found around your home. Use native plants in your garden, The Nation Trust for the Cayman Islands can provide a lot of information on native plants. Most of these species will support local wildlife, use less water and do not need any fertilizer.




**Be a Smart Consumer**

Choose seafood that is sustainable. Find out which seafood is best to eat by reviewing the local Cayman Sea Sense Seafood Watch Guide at https://nationaltrust.org.ky/wp-content/uploads/2019/09/Sea-Sense-Guide2.pdf

Cayman Sea Sense is a sustainable seafood education initiative of the National Trust for the Cayman Islands, helping restaurants and diners to make informed and environmentally positive seafood choices. To date, the program endorses over 30 Sea Sense restaurants on-island. For a list of restaurants, visit https://www.nationaltrust.org.ky/education.

Want to have the latest info available on your mobile device at the touch of a finger? Download the Seafood Watch app.

Don't buy coral jewelry or curios and household goods made from animals that once lived in the ocean, this includes seashells! Harvesting these species can cause significant habitat destruction or dramatically reduce populations.



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**Become an Advocate**
Find out about existing and proposed laws, programs, and projects that could affect the world's coral reefs and support those that benefit the reefs. Call, email, and send letters to your elected officials to let them know you are passionate about ocean conservation. It does make a difference!

Get involved with the local Mangrove Rangers, a conservation group that advocates for and monitors the ecological health of the mangrove ecosystems in the Cayman Islands. This group focuses on educating and empowering local communities of the Cayman Islands to understand the true value of mangrove ecosystems and their importance in sustaining our island environment, which will in turn sustain the health of all its interconnected ecosystems.

Mangrove Rangers
National Trust for the Cayman Islands
DoE Conservation Law
Island Offsets

Our environmental beliefs and behaviors are established through the integration of learning experiences. Interactive environmental education allows students to develop an increased concern for the environment through contact with natural environments. It provides opportunities for students to learn and see firsthand how nature may be affected by human actions. Active participation and contact may prove to be a catalyst for shaping responsible environmental behavior and attitudes. The symbolism of the encounter combined with direct interaction provides a powerful opportunity for the creation of a sense of stewardship, as this belief is enhanced during critical stages of learning, understanding, and knowledge.


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Classroom Activities and Field Trips

**Field Trip: Marine Pollution - Plastic Beach**

The **purpose** of this lesson is to educate students on plastic pollution/trash found in our seas and on our beaches. Students will learn the negative environmental effects of plastic pollution, along with solutions. The students will carry out beach research to document how much plastic pollution is on a local beach by analyzing plastic pollution in multiple 1-meter by 1-meter quadrants.

The **goals** for this lesson are for students to understand that the ocean and humans are inextricably interconnected.

Students analyze 1-meter by 1-meter quadrants to examine plastic pollution within the quadrant. Students learn that plastic pollution (micro and macro particles) is an environmental issue. Students will discuss how the plastic pollution made it to the beach and what solutions exist to reduce plastic pollution.

**Materials Needed:**

- one square meter defined by a frame or 4-meter rope loop
- one 5-gallon bucket to hold sediment from meter section
- metal scoop (or any sort of hand shovel)
- two sieves (5mm and 1mm) or a normal kitchen sieve
- data sheet (attached)
- scale (digital or handheld)

**Background:**

- Plastic pollution is plastic trash that is found on beaches and throughout the oceans. Plastic
  pollution comes from people littering, not recycling, and poor waste management.
- Plastic pollution is an important environmental concern to local and global communities.



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- Plastic pollution can harm aquatic fish, marine mammals and birds through ingestion,
  entanglement, and possible biological effects.
- Documenting plastic pollution will help strengthen laws that keep beaches cleaner.
- Plastic pollution moves from one country to another through ocean currents.
- A lot of plastic pollution can be found on the beach. Waves push the plastic to the beach from the center of the oceans.
- Single-use plastics are items that are only used for a few minutes and then thrown away. A lot of single-use plastic items cannot be recycled and end up in landfills and our oceans.

**Activity:**

1. Select a local beach. Depending on how many students are involved, determine the number of quadrants to carry out. 3-4 students should be assigned to each quadrant. Quadrant locations should be spread out along a debris deposit line, at least four 1-meter by 1-meter quadrants will be carried out at each beach. Please make a detailed map of the site with the location identified by landmarks and GPS (if possible) for each quadrant.
2. At each collection site, take the 1-meter by 1-meter wood frame, or rope stretched to make a 1-meter by 1-meter square, over the high tide wrack-line. If using a rope, use stakes to hold the corners.
3. Remove big pieces of natural debris, like seagrass, leaves and wood.
4. Mark the 10-liter level, usually the halfway point on a 5-gallon bucket, on the large plastic
   Bucket.
5. Using a small shovel, scoop the surface of the grid evenly until the 10-liter level is reached.
   This is approximately 3cm. of the surface. Scrape the surface EVENLY! Do not dig a hole in
   the sand.
6. Sieve all of the sand through the stacked sieves. If the sand is wet, you will likely need to push the sand through the sieves with water. This works very well if you bring a second bucket with you and fill it with water.
7. A wire mesh colander can be used. Please note the size of sieve/s used.
8. Transfer the contents of the colander to the collection bag or box.
9. Empty each sample into a pan and sort items (and weigh) into the categories listed on the Trash Collected data sheet. Fill out a data sheet for each sample that is taken or download the Marine Debris Tracker App.

Further Your Impact Compare data amount groups. Look up plastic and litter items and determine the timeline and impacts to the environment. Discuss how the plastic pollution made it to the beach and what solutions exist to reduce plastic pollution.

References:
5 Gyres: Science to Solutions; 5gyres.org
Santa Monica, California, USA
Blue Ocean Society for Marine Conservation; blueoceansociety.org
Blue Ocean Discovery Center Address: 180 Ocean Boulevard, Hampton



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# TRASH COLLECTED

**Citizen scientist:** Pick up all trash and record all items you find below. No matter how small the items, the data you collect are important for Trash Free Seas.®

**EXAMPLE:** TOTAL #

Plastic Bags: 𝍸 III = 8

Please DO NOT use words or check marks. Only **numbers** are useful data.

## MOST LIKELY TO FIND ITEMS: TOTAL #

Cigarette Butts: =
Food Wrappers (candy, chips, etc.): =
Take Out/Away Containers (Plastic): =
Take Out/Away Containers (Foam): =
Bottle Caps (Plastic) =
Bottle Caps (Metal) =
Lids (Plastic) : =
Straws/Stirrers: =
Forks, Knives, Spoons: =
Beverage Bottles (Plastic): =
Beverage Bottles (Glass): =
Beverage Cans: =
Grocery Bags (Plastic): =
Other Plastic Bags: =
Paper Bags: =
Cups & Plates (Paper): =
Cups & Plates (Plastic): =
Cups & Plates (Foam): =

## FISHING GEAR: TOTAL #

Fishing Buoys, Pots & Traps: =
Fishing Net & Pieces: =
Fishing Line (1 yard/meter = 1 piece): =
Rope (1 yard/meter = 1 piece): =

## PACKAGING MATERIALS: TOTAL #

6-Pack Holders =
Other Plastic/Foam Packaging: =
Other Plastic Bottles (oil, bleach, etc.): =
Strapping Bands: =
Tobacco Packaging/Wrap: =

## OTHER TRASH: TOTAL #

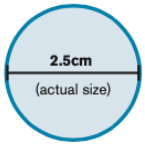
Appliances (refrigerators, washers, etc.): =
Balloons: =
Cigar Tips: =
Cigarette Lighters: =
Construction Materials: =
Fireworks: =
Tires: =

## PERSONAL HYGIENE: TOTAL #

Condoms: =
Diapers: =
Syringes: =
Tampons/Tampon Applicators: =

## TINY TRASH LESS THAN 2.5CM: TOTAL #

Foam Pieces =
Glass Pieces =
Plastic Pieces =




| DEAD/INJURED ANIMAL | STATUS | ENTANGLED | TYPE OF ENTANGLEMENT ITEM |
|---|---|---|---|
| | **Dead** or **Injured** | **Yes** or **No** | |

## ITEMS OF LOCAL CONCERN:

1. 2. 3.

## CLEANUP SUMMARY (circle units)

**Number of Trash Bags Filled:** **Weight of Trash Collected:** lbs/kgs **Distance Cleaned:** miles/km



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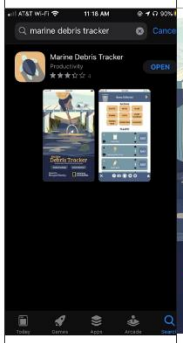
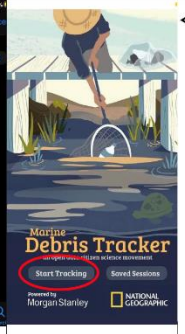
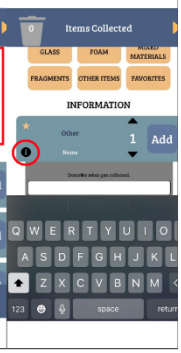
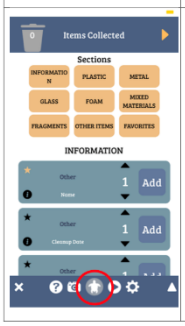
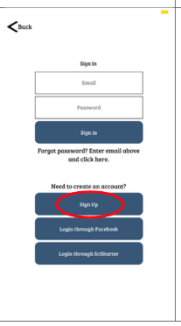
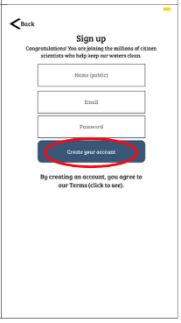
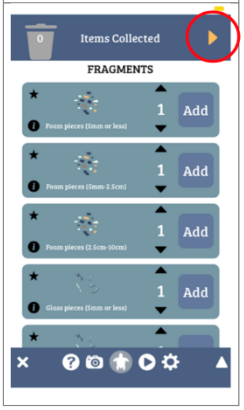
## Collecting Data with the Marine Debris Tracker App:

If you have access to a smartphone or tablet that you can use during your cleanup, you may choose to download and submit data through the Marine Debris Tracker app rather than collecting data on our paper data cards. Please see the instructions below to learn how to use the app.

| 1. Download the app Marine Debris Tracker from the app store on your phone. Available on iPhone and Android phones. | 2. Begin by clicking on "start tracking" to open all lists. | 3. Scroll until you see Blue Ocean Society's logo, click on it to use our list. |
|---|---|---|
|  |  |  |

| 4. After you click on our logo you will be brought to this screen, tap on "use this list". | 5. Tap on the category names to be brought to the different sections of your list. | 6. To enter in your information tap on the information category. Next, tap the small "i" located in the bottom left corner and type in your information (name, date, site, etc.) *Note: It will add your information to your trash can. That is okay, on our end they come in as their own categories* |
|---|---|---|
|  |  |  |

| 10. If it is your first time using this app you will need to make an account. Tap on the small turtle icon at the bottom of the screen to do so. | 11. If you already have an account sign in. If you do not tap on "Sign Up" to create an account. | 12. Enter in your name (this will be public), email and a password, then tap on "create your account". |
|---|---|---|
|  |  |  |

| 13. Once finished with your cleanup tap on the yellow arrow in the upper right-hand corner to submit your data. Be sure to dispose of your trash in the appropriate receptacle. That wraps up your cleanup – great work! |
|---|
|  |



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**Classroom Activity: Sustainable Fishing**

This activity allows students to explore the "tragedy of the commons," in which common usage of a limited, potentially renewable resource invariably leads to its exploitation. In this simulation, students imagine that they are fishermen sharing access to a common fishing pond. The fish are Hershey's Kisses. Two different stages of the simulation are performed. In the first, students are not allowed to communicate, and each fisher has no knowledge of how many fish have been taken before them. In the second, students are allowed to strategize, plan, and learn from their experiences.

The **goals** for this lesson are for students to:

1. In this way, the ability (or not) to communicate is the independent variable, and the size of the resource over time is the dependent variable.
2. At the end of this simulation, students should have an understanding of what leads to the "tragedy of the commons" and what can be done to prevent it.

**Lesson Objectives**: Upon completion of this lesson students should be able to:

1. Understand the conditions that lead to a "tragedy of the commons."
2. Learn strategies that prevent the destruction of a common resource.
3. Apply these strategies to environmental issues and suggest solutions.

**Introduction**
The purpose of this activity is to explore how resources are used and exploited when they are available to multiple parties. When Garrett Hardin (1968) first proposed this concept, he used the example of the traditional "commons" in New England towns to signify a public resource available for private gain. In this case, the commons were used for grazing the townspeople's livestock. He demonstrated the idea that a small increase in use of the resource (e.g., one extra cow) provides a great benefit to an individual, while the cost of that additional use (decreased grass supply) is shared by all. Therefore, each user has an incentive to use (and exploit) the resource to the greatest of his or her ability. Ultimately, there is a decrease in yield for both the group and the individual.

This idea has been adapted to explain the pattern of overuse of many common, limited resources. Even a clean school campus (and the treatment of it by trash-leaving students) can be explained by the tragedy of the commons.

Fortunately, there are strategies that can be employed to ensure the long-term survival of a resource despite the natural tendency toward exploitation. Several are explored in this activity. These are incentives, privatization, communication, and education. With these solutions in hand, strategies can be devised to help protect common resources in the environment and work toward sustainable resource use

**Materials Needed**:

For each group of four
- Hershey's Kisses
- Plastic spoon

- 400 ml beakers
- Fabric sleeve

Bonus material: Watch ***Netflix: Seaspiracy***

***Seaspiracy is a 2021 documentary film about the environmental impact of fishing directed by and starring Ali Tabrizi, a British filmmaker. The film premiered on Netflix globally in March 2021 and garnered immediate attention in several countries.***

**Sequence of Lesson:**

Divide yourselves into groups of four. Imagine this scenario. Each person represents the head of a starving family, which requires food. The only food source for these four families is a small fishing pond that can accommodate an unknown amount of fish. Fortunately, after each round of fishing by the four family heads, each remaining fish is able to spontaneously reproduce. Each person is allowed to take as many or few fish as you want, but if you take only one fish, your family will starve.

In this simulation, our pond is a beaker, and our fish are Hershey's Kisses. Fish are caught using plastic spoons. Each fishing round will last for 1 minute. You should rotate your fishing order every round so that everyone has a chance to go first. The simulation will continue for three rounds. The pond will be covered with a fabric sleeve, so that it is not possible to tell how many fish have been taken before you fish. No talking is allowed in this part.

## Data

1) All data should be recorded in the following tables.

Part 1: Commons pond

| Round # | # of fish at beg. of round | # of fish taken by 1st fisher | # of fish taken by 2nd fisher | # of fish taken by 3rd fisher | # of fish taken by 4th fisher | Total fish left at end of round |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| Total | | | | | | |

**Procedure**

Part 2:

In this part, you will have access to two ponds, one common and one private. The rules for the common pond are the same as before. However, talking and strategizing is allowed in this part. The cloth sleeve will be removed so that you will know exactly how many fish are in the ponds at all times, and how quickly the fish will reproduce. The carrying capacity for the common ponds is 16 and for the private ponds is 4. You must

remove at least one fish from each pond each round. As before, you may catch as many fish as you would like from both ponds during each round.

### Data

Part 2: Commons pond

| Round # | # of fish at beg. of round | # of fish taken by 1st fisher | # of fish taken by 2nd fisher | # of fish taken by 3rd fisher | # of fish taken by 4th fisher | Total fish left at end of round |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| Total | | | | | | |

Part II: Private pond

| Round # | # of fish at beg. of round | # fish taken this round | # of fish at the end of round |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| Total | | | |



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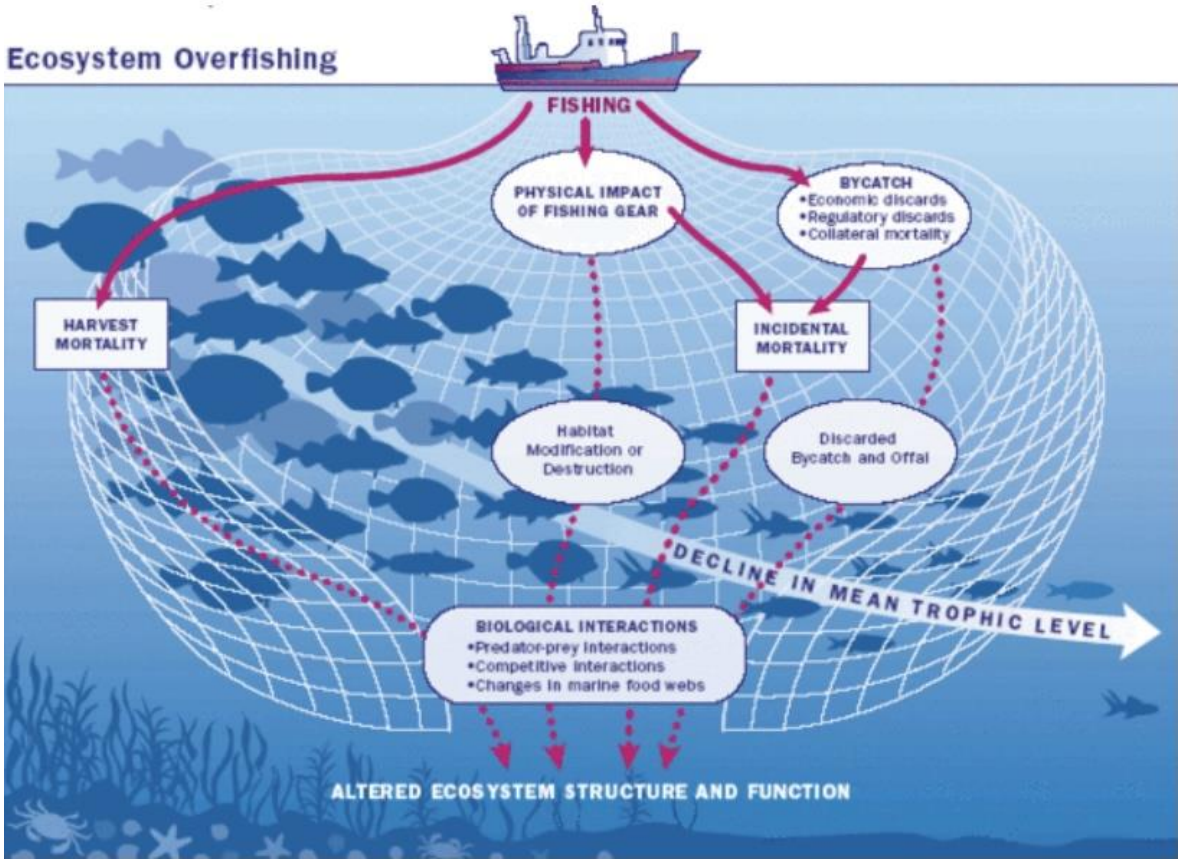


References:
Hardin, Garrett. "The Tragedy of the Commons." Science 162 (1968): 1243-48



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## Classroom Activity: **Endangered Marine Life**

The **purpose** of this lesson is to familiarize students with the dilemma of endangered species and to help them understand and gain perspective on human issues that continues to endanger species and threaten our global environment.

**Lesson Objectives**: Upon completion of this lesson students should be able to:

1. Students will learn what it means for a marine mammal or fish to be threatened or endangered.
2. Students will be able to identify why we need to protect our marine environment and what we can do to help protect ecosystems.
3. Students will be able to describe endangered and threatened Caribbean species.
4. Students will be educated on the dynamic interconnections of natural systems, human impacts, and solutions.

**Materials Needed**:

- Materials for creating posters (paper, markers, tape, etc.)/ Art supplies.
- Endangered Marine Life ppt presentation
- Endangered Species Profile sheet

**Background**

The number of threatened and endangered species is growing. An endangered classification means "any species which is in danger of extinction throughout all or a significant portion of its range".

There are a variety of factors causing threatened or endangered marine species. They are primarily the result of human actions within their environment. Historically, this was not always the case, but it has been the trend since the mid-1800s. Several examples of overuse of marine resources since the mid-19th century are:

· Collection turtle eggs and meat for food
· Loss of habitat both in and out of the water (e.g. turtle nesting beaches, coral reefs) due to variety of factors
· Pollution
· Commercial fishing (overfishing)

Commercial fishing includes the catch of species that are not the primary target of fishing operations (bycatch), as well as overfishing target species until the populations have declined to significantly low levels.

**Sequence of Lesson:**
Presentation, *Endangered Marine Life*



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As a way to stimulate interest and focus students for the lesson, hold an open class discussion to find out what students already know about endangered species. Ask questions like the ones below. Accept all reasonable answers in an effort to create a broad-ranged and free-flowing discussion of students' ideas and feelings about this ongoing, global dilemma.

Ask students:

- What is the difference between a threatened species and an endangered species? (Endangered species are those plants and animals that are so rare they are in danger of becoming extinct. Threatened species are plants and animals whose numbers are very low or decreasing rapidly. Threatened species are not endangered yet, but are likely to become endangered in the future.
- Why should we protect endangered species? (Some possible answers might include: (1) saving species preserves ecosystems: species are an important part of what make up ecosystems; maintaining healthy ecosystems ensures a healthy biosphere; (2) practical uses of species: when species become extinct, we may lose a potentially valuable product; and (3) aesthetic reasons: when species become extinct, we lose objects of fascination, wonder, and beauty.)
- As a human being, how do you think or feel about this ongoing global and potentially disastrous problem? (Accept all answers. Encourage students to support their feelings and views with examples.)
- How can you as an individual help this cause? (Possible answers might include some of the following: (1) support nature centers, nature reserves, or botanical gardens. Can they list local places? Volunteer money, time, and ideas; (2) start a native plants garden or use a spot in your backyard to attract wildlife; (3) avoid buying products made from endangered animals; and (4) keep learning about plants and animals; share what you've learned with others.)

In groups, students will complete the Endangered Species Profile to select what they will focus on to create their Protect Marine Life poster.

Lesson Extension
Upon completion, groups could present poster to the class.
Snorkel the coral reef or the mangrove forest!

References:
NOAA Fisheries: Office of Protected Resources www.nmfs.noaa.gov/pr/



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