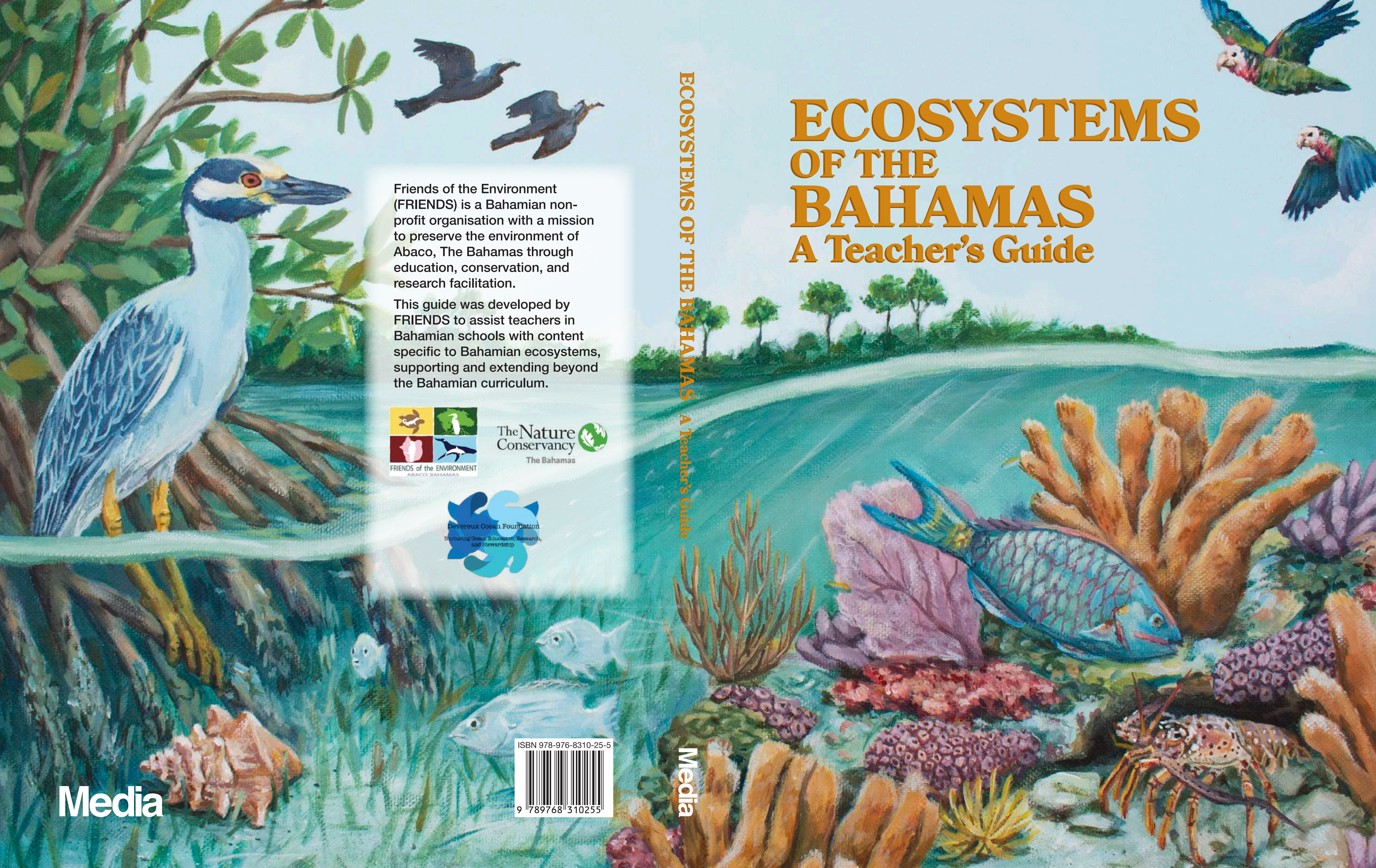

Friends of the Environment (FRIENDS) is a Bahamian non-profit organisation with a mission to preserve the environment of Abaco, The Bahamas through education, conservation, and research facilitation.

This guide was developed by FRIENDS to assist teachers in Bahamian schools with content specific to Bahamian ecosystems, supporting and extending beyond the Bahamian curriculum.

FRIENDS of the ENVIRONMENT
ABACO, BAHAMAS

The Nature Conservancy
The Bahamas

Devereux Ocean Foundation
Nurturing Ocean Education, Research, and Stewardship

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Media

ECOSYSTEMS OF THE BAHAMAS A Teacher's Guide

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How to Use this Guide

This guide has been developed to provide information and activities for various Bahamian ecosystems. The book is divided into ten chapters of highlighted ecosystems, containing essential sections:

1. **Introduction** - A brief overview for each particular ecosystem.
2. **Chapter Objectives** - Key take away messages for each ecosystem
3. **Ecosystem Flora and Fauna** - An introduction to the various plants and animals that make up that particular ecosystem.
    a. **Spotlight Species** - In these subsections you will find the 'spotlight' or highlighted species. The organism(s) highlighted can be any plant or animal that is considered significant to that ecosystem due to characteristics such as rarity, frequency, conservation status, endemism, or cultural significance.
4. **Habitat Adaptations** - A discussion of the various 'adaptations' or changes that plants and animals have made to be able to thrive in the conditions of this particular ecosystem.
5. **Ecological Role** - A discussion of the importance of this ecosystem's relationship with the organisms living in it and the interaction of the organisms with each other.
6. **Economic Value** - Insight into the economic importance of each ecosystem. A detailed list of the ecosystem services that each ecosystem provides. Ecosystem services are the benefits that humans derive from natural ecosystems. These services can range from providing habitat for commercially and recreationally important species, coastal protection, and ecotourism (Barbier et al. 2011).
7. **Threats** - A discussion on both natural and **anthropogenic** threats facing each ecosystem.
8. **Conservation and Management** - A focus on steps being taken in The Bahamas to address the need for conservation and management of relevant ecosystems and species. This segment will include regulations established for the protection of these ecosystems, national parks and protected areas, Government departments, and other management strategies.
9. **Classroom Activities** - Each chapter has a complementary classroom activity that may assist with digesting the information provided in the lesson.
10. **Field Trip/ Activities** - In this section, a list of suggested places may be provided for field trips to explore that particular ecosystem. Field trip activities may also accompany the field trip location idea to help teachers and students immerse themselves into the ecosystems and guide observations.

Supporting chapters:

1. **Anthropogenic threats** - Since all ecosystems are impacted by the presence or activities of humans, this chapter provides a general overview of the major anthropogenic threats and their overarching effects.
2. **Glossary** - An alphabetical listing of terms or words found in the individual chapters related to the particular ecosystem. If unsure about word use or how to best define a word or term to students this is where you would go.

To supplement the teacher's resource guide, a page is available on our website offering further information and activities.

These resources are for your use with the classroom and other informal learning environments. For other uses or citations, please contact Friends of the Environment.

Introduction

The Bahamas is an archipelagic country of subtropical carbonate islands that extend over 500 miles from north to south and cover an area of approximately 100,000 square miles. The country lies between latitudes 20° and 28°N and longitudes 72° to 80°W. Having such a wide geographical span means that islands experience different climatic conditions causing a variance in types of terrestrial ecosystems found throughout the islands. Terrestrial ecosystems are further characterised by the physical and biological material found on the surface of the land and the interactions between them. Marine ecosystems encompass the communities of organisms found in the sea and their interactions with the marine environment. While marine ecosystems are connected by shared waters, each ecosystem has unique characteristics that are determined by factors such as depth, tide, geology, available sunlight, and plant and animal communities. The Bahamian marine environment is inclusive of open ocean, coral reefs, seagrass beds, mangroves, sandy beaches, tidal flats, rocky shores, and oceanic blue holes. The marine environment covers a large area of The Bahamas, with 95% of The Bahamas' geographical area underwater. The Bahamas' exclusive economic zone (EEZ) is 654,715 km^2 (252,787 sq mi) (CIA, 2019).

Bahamian ecosystems are very diverse and serve many functions ecologically, economically, socially, culturally, and aesthetically. Therefore, it is necessary to protect and conserve these ecosystems to ensure that the benefits being gained are sustainable. Friends of the Environment is a non-profit organisation with the mission to preserve Abaco's environment through education, conservation, and research facilitation. We aim to inspire an appreciation for nature, nurturing sustainable behaviours within our island community through education and immersion in our surrounding ecosystems. Through our students, we hope to see a paradigm shift in the Bahamian perception of preservation and conservation of our natural environment.

This guide is designed to help educators communicate the importance of Bahamian ecosystems to their students. In our effort to present this information we have attempted to be as inclusive as possible, however some information may have been excluded whether intentional or not. All of the information provided in this booklet is relative to The Bahamas Ministry of Education Curriculum Biology Grade 11-12. The lessons are designed for high school students but the information can also be used in primary education. The activities and lessons in this booklet are designed to promote environmental awareness and stewardship. We encourage educators to take their students out of the classroom and into the field to allow them to become immersed in nature and science!

Pine Forest

Chapter Objectives

- Understand where pine forests are found in The Bahamas
- Describe a typical pine forest food chain/web
- Understand the economic importance of pine forests
- Discuss threats to and conservation of pine forests

There are three main types of forest based on geography: tropical, temperate, and boreal. Under those categories there are different classifications such as **deciduous** and **coniferous** that help identify the types of tree found in the forest. Forests can be very complex **ecosystems** that support abundant life. There are three main forest types in The Bahamas: pine, coppice, and mangrove. In this chapter, we will focus on Bahamian pine forests.

Bahamian pine forests are coniferous forests that exist only on the four northernmost islands: Grand Bahama, Abaco, Andros, and New Providence. These forests comprise primarily of Caribbean Pine, also known as Yellow Pine (*Pinus caribaea* var. *bahamensis*) with an understory of small coppice trees, ferns, and native palms. The Caribbean Pine may grow up to 30 metres in height and 75 centimetres in diameter. The trunk is largely unbranched forming a main trunk and a crown, which means that all of the fronds are primarily at the top of the tree. The bark is dark reddish brown, which flakes off in plates. The leaves are shaped like needles, which are produced in **fascicles** (a close cluster of flowers or leaves) of two or three and can grow up to 25 cm in length. (*Leon Levy Native Plant Preserve - Plant Listings - Pinus Caribaea Var. Bahamensis,* n.d.). The conservation status of the Caribbean Pine is listed as vulnerable. They are distributed throughout The Bahamas and Turks and Caicos Islands.

Pine forests may be surrounded by larger coppice or mangrove forests. Soil in the pine forest is relatively thin and is typically comprised of eroded **limestone** mixed with organic matter from decomposing leaf litter. The amount and composition of the soil can be affected by moisture, tree diversity and abundance, and **erosion**. Pines are monoecious and are characterised as **gymnosperms**.

Ecosystem flora and fauna

Organisms in the pine forest occupy habitats underground, on the forest floor, within the **understory**, on/in pine trees, or in the canopy. These include lizards, anoles, land crabs, snakes, various insects, and resident and migratory birds. The tables below give examples of plants and animals commonly observed in the pine forest.

Table 1. Typical Flora of the pine forest ecosystem

Common Name	Scientific Name	Gymnosperm	Angiosperm		Pteridophyte
			Monocotyledon	Dicotyledon	
Poisonwood	*Metopium toxiferum*			√	
Southern Bracken Fern	*Pteridium aquilinum*				√
Wild Guava	*Tetrazygia bicolor*			√	
Five Finger	*Tabebuia bahamensis*			√	
Coontie	*Zamia pumila*	√			
Thatch Palm	*Leucothrinax morrisii*		√		
Sabal Palm	*Sabal palmetto*		√		

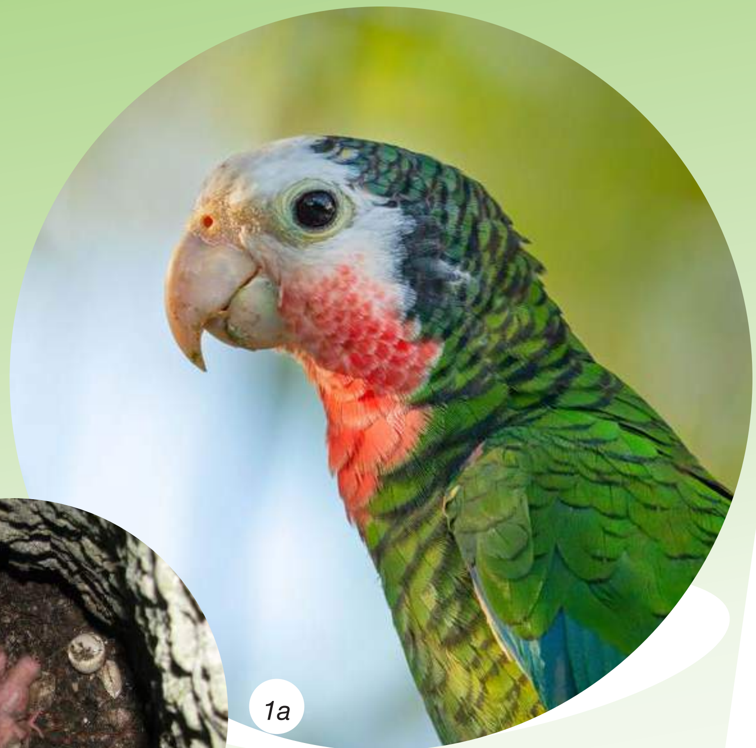
Table 2. Typical Fauna of the pine forest ecosystem

Reptiles			
Bahama Brown Anole	Brown Racer	Curly Tail Lizard	Andros Rock Iguana
Pygmy Boa Constrictor		Bahamian Boa Constrictor	
Insects			
Atala Hairstreak Butterfly		Horse wasp	
Migratory Birds			
Kirtland's Warbler		Cape May Warbler	
Resident Birds			
Bahama Yellowthroat	Pine Warbler	Bahama Woodstar Hummingbird	Bahama Swallow
Abaco Parrot	Bahama Parrot	West Indian Woodpecker	
Non-Native / Invasive Animals			
Raccoons	Feral Cats	Wild Hogs	
Non-Native / Invasive Plants			
Casuarina Pine Tree	Paper Bark Tree	Brazilian Pepper	

spotlight species

Abaco Parrot

Scientific Name: *Amazona leucocephala var. bahamensis*
Conservation Status: Near threatened, Endemic
Distribution: Abaco (New Providence & Great Inagua Islands)



1a

1b

Figure 1(a) The Bahama parrot has striking colouration. Credit: Chris Johnson.

Figure 1(b) The Abaco Parrot has adapted to threats of fires by nesting in limestone cavities in the ground within the pine forest. Credit: Caroline Stahala.

The Bahamian/Cuban Parrot (*Amazona leucocephala*) is found across Cuba, The Cayman Islands, and The Bahamas. Multiple populations across these islands differ in plumage and behaviours. The Abaco parrot is a subspecies of the Bahamian Amazon parrot that is found only on Abaco Island. They are unique because they nest in limestone cavities in the ground of the pine forests and are the only fire adapted parrot in the western hemisphere. Bahama parrots (found in Inagua and New Providence) nest in trees and have slight variations in colour pattern and vocalisations that set them apart from Abaco parrots. Parrots on Inagua live in the coppice forest areas nesting in the cavities of large hollow trees like lignum vitae and mahogany. They feed on a variety of wild fruit including wild guava, pigeonberry, gumelemi, seeds from madeira pods, and pine cones and pollen cones from Caribbean pine trees. Both paleontological and archaeological data show that Indigenous peoples moved this species as they moved across the islands and that the Turks and Caicos were once home to these parrots as well.

Bahama parrots are protected in The Bahamas under the Wild Birds (Protection) Act. It is illegal to harm or capture or offer this bird for sale.

spotlight species

Atala Hairstreak Butterfly

Scientific Name: *Eumaeus atala*
Conservation Status: Very rare, Threatened throughout its range
Distribution: Southeastern Florida, Grand Bahama, Abaco, Andros, Turks and Caicos, Cayman Islands, and Cuba

Figure 2. An Atala Hairstreak Butterfly perched on a tree within a Bahamian pine forest. Credit: Lianna Burrows.

Atalas have a mutualistic relationship with the coontie cycad (*Zamia pumila*) (Koi & Daniels, 2015). The caterpillars feed exclusively from the coontie, and thus can only be present where coonties are found. From their food source, the caterpillars also obtain a chemical called cycasin which is incorporated into their body and stored for life. This chemical becomes part of the Atala's defence mechanism - aposematic (warning) colouration. Any predator attempting to eat a caterpillar, pupa, or butterfly would be deterred due to their bad taste and discouraged to eat animals with similar warning colouration in the future. Adult butterflies sometimes roost in trees. Atala hairstreaks are not seasonal; therefore, adults can be seen through much of the year (Koi, S and DW Hall, 2019).

spotlight species

Bahama Yellowthroat

Scientific Name: *Geothlypis rostrata*
Conservation Status: Endemic, Least Concern
Distribution: Grand Bahama, Abaco, Andros, New Providence, Eleuthera, Cat Island

3

Figure 3. An endemic species of warbler found in The Bahamas, the Bahama Yellowthroat. Credit: Christopher Johnson.

The Bahama yellowthroat is an **endemic** species of warbler found in The Bahamas. There are three subspecies of Bahama Yellowthroat: *G. r. rostrata* on Andros and New Providence islands (uncommon to rare); *G. r. tanneri* on Grand Bahama, Great Abaco and associated islands (common); and *G. r. coryi* on Eleuthera and Cat islands (common) (Rolling Harbour Abaco, 2011). The song of the Bahama yellowthroat is described as a loud witchetty witchetty witchetty wich (Birdlife International, 2016).

Habitat adaptations

Bahamian pine forests are known as **fire climax communities**, meaning they need fires in order to survive. The Caribbean pine depends heavily on light for proper growth, therefore, forest fires are necessary in Bahamian pine forests to thin the understory at the bottom of mature pine trees in order for sunlight to reach the juvenile pine trees. Natural forest fires are often started by lightning in the summer months, however they may be extinguished or controlled if they threaten human communities. Since humans disrupt the natural processes of forest fires, some intervention in the form of “controlled burns” is sometimes required to ensure that the pine forest remains healthy and that the amount of dry brush and other consumable material does not build up too much which can result in intense fires that can damage the ecosystem. Controlled burns are set and managed by trained professionals in the Forestry Department called “burn bosses”. These burn bosses create a detailed burn plan that has to be submitted to the Director of the Forestry Unit for approval. Without fires, Bahamian pine forests would be overgrown by their understory.

Figure 4. A photo of burn bosses in the Pine Forest of Abaco performing a controlled fire. Credit: Terrance Rodgers, Bahamas Forestry.

Caribbean Pine trees have special adaptations that protect them from these forest fires. One adaptation is their very thick bark, which protects and insulates the tree. The heat from the fire causes the bark to swell, which reveals a sap inside of the bark called resin. On its own, resin is a flammable substance. However, when it seeps out of the bark, carbon dioxide gas is released with a "pop" and extinguishes the fire. When left to harden, resin creates a thick layer that helps protect the tree. Caribbean pine trees are also extremely tall, with the majority of their branches and pine needles located near the top of the tree, away from the hottest part of the fire which passes below.

Figure 5. Resin found within the bark of the Caribbean pine tree. Credit: Rashad Penn Photography.

Ecological Role

Pine forests support a diversity of organisms

Plants play the very important roles of oxygen producers and carbon dioxide absorbers: without them life here on Earth would be impossible. All of Earth's organisms are **interdependent**. For example, plants produce the oxygen that is breathed by animals (including humans) and in turn, animals exhale the carbon dioxide that the plants need to live - one cannot survive without the other. This interdependence extends beyond the basic building blocks of life to other necessities like habitat and food. A great example of this dependence is the relationship between the Atala hairstreak butterfly and the coontie plant. In return for the plants providing food and habitat for the caterpillars, the abundant droppings of the caterpillars fertilise the plant and enrich the nutrient-poor pine rockland soils.

A significant portion of the biomass within a forest ecosystem is situated beneath the surface, residing in the soil. The soil's composition, water content, and concentrations of different nutrients can exhibit substantial variations. Forests present notably diverse surroundings compared to other terrestrial habitats. This diversity within forests can foster a rich variety of plant and animal species. Certain elements within this ecosystem, such as tree ferns, might serve as pivotal species supporting a wide array of other organisms.

Pine forests are carbon sinks

Pine forests absorb carbon from the atmosphere in both their trees and the soil, making them known as carbon sinks. This carbon is used for photosynthesis, which releases oxygen back into the atmosphere. Some of the carbon that is initially absorbed by the trees ends up in the soil after pine needles fall off and **decompose**.

Pine forests store water

Pine forests' limestone bedrock helps with water storage, due to limestone being very porous. Pine forests are important regulators of hydrological processes, especially those involving groundwater **hydrology** and local **evaporation**.

Economic Value

Pines are among the most commercially important tree species valued for their timber and wood throughout the world. Pines are also used for the manufacture of **turpentine**, **rosin** (hardened **resin**), pulp, and paper.

Historically, Bahamian pine forests have been logged for lumber and pulp. However they were nearly clear cut in many areas and the logging companies retreated, leaving the pine forests to re-grow. The Bahamas Forestry Unit is initiating some selective logging programs as a way to manage the forest and improve habitat quality.

Pine wood is a popular wood recommended for construction purposes. If used outdoors, untreated pine wood can last for 5-10 years, depending on the climate (Pine-Admin, 2023).

A wide variety of resident and migratory birds find their home in Bahamian pine forests. Pine forests are a haven for birdwatchers in The Bahamas, attracting tourists to our country and contributing to ecotourism revenue.

Figure 6. Pine forest tours are a great way to spark the curiosity of young bird watchers. Credit: Olivia Patterson Maura

Cultural Uses:

- Wood carving - The use of pine to create various works of art.
- Lumber and logging (historical)
- Crawfish condos and other rough construction (pine) - The Caribbean Pine is one of the fastest growing species with other favourable characteristics such as impressive girth diameter and being rich in resin, making it a suitable choice for construction.
- Bush medicine - Some understory plants of the pine forest such as five finger and wild guava are used medicinally for Bahamian bush medicine practices.
- Palm/plait - The leaves of the silver palmetto are used for thatch. The leaves are also woven into plaits to create hats, bags, and other cultural treasures.
- Hunting - Invasive animal species that pose a threat to this native ecosystem such as wild boar are culturally hunted during certain times of year for sport and subsistence. Native birds such as white crowned pigeons are also hunted during open season. The hunting season for the white-crowned pigeon opens on September 29th and closes on March 1st.

Threats

Direct threats are classified as "the proximate human activities or processes that have impacted, are impacting, or may impact the status of the taxon being assessed (e.g. pine forests). Direct threats are synonymous with sources of stress and proximate pressures" (IUCN, 2024) Threats can be past, ongoing, and/or likely to occur in the future.

Deforestation

Physical removal of pine trees and related understory can result in a loss of biodiversity, reduced ecosystem function (e.g. oxygen production, food, shelter), erosion, and the release of stored carbon. When animals lose their natural habitats due to forest destruction, they struggle to survive in the remaining fragmented areas. Without shelter, this makes them easier targets for predators, as well as hunters and poachers, leading to declining populations and possibly eventual **extinction**. Even the deforestation of localised areas can wipe out species as many are uniquely adapted to specific, isolated areas, such as the endemic Abaco parrot which nests in the pine forest.

Practices such as clearcutting and illegal logging can affect the delicate balance of the pine forest, impacting biodiversity, ecosystem function, and potentially causing shifts in dominant tree species. In The Bahamas, the pine forest is managed by the Forestry Unit and the removal of protected trees is only allowed with a permit, and clear-cutting is discouraged through the issuance of a Certificate of Environmental Clearance from the Department of Environmental Protection and Planning.

Pollution

There are many different forms of pollution that can impact pine forests.

Illegal dumping - Disposing of trash in the pine forests is illegal and can be harmful to the animals that live there. Improper disposal of flammable materials can lead to forest fires. It also takes away from the natural beauty of the ecosystem. Trash should be responsibly disposed of in covered trash cans and at the public dump. If you are visiting the pine forest for recreation you should take all your trash home with you.

Water pollution - There are many sources of water pollution both direct and indirect. Direct sources of water pollution look like the introduction of pesticides and fertilisers from neighbouring farms, oil spills from industrial facilities or untreated municipal waste. Indirect sources of water pollution are less traceable and occur in the form of urban runoff, groundwater contamination and atmospheric deposition. Whether the source is direct or indirect; the introduction is primarily anthropogenic. The effect may be immediate like loss of a safe water source for animals and plants as well as there can be delayed impacts due to **bioaccumulation** in the **food chain**.

Forest Fires

Some ecosystems require forest fires to support their natural processes - fires can open up space for new trees to grow, add nutrients to the soil, and even encourage seeds to sprout. These fires start in natural ways, such as from lightning strikes. However, human activities such as hunting, farming, and pollution may also lead to fires in the forest (whether intentional or unplanned) burning at the wrong frequency, intensity, or time of year. In these situations fire can be detrimental to the ecosystem, altering biodiversity, soil fertility, water cycles, and structural complexity of the forest, while leaving it vulnerable to invasive species, and impacting livelihoods of nearby communities. In The Bahamas, a common illegal practice is the removal of pine and coppice trees to burn for charcoal.

Invasive species

Plants like Brazilian pepper and Australian pine were brought in from other countries to The Bahamas and have invaded and destroyed entire habitats of native **flora**. The rapid reproduction of these invasive plants helps them outcompete native plants for space and other resources, ultimately reducing biodiversity of native flora in the pine forest.

Figure 7. A forest fire blazes in the Caribbean pine forest (left). After the fire passes, the Caribbean pine trees remain standing while the understory is burnt (right) - notice the understory recovering already. Credit: Terrance Rodgers, Bahamas Forestry.

In The Bahamas, raccoons, feral cats, and hogs are the main invasive animals species of concern in pine forests. Cat and raccoon prey include native species that are important in the pine forests' food chain, such as lizards and birds (e.g. Abaco parrot). Hogs can be very destructive to the environment by digging burrows and digging up the ground when looking for food.

Population growth, infrastructure
Roads are a necessary evil in the development of human civilization; they are used to transport goods and people to wherever they are needed. Unfortunately, the development of forest areas for roads and communities etc. leads to ecosystem fragmentation. Traffic in these newly developed areas can be harmful for animals that live in nearby habitats, contributing to noise pollution.

Hill cutting and mining
Hills are often used as a source of **quarry** in The Bahamas, however hills have an important role to play in our natural environment. Hills act as a form of coastal protection for coastal communities in the wake of natural disasters such as hurricanes and flooding. With the continuous cutting and mining of these hills we are weakening our natural defences leaving us more susceptible to the forces of nature. Legislations have been created to manage hill cutting and mining in "Chapter 260- CONSERVATION AND PROTECTION OF THE PHYSICAL LANDSCAPE OF THE BAHAMAS".

Water scarcity
Seventy-one percent of Earth's surface is water, but it's deceptive to assume its abundance will persist. Unfortunately, only three percent of this is freshwater, with two-thirds of it locked in ice caps or otherwise inaccessible for human consumption.

This means that the freshwater we need for drinking, cleaning, and agriculture is very rare. In The Bahamas, most of our available freshwater is found under our pine forests.

Water systems around the world are stressed due to the ever increasing global population. **Aquifers** are being overexploited leading to the loss of these freshwater resources whether from over extraction or pollution.

Climate Change
As the climate continues to warm, sea levels are rising causing saltwater to infiltrate ground water resources which may ultimately cause a reduction in our fresh water lenses. Unfortunately, the Caribbean pine is not a salt tolerant plant so with increasing events of salt water inundation and lack of access to fresh water we may see the degradation of our pine forest. For example, some areas impacted by salt water inundation during Hurricane Dorian appear to be experiencing delayed pine regeneration.

Rising temperatures also increase the risk of forest fires and their intensity. In the wake of catastrophic forest fires, the pine forest ecosystem's composition is altered because the more adaptable species are able to thrive whilst other species are lost. This cycle of loss and regrowth upsets the natural balance of the ecosystem, ultimately hindering their resilience and making them more susceptible to other adversities.

Agriculture
Across the globe, agriculture accounts for 70% of the world's freshwater usage on average (Food and Agriculture Organization of the United Nations, 2017). However, around sixty percent of this valuable resource is wasted due to ineffective irrigation systems, inefficient application techniques, and the cultivation of crops that demand excessive water for the environment in which they are planted.

Sometimes agriculture fields take the place of natural vegetation, which exposes the topsoil, causing it to dry out. There are a large number of diverse **microorganisms** that help to keep the soil fertile, and this number can decrease because of this, causing nutrients to wash out. Soil levels can also decrease from wind or rain.

With an ever increasing global population there is a growing demand for food leading to the deforestation of native forests to create farms. Once forested areas have been cleared for agricultural use they are not usually returned to their natural state; thus, displacing native plants and animals leading to their possible extinction

Conservation and Management

Bahamas Forestry Unit, Ministry of the Environment Mandate
The mandate of the Forestry Unit is as follows: "To develop the forest resources of the Bahamas to their maximum potential by applying sound, scientific, and sustained yield forest management principles and concepts." The Forestry Unit has been known to employ such practices as prescribed burning and selective logging in the management of our pine forests. Prescribed burning helps reduce the density of the undergrowth, facilitating growth of juvenile pines, and also helps reduce the risk posed by fire in the event of a lightning strike or other unplanned fire. Selective logging is the practice of removing trees intentionally, usually those which are unhealthy, of a certain size, or in dense areas.

Conservation forest and other designations

Conservation forests are forests that are protected, dedicated to the preservation of this unique ecosystem and the native species that live there. Conservation forests are primarily found on the four pine islands in The Bahamas. Conservation forests are part of the medium-term goals of the Forestry Unit as part of their National Forest Estate, which compromises other designations such as protected forests and forest reserves.

Queen's Commonwealth Canopy

Recently, The Bahamas has joined other commonwealth countries around the world by dedicating a forest as part of the Queen's Commonwealth Canopy (QCC). This initiative began in 2015 with the goal to raise awareness and protect forest ecosystems in commonwealth countries. As of 2019, The Bahamas became one of the countries with a forest dedicated to the QCC, located on the island of Abaco. The Blue Hole Conservation Forest covers 32,774 acres and encompasses all three of the forest types found in The Bahamas. Many important blue holes are found in this forest, which is an important part of our natural history in The Bahamas through the discovery of **fossils** in these blue holes, adding value to its dedication to the QCC.

Protected Trees

The Caribbean Pine is listed as a protected species under the Conservation & Protection of the Physical Landscape of The Bahamas Act. This means that harvesting of the Caribbean Pine requires a permit in all instances.

Bahamas National Trust (BNT)

The BNT has dedicated areas of pine forests that are protected by national parks. These parks with protected pine forests include: Abaco National Park and South Abaco Blue Holes National Park in Abaco, Blue Holes National Park in Andros, Lucayan National Park and the Rand Nature Centre in Grand Bahama and Bonefish Pond National Park in New Providence.

classroom activities

Classroom Activities

Objectives: This section aids students in comprehending that our pine forests are interconnected ecosystems where every component relies on one another. It illustrates the layered organisation of forests, comprising the pine trees themselves, other plants, and various organisms. Students gain insight into the dynamic nature of forests, both through natural processes and human influence. Moreover, it offers perspectives on the significance of this intricate ecosystem, motivating students to take action in preserving and safeguarding forests for generations ahead.

Classroom Discussion
Discuss what is and why the Caribbean Pine is the most abundant species in the forest. Construct a possible food web in this ecosystem.

Life as a Pine Tree: Tree Cookie Activity

Summary: Students will learn the structure of the Caribbean pine tree, and how to read year rings and the conditions the tree has endured over time.

Level: Grades 7-12

Duration: 45 minutes

Setting: Classroom

Objectives: This information can be used to discover the history of the land. Its growth stages. Students will gain an understanding of the life of the Caribbean Pine, so they are able to spread the word to others about the value of a healthy pine forest.

Materials:
- Tree cookies (Printables or Actual)
- Sheet of paper
- Pencils
- Magnifying glasses

Background:
The Caribbean pine tree makes up the 5,000 acre forest of the protected Abaco National Park. Grand Bahama, Abaco, New Providence and Andros. Pinelands cover approximately 23% of the terrestrial ecosystems in The Bahamas. Approximately 90% of The Bahamas' pine land is state-owned crown land. Crown lands include national parks and national forests. These ecosystems are home to a variety of insects, animals, and birds, as well as an assortment of undergrowth plants. Pine forests provide many different services to Bahamian wildlife and people. They offer habitats for different types of wildlife, watershed protection, an abundance of undergrowth plants, plus lumber, charcoal, and mulch. Pines mature quickly and can live more than 100 years, but they rarely do. The bark protects the tree from external injury. Peeling the bark away from a tree can be detrimental to the tree's survival.

classroom activities

Trees can have a range (in an open or woodland area), and age can all be determined by the tree's core circle. Bore cuts, or deep cylindrical cross-sections taken at the base of the tree, can also determine a tree's age. Aside from its age, these rings also let us know the general weather conditions that occurred during each year of the tree's life.

The core sample indicates:

1. Light-coloured rings indicate the tree's growth during the spring and early summer.
2. Dark rings indicate the tree's growth during late summer and fall.
3. The combination of a light-coloured ring and dark-coloured ring are equivalent to one year of the tree's life.
4. Tree rings usually grow wider in warm, wet years and they are thinner in years when it is cold and dry.
5. In the event of stressful conditions, like a drought, you will see hardly any growth in the tree during this time (possibly years).
6. A blackened scar can indicate a wildfire.
7. Other marks or 'scars' can indicate an insect infestation, damage from machines, or loss of a branch in its earlier years etc.
8. Observation of rings with wider growth on one side and narrower growth on the other side is a condition that can be an indication of competition from other nearby trees.

According to "A Dictionary of Geology and Earth Sciences, 5th ed.", dendrochronology is the science of dating by means of tree rings and includes all aspects of the study of annual growth layers in wood (Allaby, 2020).

In this activity, you will be given a slice of desiccated, or dried out, tree trunk. This is called a **tree cookie**. Using the information above, you will look for the age and life history of a pine tree.

Procedure:

1. Pass out a tree cookie, pencil, and paper to each student.
2. Instruct them to come up with a story about the history of their tree. Once rings are counted to determine the age of the tree, they can begin writing their story. Encourage them to be creative! An example of the beginning of a story could be "This is my story. My name is Spike. It was a cold, dark day in the forest when I experienced a lightning storm. I was 10 years old when I was struck by lightning next to my best friend"…

Instructions for students:

1. Gather materials needed for this activity: tree cookie, pencil and paper.
2. Count rings to determine the age of the tree (one light ring and one dark ring is equal to one tree year).
3. Record age of the tree.
4. Observe the width of the tree cookie layers to determine rainy and warm years

classroom activities

versus drought years.

5. Examine the tree for any scars and determine possible reasons for scarring (Black scars indicate fires, widespread darkening of the core may identify insect infestation, acute scarring may indicate damages to the tree).
6. Indicate which years these scars may have developed.
7. Use all information you have gathered from the tree cookie to create a story. Within your story you can give your tree a name, indicating how old your tree was at the time the cookie was made (which means this was the lifespan of the tree) and making mention of any significant events you experienced and at what age if possible.

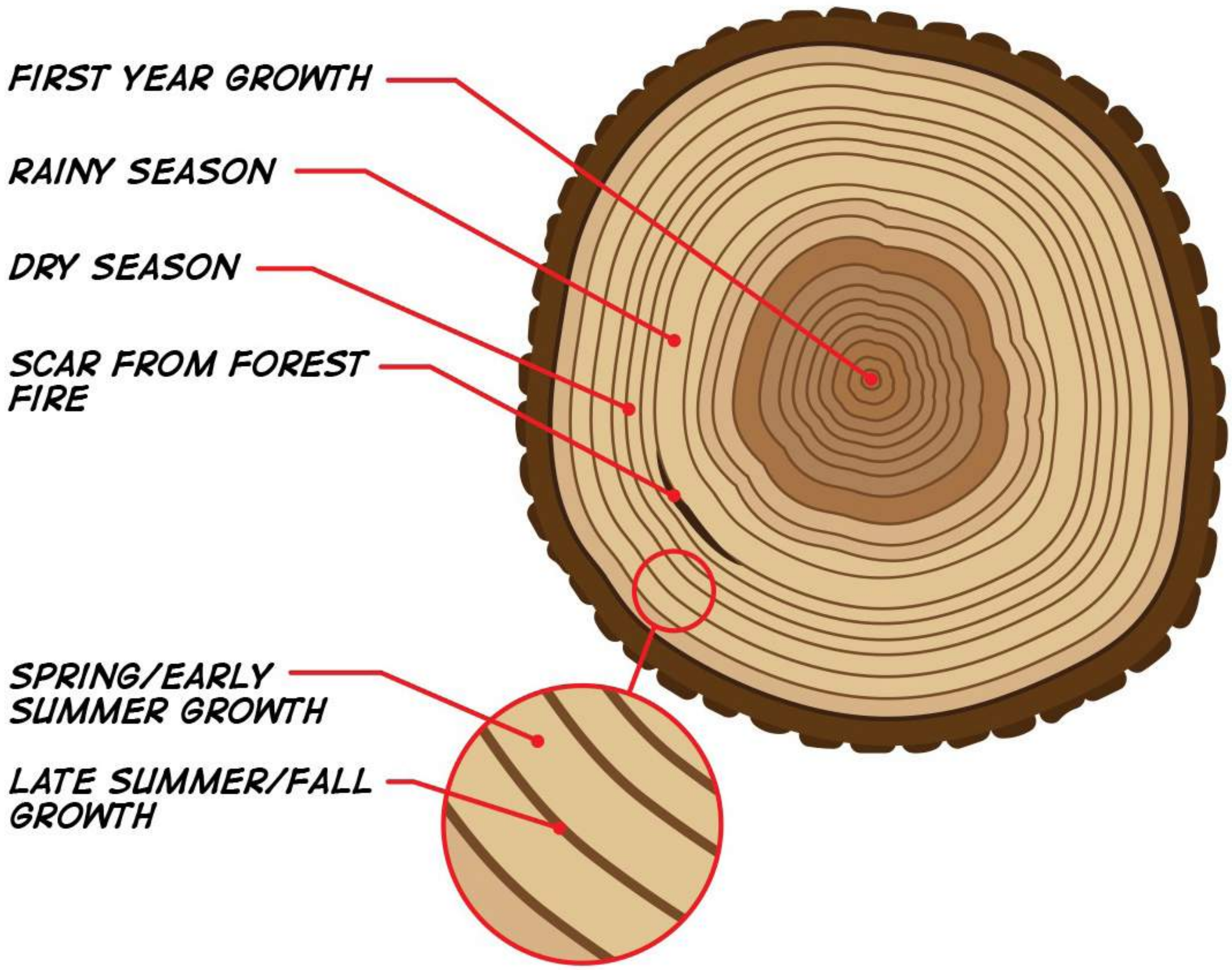


Figure 8. Illustration of a tree cookie depicting what occurred during each year. Credit: NASA Climate Kids.

Figure 9. Printable Tree Cookies for Activity. Credit: CG_dmitriy/Shutterstock.com.

field trip activities

Example Field Trip Locations

- Coral Harbour
- Southwestern New Providence
- Norman's Castle
- Abaco National Park
- Blue Hole Conservation Forest
- Lucayan National Park
- Central Andros Blue Hole National Park

Field Trip Activity: Measuring Diameter Breast Height (DBH)

This activity was revised from Merry, K., T. Lee, and P. Bettinger. OLAF: Tree and wood related measurements. https://olaf.uga.edu/topic/twm_dbh.

Level: Grades 10 - 12

Duration: 60 - 90 minutes

Objectives: Students will learn the scientific way to measure tree size. They will learn how to perform the standard unit of measurement for measuring trees (DBH) and practice using a GPS to find coordinates.

Materials:

- Flexible measuring tape
- Thumbtack
- Calculator
- Notebook and pencil
- For circumference measurements: scissors and string
- GPS or cellular device to mark your location

Background

The standard method for measuring the girth (circumference) of a live tree is known as diameter-at-breast height (DBH). This method ensures that growth measurements are accurate overtime. DBH is measured 1.37m above ground level. DBH measurements can determine the weight, volume and biomass of a tree.

To measure the circumference of the tree, you first must determine the diameter. Use the following equations:

Circumference= π x Diameter

Diameter = Circumference / π

$\pi = 3.14$

field trip activities

Procedure:
1. Use your measuring tape to measure 1.37m above ground on the tree. Use your thumbtack to mark this measurement.
2. Using the string, wrap it around the tree trunk at 1.37m. Ensure it is straight and taught.
3. To determine the circumference, use your measuring tape to measure the length of the string.
4. Find out the diameter by using this equation: $D=C/\pi$, where $\pi=3.14$.
5. Perform this procedure on at least 10 trees. At each tree, use a GPS or cellular device to record coordinates of the tree.

field trip activities

Worksheet for Field Trip - Measuring Diameter at Breast Height

Name: ______________________________

Date: ______________________________

Location Name: ______________________________

Tree #	Coordinates	Circumference	Diameter (C/π)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Discussion:

1. What would scientists use DBH Measurements to determine in living trees?
2. What purpose does it serve to gather this information?

Coppice Forest

Coppice forests are what Bahamians often call "bush", being comprised typically of broadleaf hardwood trees and shrubs. This ecosystem is found on every island in The Bahamas and is a **biodiversity** hotspot, being home to hundreds of plant and animal species. Bahamian coppice forests are classified into two main types based on their soil and the types of plants found there: blackland coppice and whiteland coppice. The two forest types have many similarities and may even share species, but have visible defining features. The coppice forest provides important habitat for many **endangered** and **endemic** animal species.

Chapter Objectives

- Understand key features of each coppice forest type
- Describe the key differences between forest types
- Understand the ecological and economic importance of coppice forests

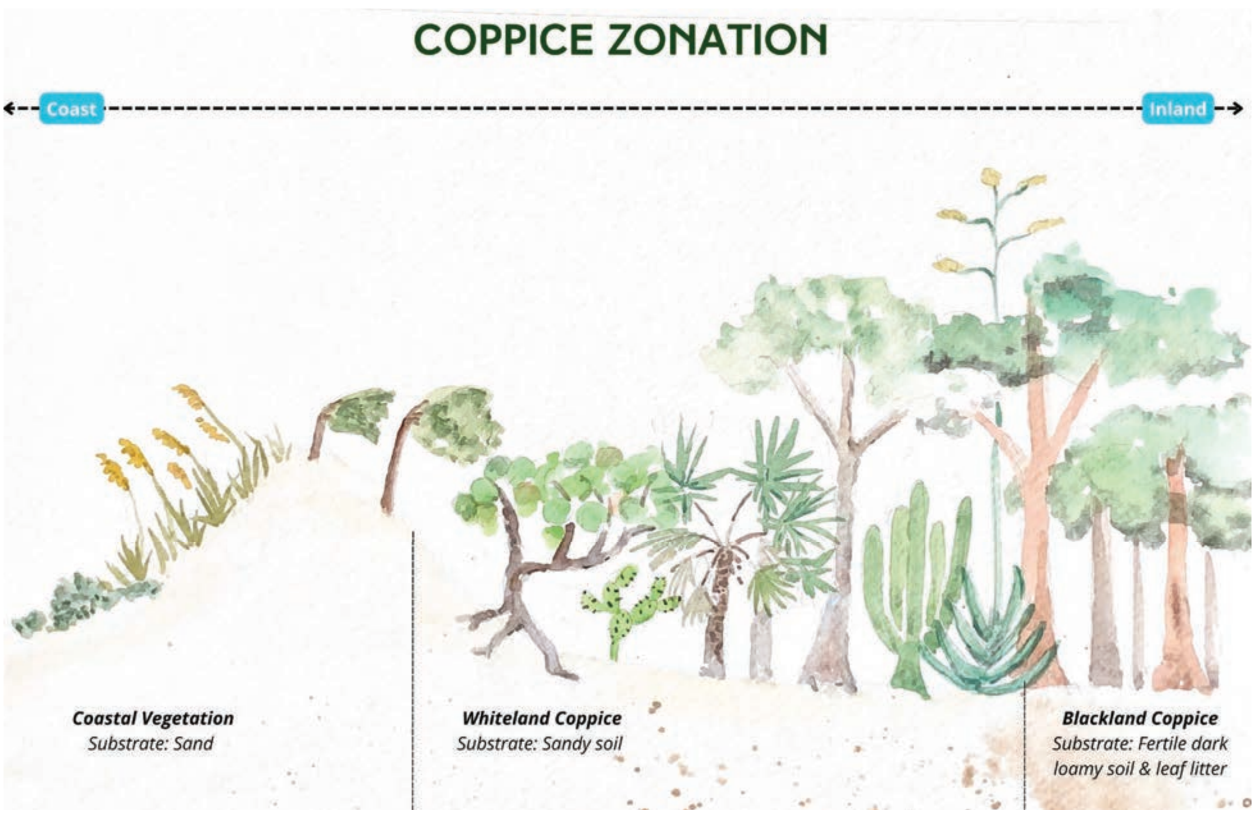


Figure 1. Illustration of coppice zonation. Credit: Olivia Patterson Maura for Friends of the Environment.

Habitat Adaptations

Blackland Coppice Forest

The Blackland coppice forest's most defining feature is the presence of rich black soil resulting from the decomposition of leaf matter, hence the origin of the name "blackland" coppice. The trees found in this area form a lush canopy that deprives any plants below from getting sunlight. The flora typically comprises broadleaved **angiosperms**, while some areas also have scattered pine. The plants that are normally found in the **understory** of this ecosystem have adapted to survive in shady environments. Some special **adaptations** of plants that live in these shady conditions versus sunny conditions are;

- Leaves are larger and thinner, this is to ensure successful growth of plants at low light intensity. For example, smaller (younger) pigeon plum trees have large leaves and taller pigeon plum trees have smaller leaves. Thin and large leaves help to efficiently trap the available light and convert it into chemical energy while also maintaining a low rate of respiration.
- Slow growth rate
- Very simple flowers with low flowering frequencies

Figure 2. Blackland coppice. Credit: Lyndeisha Curry.

Figure 3. Whiteland coppice. Credit: Olivia Patterson Maura.

Whiteland Coppice Forest

Whiteland coppice is found in the transition zone between blackland coppice and mangrove or sandy beach ecosystems. The soil in this area is characteristically light in colour and nutrient poor because it is derived primarily from **limestone**. This soil is also higher in **salinity** because of its proximity to the ocean, some areas even being susceptible to occasional flooding at high tide. The plants in this area play an important role by helping stabilise the shoreline and dunes. On windward coasts salt spray may cause sculpting and wind-shaping of the vegetation. Some of the plants found in this area include cacti, poisonwood, seagrape, love vine, mahogany, and autograph tree.

Figure 4. Notice the sculpting and wind-shaping of vegetation from salt spray on the cay in the background. Credit: Olivia Patterson Maura.

Geographical Differences

The northern Bahamas typically receives more rain than the southern islands so the coppice forests grow taller and more lush. Annual rainfall in the northern islands averages 1549mm, whereas annual rainfall in Turks and Caicos island [southern islands of the archipelago] is 605mm (Currie et al.,2019) . Southern islands experience less rainfall and higher average temperatures. Many of the same plant species are present in the southern Bahamas, however they tend to grow in stunted forms, these forests are referred to as drought-resistant woodlands. Cacti, which are characteristically drought tolerant, are also more common in the south.

Figure 5. Comparative photos of Northern (left) and Southern (right) Bahamas coppice forests. The northern photo was taken in Abaco, Bahamas and the southern photo was taken in Half Moon Cay, Bahamas. Credit: Lyndeisha Curry and Ramunas Bruzas/Shutterstock.com.

Ecosystem flora and fauna

The majority of vegetation found in the coppice forest can be classified as dicotyledonous angiosperms, with a few exceptions. Of the examples given below in Table 1, only sisal and silver thatch palm are monocotyledons. Invasive alien (non-native) plants are also found in the coppice forest; examples include Brazilian pepper, monkey tamarind, and paperbark tree (*Melaleuca*).

Table 1. Typical flora of Bahamian coppice forests

Whiteland Coppice	
Common Name	**Scientific Name**
Bahama brasiletto	*Caesalpinia vesicaria*
Haul Back, Bahama Mimosa	*Mimosa bahamensis*
Old Mans cactus	*Pilocereus polygonus*
Blackland Coppice	
Mahogany or Madeira	*Swietenia mahogani*
Balsam apple or autograph tree	*Clusia rosea*
Seagrape	*Coccoloba uvifera*
Manchineel	*Hippomane mancinella*
Mahogany or Madeira	*Swietenia mahogani*
Mastic	*Mastichodendron foetidissimum*
Horseflesh	*Lysiloma sabicu*
Wild coffee	*Psychotria nervosa*
Satin leaf or saffron	*Chrysophyllum oliviforme*
Bahamas Strong Back	*Bourreria succelenta*
Pigeon plum	*Coccoloba diversifolia*
Poison Wood	*Metopium toxiferum*
Sisal*	*Agave sisalana*
Silver Thatch Palm*	*Coccothrinax argentata*

*Monocotyledons

Table 2. Typical fauna of Bahamian coppice forests

Mammals			
Funnel-eared Bat		Bahamian Hutia	
Reptiles			
Bahamian Blind Snake	Bark Anole	West Indian Rock Iguanas	Bahamian Boa
Arthropods			
Blue-faced katydid		Land Crabs	
Migratory Birds			
Kirtland's Warbler		Painted bunting	
Resident Birds			
Bahama Lizard Cuckoo	Smooth-billed Ani	Key West Quail Dove	White Crowned Pigeon
Bahama Mockingbird	Bahama Yellowthroat	Bahama Woodstar	
Non-Native Invasive Animals			
Raccoons	Feral Cats	Corn Snake	
Goats	Sheep	Donkey	Chickens

spotlight species

Bahamian Boa Constrictors

Figure 6. Image of Bahamian Boa Constrictor on forest floor. Credit: Sean Giery.

Scientific name: *Chilabothrus spp.*
Conservation status: Threatened
Endemic, Distribution: New Providence boa (*Chilabothrus striatus strigilatus*) – New Providence, Eleuthera, Long Island & Exuma
Andros boa (*Chilabothrus striatus fowleri*) – Andros, Berry Islands
Bimini boa (*Chilabothrus striatus fosteri*) – Bimini Island
Ragged Island boa (*Chilabothrus striatus mccraniei*) – Ragged Island
Cat Island boa (*Chilabothrus striatus ailurus*) – Cat Island
Abaco boa (*Chilabothrus exsul*) – Abaco (mainland and Elbow Cay) and Grand Bahama
Acklin's boa (*Chilabothrus chrysogaster schwartzi*) – Acklin's Boa and Crooked Island
Great Inagua boa (*Chilabothrus chrysogaster relicquus*) – Great Inagua

Bahamian boas typically live in trees, but can still be found in protected places such as within rock crevices and under leaf litter. Bahamian boas eat lizards, frogs, birds, and rats; they are non-venomous so instead they suffocate their prey through constriction and then swallow them whole. The Bahamian boa is **ovoviviparous**. Did you know: Bahamian boas can consume thousands of rats in their lifetime! This makes them especially valuable for natural vector control (Bahamas National Trust, 2008).

spotlight species

Kirtland's Warbler

Scientific Name: *Setophaga kirtlandii*
Conservation Status: Endangered
Distribution: Breeds in Michigan and Wisconsin, USA, and Ontario, Canada; winters in The Bahamas.

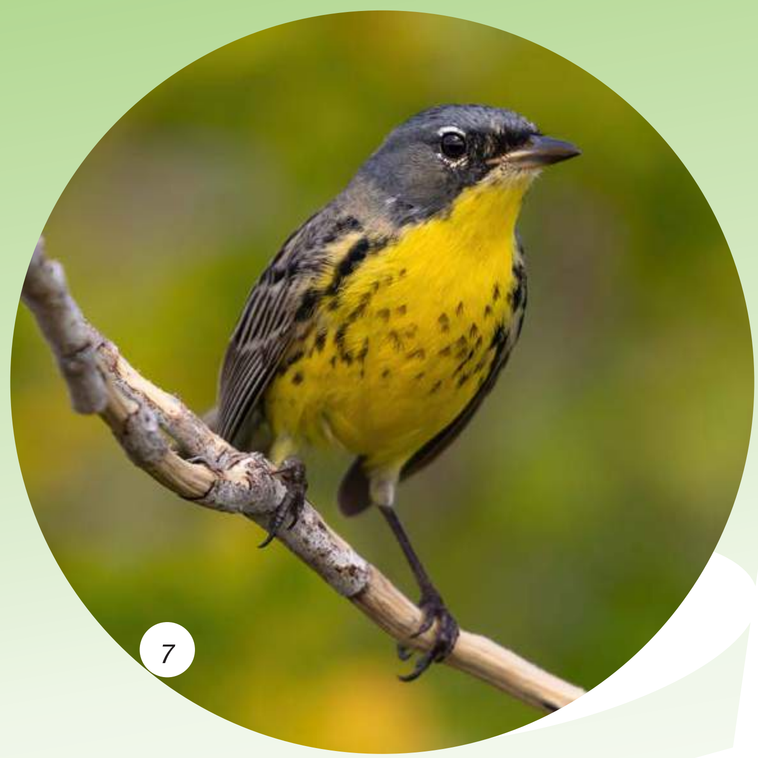


Figure 7. Kirtland's Warbler. Credit: Christopher Johnson.

Kirtland's Warblers migrate to The Bahamas and Turks & Caicos Islands for the fall and winter months. In The Bahamas the majority of sighting records are from Abaco, Eleuthera, and New Providence with the birds preferring areas of short coppice scrub where they eat insects and fruits (Bahamas National Trust, 2008). They are one of the rarest songbird species in North America, and once faced extinction due to predation, habitat loss and its natural rarity. Recovery strategies including habitat management, cowbird control, annual monitoring, research and education have enabled population growth. (BirdLife International, 2012)

spotlight species

West Indian Rock Iguana

Scientific Name: *Cyclura,* seven subspecies exist in The Bahamas
Conservation Status: Rare
Distribution: restricted to specific locations including Booby Cay (near Mayaguana), the Exuma Cays, Andros, Acklins, and San Salvador (Gicca,1980).

Figure 8. Bahamian rock iguana basking on a rock in Exuma. Credit: Chuck Knapp.

Rock iguanas are large brown lizards averaging two and a half to three feet in length at maturity. Iguanas shift their diet over their life stages, eating plants and insects as juveniles and restricting primarily to plants as adults. As **herbivores** they feed on leaves, fruits and flowers of a large variety of plants including: manchineel (*Hippomane mancinella*), wild dilly (*Manilkara bahamensis*), and darling plum (*Reynosia septentrionalis*). Rock iguanas prefer to live in dry areas such as the whiteland coppice which provides sufficient shelter and sandy patches for breeding (Bahamas National Trust, 2008).

Bahamian rock iguanas are protected by the Wild Animals (Protection) Act. The International Union for the Conservation of Nature (IUCN) lists all Bahamian populations of rock iguanas as "rare". The Convention for International Trade in Endangered Species (CITES) lists the rock iguana in Appendix 1, meaning the species is near **extinction** or very endangered. Therefore, it is illegal for these animals to be harmed, captured, sold or exported (Bahamas National Trust, 2016).

spotlight species

Bahamian Hutia

Scientific Name: *Geocapromys ingrahami*
Conservation Status: Vulnerable
Distribution: Abaco (New Providence & Great Inagua Islands)

Figure 9. Hutia specimen collected in 1891 on East Plana Cay at the time the Bahamian population was first scientifically described. Specimen held by the Faairbanks Museum & Planetarium of St. Johnsbury, Vermont. Credit: Alexis M. Mychajliw

The Bahamian hutia is the only non-volant mammal endemic to The Bahamas. The rodent is approximately the size of a rabbit with an average adult weight of 700g. Bahamian hutias are nocturnal herbivores, preferring folivore diets composed of leaves and bark from a variety of plants. They have been observed living in rocky crevices or sheltered areas (such as under silver leaf palms). Although now largely restricted to East Plana Cay, paleontological and archaeological collections from across The Bahamas indicate the species was once much more widespread. Bahamian hutias have been largely lost (e.g., extirpated) from the region due to habitat destruction and the introduction of predators (e.g., dogs), especially following the arrival of European explorers toward the end of the 15th century. The extirpated populations are different enough from living populations, both based on differences in their bones (morphologically) and DNA (genetically), that they have their own subspecies or population names.

Ecological Role of Coppice Forests

Coppice forests have a high plant biodiversity

Coppice forests are the most diverse **terrestrial** habitat in The Bahamas, hosting hundreds of species per acre (BEST, 2002). The coppice is home to a number of species of orchid and bromeliad. Most of the plants found on the Bahamas Protected Trees list are found in this ecosystem.

Coppice forests are important wildlife habitat

Coppice forests are home to a wide variety of **vertebrate** and **invertebrate** species. Coppice forests are comprised of a number of fruiting trees (e.g. poison wood, pigeon plum) which are an important food source for frugivores (fruit-eating animals) including birds like white-crowned pigeons and Key West quail dove, as well as crabs. The year-round availability of fruit, and insects, makes coppice a crucial habitat for migratory birds such as warblers.

Coppice forests trap and store water

Forests play a key role in the water cycle by storing water in the forest canopy, branches, and roots. That water is eventually filtered and released through evaporation and transpiration. This contributes to atmospheric water available for precipitation. Forests can also buffer the impact of storms by slowing down flooding and runoff (Lyons & Gartner, 2017).

Coppice forests protect the soil

Coppice forests generate a lot of soil due to **decomposing** leaf litter and other vegetation. Their roots also hold sediment together preventing soil **erosion** which prevents the loss of nutrients from the ecosystem and excessive runoff into the ocean. Plants of the coppice forest also retrieve nutrients from the soil; thus trapping and recycling nutrients which would otherwise be lost by **leaching**.

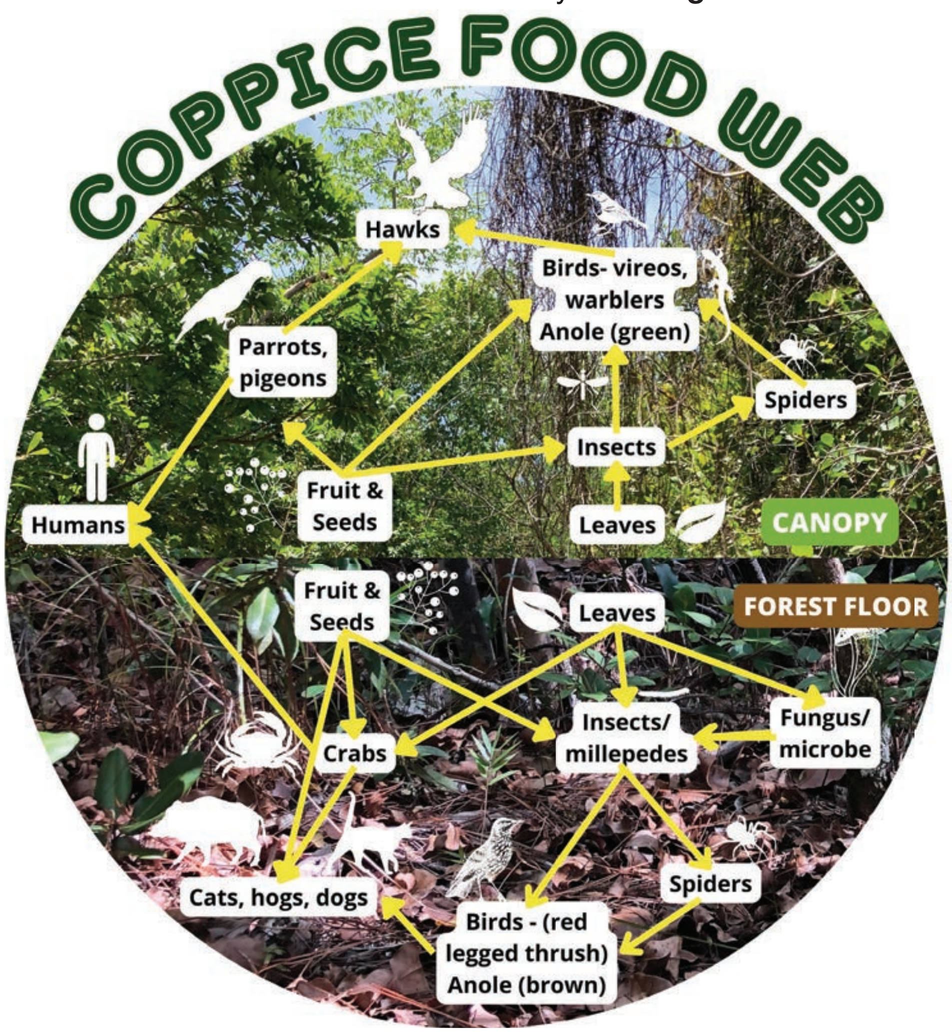


Figure 10. Diagram of the coppice forest food web depicting the canopy web, the forest floor food web and how they interlink. Credit: Content - Sean Giery, artwork - Lyndeisha Curry.

Forest **food webs** consist of two main components or subwebs. There is a 'green' canopy web fuelled by living tissues such as green leaves and fruit. Then there is a 'brown' understory web fuelled by fallen fruit, dead leaves and other **detritus**. The canopy food webs are typically simpler than the brown webs. These two subwebs are linked in two main ways. First, obviously most of the food on the forest floor is derived from the gravity driven flow of fruit and leaves from the canopy falling down. Second, large mobile animals like humans will eat from both subwebs. In this figure, humans consume crabs, hogs, and pigeons from the forest – showing how humans (and other top consumers) depend on both food web components.

Economic Value of Coppice Forests

In The Bahamas, coppice forests have offered a wide range of social and economic benefits. Cultural practices such as bush medicine, palm/plaiting, wood carving and boat building thrived on materials sourced from the coppice forest. Many of these practices were established due to lack of access to other products and are now a mainstay in Bahamian culture and can be seen being sold throughout the islands.

Bush Medicine

In the absence of medical facilities, many early settlers of The Bahamas resorted to what we call "bush medicine". This knowledge has been passed down through generations, much of it by word of mouth. Many coppice trees are used for medicinal purposes; most useful parts include bark, flowers, and leaves. Bush medicine is an important part of Bahamian culture, each island having different remedies reflecting the diversity of plants available in their local environment. It should be noted that if you are sick you should first consult your primary care physician. Some bush medicine may cause allergies or contraindications with other medicine you may be taking.

Plant	Uses/ Used to treat
Blue flower	High blood pressure, worms, constipation, the respiratory system, blisters/boils, chills, and fevers
Cocoplum	Diarrhoea, haemorrhage or strong periods
Five finger	Backache
Gumelemi	Poisonwood antidote
Hardhead bush	Mouthwash, haemorrhaging
Lignum vitae	Gout and rheumatism, constipation, joints
Love vine	Itchy skin, prickly heat, backache
Seagrape	Eat as fruit, or make jelly or wine, tea for diarrhoea
Wild guava	Night sweats

Palm/plait

Silver thatch palm (*Coccothrinax argentata*) tops are collected and put out to dry; the straw (dried palm fronds) are plaited and sewn together to create baskets, mats and bags. Today, these bags are made with more flair and sold in straw markets, boutiques and gift shops throughout The Bahamas. Due to increasing demand and challenges of

*Figure 11. Image of blue flower (*Stachytarpheta jamaicensis*) growing on FRIENDS' campus (left) and boiling for herbal tea (right). Credit: Lyndeisha Curry.*

accessing native materials, some people have begun to import straw products; however, many people still choose to do it the traditional way.

Other Uses

Hardwood coppice trees have also been used for boat building, art, etc. In the past, there were large exports of these hardwood species to the United States of America for the construction of buildings and furniture (BEST, 2005). Trees are still allowed to be harvested for commercial purposes with a permit.

The harvesting of Cascarilla bark (*Croton eluteria*) in Crooked Island, Acklins and Long Cay is still ongoing. A 2018 Nassau Tribune article mentioned that Cascarilla bark was being exported to the United Kingdom, Italy, France, the United States of America and Germany. Cascarilla is commonly used in the production of the popular European aperitif Campari, but is also used as an essential oil and in medicines and perfumes (Robard, 2019).

Threats

Fire

In the northern Bahamas, coppice grows adjacent to pine forest, which is a **fire climax community**. Fires which are not contained in the pine forest can quickly overtake coppice habitat destroying years of hardwood growth. Fires may also kill fauna that are unable to escape a fast moving blaze. Fires may be natural or man-made.

Development

As human populations increase on our islands, space is also needed. Clear cutting for development has become a common practice which is regulated by the Conservation and Protection of the Physical Landscape of The Bahamas Act. This act " [regulates] the excavation, landfill operations, quarrying, mining and harvesting of protected trees in The Bahamas, for the purpose of providing for and ensuring the conservation and maintenance of the environment." (Conservation and Protection of the Physical Landscape of The Bahamas Act, 1997).

Illegal dumping
Dumping is the most common **anthropogenic** threat to coppice. It is against the law in The Bahamas, however the fine for illegal dumping is very minimal and does not serve as a deterrent to this practice. Dumping also contributes to unnatural forest fires.

Agriculture
Coppice forests are often clear cut for the development of farms. Farms often introduce harmful chemicals like herbicides and insecticides that may negatively impact neighbouring coppice forest ecosystems.

Invasive species
Hogs, cats, and racoons pose similar threats to coppice ecosystems as they do to pine forests ecosystems.

Charcoal production
Burning coppice for charcoal is not a sustainable use of the resource.

Other
Some other natural threats to coppice forests include storm damage and plant disease.

Conservation And Management

Legislation
The Protected Tree Act helps to manage the types and quantities of protected trees that can be removed from public and private lands. Any new development in the country is required to obtain a Certificate of Environmental Clearance from the Department of Environmental Planning and Protection and one of the requirements is no clear-cutting. The Bahamas National Protected Area System includes some coppice forest; those areas are managed by various bodies such as The Bahamas National Trust and the Bahamas Forestry Unit.

Protected Trees of the Bahamas List
In 2007, a list of trees were deemed protected under The Bahamas law to conserve and protect the physical landscape of The Bahamas. This list was revisited in 2018 to include the four mangrove species found in The Bahamas and a considerable number of other key native plant species. Now named The Forestry (Declaration of Protected Trees) Order, 2021, this list includes over 100 plant species that are now protected. Plant species listed in Part I are protected for ecological reasons (endemic, endangered or threatened) for example thatch palm, seagrasses (turtle, manatee and shoal grass) and granny bush. Plant species listed in Part II are recognized for socio-economic reasons (cultural, historical or economic), for example mangroves (black, red, white), lignum vitae, sabal palm and wild tamarind. For a full list of protected species, you can view the full Order online.

Wild Birds Protection Act
"The Wild Birds Protection Act of 1905, revised in 1972, makes provisions for the designation of areas protected from hunting through the creation of Wild Bird Protection Reserves. Between 1951 and 1965, 11 orders were passed designating 25 areas as wild bird reserves" (worldwildlife.org).

classroom activities

Discuss what animals are found in the coppice forest. Have students make their own coppice forest food web.

Have students construct a poem or rap on the importance, threats and flora/fauna of coppice forests. Refer to the background information found in the chapter.

Reflect on Species Highlight: Land Crab and Bahamian Boa

1. Read the background information out loud to your class for both Land Crabs and Bahamian Boa Constrictors

Background: Land Crabs
Land crabs, also known as blue land crab, white land crab or giant land crab, are native to the Bahamian coppice forest. They can survive in both salty and freshwater conditions, in fact, a huge part of their life cycle takes place in the ocean. Female land crabs migrate to the ocean to release their spawn, where overtime the eggs drift in ocean currents and become swimming larvae before settling in mangrove ecosystems. Once they are adults, land crabs spend their lives near the coast in coppice forests. Because of this complex life cycle, they face many threats including predation (both in the ocean and on land), crossing the road and having to avoid vehicles, over harvesting for commercial sale and more. Land crabs play an important role in the coppice forest food web as **detritivores**, which are animals that feed on fragments of dead and decaying plant and animal material (Mayhew, S., 2015). They are caught for both subsistence and commercial purposes.

Background: Bahamian Boa Constrictor
Bahamian boas typically live in trees, but can still be found in protected places such as within rock crevices and under leaf litter. Bahamian boas eat lizards, frogs, birds, and rats; they are non-venomous so instead they suffocate their prey through constriction and then swallow them whole. Within its natural lifetime a Bahamian boa can consume thousands of rats, meaning they play an important role in controlling rodent populations in The Bahamas. The Bahamian boa is **ovoviviparous**; the young hatch from eggs inside the mother and appear to be born alive. Bahamian boas are one of few endemic species found in coppice and pine forests. They are threatened by anthropogenic causes such as habitat destruction, as well as the common cultural belief that snakes are evil and should be killed.

2. Based on this information, lead a discussion on the importance of both species to the Bahamian Coppice Forest. Some questions to consider:
   a. What are some common myths that Bahamians believe about these species?
   b. Identify threats to the local land crab population. Suggests measures for conservation of their populations.
   c. Identify threats to endemic snake populations (Bahamian Boa, Pygmy Boa, Bahamian Racer). Suggests measures for conservation of their populations.
   d. Identify the economic and ecological importance of these species.
   e. Why do you personally believe these species are important?

field trip activities

Split class into two groups and assign them each a coppice forest type. On the field trip each group is responsible for observing characteristics of their designated forest type and presenting to the class in the next class session. Focus on soil type, vegetation, and fauna.

Level: Grades 7-12

Duration: 60 - 90 minutes

Objectives: Students will observe the differences between whiteland and blackland coppice, especially differences in soil type, vegetation and fauna.

Materials:

- 1 whiteland and 1 blackland coppice worksheet
- Pencil
- This guide for reference on flora in the coppice forest
- Clipboard/ Something to press on

field trip activities

WHITELAND COPPICE

Name: ______________________________

Date: ______________________ **Time:** ____________

Location Name: ______________________________

Please record characteristics that you observe:

1. Soil Type. Questions to think about: Is it more like sand, silt or clay? Is it wet or dry?

____

____

2. Vegetation. What species do you observe?

____

____

____

____

3. Fauna. What are some animals you observe? Look at plants/trees, on the ground, in the sky.

____

____

____

____

field trip activities

BLACKLAND COPPICE

Name: ______________________________

Date: ______________________ **Time:** __________

Location Name: ______________________________

Please record characteristics that you observe:

1. **Soil Type.** Questions to think about: Is it more like sand, silt or clay? Is it wet or dry?

____

____

2. **Vegetation.** What species do you observe?

____

____

____

____

3. **Fauna.** What are some animals you observe? Look at plants/trees, on the ground, in the sky.

____

____

____

____

Blue Holes and Caves

A cave is defined as a natural hollow or opening in the earth, side of a hill or cliff, which extends beyond the zone of light and is large enough for a human to enter (Merriam-Webster 2018; U.S. National Park Service). Caves can be horizontal or vertical.

Blue holes are water-filled subsurface voids in carbonate bedrock that open to the earth's surface. The underwater cave systems of The Bahamas are collectively called "blue holes" (Bahamas Caves Research Foundation 2018). Blue holes contain tidally influenced waters of fresh, marine or mixed chemistry. Blue holes can give access to cave passages that are submerged as their depth extends below sea level (Mylroie and Carew 1995).

Chapter Objectives

- Describe the differences between blue holes and caves
- Name prehistoric and modern animals that are connected with blue holes and caves
- Explain the connection between blue holes and climate change
- Understand the cultural significance of blue holes and caves

Figure 1. Sawmill Sink Blue Hole (left), an inland blue hole on Abaco, and Dean's Blue Hole (right), an ocean blue hole on Long Island. Credit: Brian Kakuk, Bahamas Caves Research Foundation.

Geologic Types

Geologically, blue holes may be classified into one of three different types. They are sinkholes, fault line or fracture, and lens based blue holes.

A sink hole is large and round. These are often easily identified from the air. From above, they appear as a deep blue hole in the earth, from which blue holes were named.

Fault line or fracture blue holes are very deep as they are associated with localised faulting (breaks in the earth's surface). Fault line blue holes often parallel deep-water, offshore canyons such as the Tongue of the Ocean and the Exuma Sound (Bahamas Caves Research Foundation 2018).

Lens based blue holes are flooded flank margin caves. They extend horizontally and are usually the longest of blue holes and highly decorated with speleothems (Bahamas Caves Research Foundation 2018).

Geographic Types

Geographically, blue holes are classified into one of two types. They are ocean or marine blue holes and inland blue holes.

Inland blue holes can be of any geological type, with its entrance being accessed from land. Inland blue holes contain tidally influenced water, which extend below sea level for most of their depth and often provide access to submerged horizontal cave passages (Steadman et al. 2007). A fresh water layer is found at the surface of the blue hole and marine water at lower depths. The area where the fresh and marine water meet is called the **halocline**. In this zone of mixed water chemistry, hydrogen sulphide and sulphur-reducing bacteria block penetrating light. This combined with the lack of oxygen, helps preserve organic sediments underwater.

Marine or ocean blue holes can also be of any geologic type, but their entrances are accessed from below sea level.

Figure 2. A divers enters a marine blue hole in East Abaco Creeks National Park, Abaco. Credit: Brian Kakuk.

GEOLOGY

The bedrock of The Bahamas is a sedimentary rock made of calcium carbonate called **limestone**. Limestone is porous like a sponge. Water passes through holes and cracks in the bedrock and collects in layers underground. Fresh groundwater called a "lens" floats as a distinct layer on top of the deeper, denser salt water. This is the source of Abaco's drinking water.

Caves are formed through a process called **dissolution weathering**. Circulating ground water gradually dissolves the bedrock. Gravity may cause the cave's ceiling rock to collapse until the cave is open to the surface.

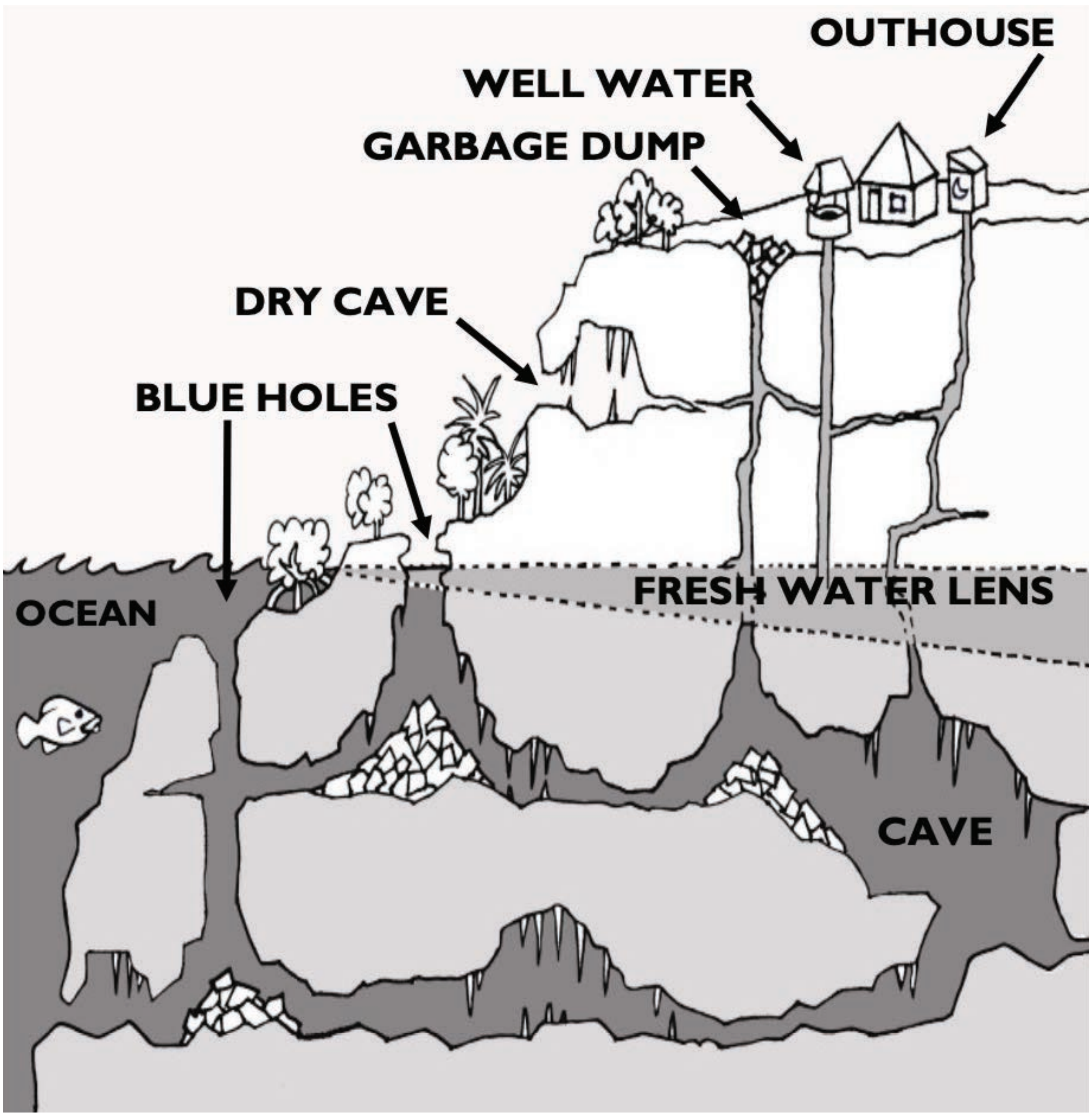


Figure 3. An illustration showing the layer of freshwater that settles underground, near the surface of the limestone bedrock, known as the freshwater lens. Credit: Nancy Albury.

Speleothems

Rainwater percolating down through the soil and bedrock slowly dissolves and absorbs a tiny amount of the mineral calcite. When the water reaches an air-filled cave, calcite is deposited on the ceilings, walls and floors of the cave. Through time, the calcite builds up as beautiful formations in the cave called **speleothems**. Speleothems is a collective term for stalactites, stalagmites, columns and other cave formations.

The colour of pure calcite is white, almost colourless. Minerals (such as iron) and acids from surface vegetation add shades of red, orange and brown colours to speleothems when combined with calcite crystals (National Park Service, 2015). .

Figure 4. Nicknamed "Ralph's Roses" this is a spectacular example of speleothems found in the Crystal Caves of South Abaco. Credit: Brian Kakuk, Bahamas Caves Research Foundation.

Did you know?

Like tree rings, speleothems hold a record of climate change in every year of their growth; at a rate of one to five centimetres every thousand years. Some climate shifts of the past that can be observed in speleothems are events such as storms that were so strong they blew Saraharn dust from Africa over the Atlantic, depositing red strips of iron visible in stalagmites and in the cave walls. The natural history of speleothems can tell us information about sea level rise and the rapid warming of Earth's atmosphere. (Todhunter, 2010).

Figure 5. Sample speleothems showing layers of trapped Saharan dust. Credit: Brian Kakuk, Bahamas Caves Research Foundation.

Ecosystem Flora and Fauna

Stygofauna are underwater, cave-adapted animals. They are only found in inland blue holes. More than 70 different species of crustaceans, worms, shrimp, and fish are found in the underwater caves of The Bahamas. The stygofauna of The Bahamas live in **anchialine** (near the sea) caves. These types of caves usually contain salt water, fresh water and mixed water chemistry. The underwater caves of Abaco Island contain some of the healthiest and most diverse cave-adapted ecosystems in the world.

Remipedes are cave-adapted crustaceans that are believed to be the oldest form of crustaceans found alive on earth. For this reason, it is referred to as a "living fossil." It kills its prey by injecting venom from its fangs. Its prey includes other crustaceans such as cave shrimps.

The red shrimp, *Barbouria cubensis*, is also known as a "broken back shrimp" due to its appearance. It is generally found in the entrance to underwater caves where food is more abundant. They can occasionally be found inside the caves during certain times of their life cycle.

Figure 6: A remipede (left) and red shrimp (right) found in the depths of underwater caves. Credit: Nancy Albury.

spotlight species

Buffy Flower Bat

Scientific Name: *Erophylla sezekorni*
Conservation Status: Least concern
Distribution: Bahamas Cayman Islands, Cuba, Jamaica.

Figure 7. A Buffy Flower Bat. Credit: Nancy Albury.

Buffy flower bats, characterised by their medium size and distinctive light brown or tan fur, possess the ability to aid in the pollination of both indigenous and crop plants, such as bananas, throughout The Bahamas. In addition to their flower-visiting habits, they also consume sturdy insects like beetles. These bats commonly roost in caves or deserted structures, often gathering in sizable colonies. Their elongated tongues, lined with tiny hair-like papillae, enable them to extract nectar from the flowers they frequent (Speer et al., 2015).

spotlight species

Blind Cave Fish

Scientific Name: *Lucifuga spelaeotes, L. lucayana*
Conservation Status: Vulnerable
Distribution: The Bahamas

Figure 8. An image of a blind cave fish. Credit: Brian Kakuk, Bahamas Caves Research Foundation.

Lucifuga are small, viviparous, eel-like fish. Even though they are called "blind" they do have small developed eyes, but shy away from direct light. *L. spelaeotes* is considered to be the most ancestral of the *Lucifuga spp. L. lucayana* is a relatively recent discovery on the Little Bahama Bank, and has eyes that are less developed.

Blind cave fish make up for their limited vision by relying on a heightened sensitivity in their lateral line system, which detects vibrations and alterations in water pressure. This specialised sensory organ, existing in fish, is essentially a canal system positioned underneath the skin along either side of the fish's body (Nielsen, 2006).

Historic Significance of Blue Holes

Fossils

The first fossil tortoise and crocodile species from The Bahamas were discovered in the early 1990s. The Cuban crocodile and tortoise fossils date to 2,000 – 4,000 years (late Holocene). It is believed that the Cuban crocodiles migrated to The Bahamas from Cuba 10,000 – 20,000 years ago. On the geologic time scale, that is the late Pleistocene ice age.

Why are animal fossils found deep in blue holes?
During the last ice age (the Pleistocene Epoch), more than 11,700 years ago, sea level was 300-400 feet lower than present as water was held in global ice sheets. The lower sea levels caused blue holes to be dry caves and they were home to bats, owls and insects. Owls used ledges to **roost** where they deposited "**pellets**" containing the indigestible bones of their prey. Bones deposited by owls remain in the bottom sediments of many caves and blue holes.

After the last ice age, sea levels rose and dry caves became flooded. The flooded caves, known as blue holes in The Bahamas, were used by animals as a source of drinking water. Many fell in, became trapped and drowned. Their remains are buried in the bottom sediments.

<u>Tortoise Fossils</u>
Large land tortoises were once native to The Bahamas. They were an important part of the terrestrial Bahamian ecosystem thousands of years ago and roamed widely across the Bahamian Archipelago until the arrival of people. At the end of the Pleistocene Ice Ages, about 10,000 years ago, melting ice caps gave way to rising sea levels that limited their wanderings. Water flooding over the Bahamas banks separated tortoise populations and other terrestrial wildlife on distant islands. Isolation and smaller island habitats limited species richness, population density, and their ability to find suitable resources for food.

Fossilised skeletal remains of the extinct tortoise, *Chelonoidis alburyorum*, have been recovered from inland blue holes, terrestrial cave deposits, and archaeological sites in The Bahamas. Their well-preserved remains tell scientists that its closest relatives were from South America and the Galapagos Islands, an archipelago in the Pacific Ocean.

Figure 9. A tortoise shell (left) and crocodile skull (right), both found in Sawmill Sink Blue Hole on the island of Abaco. Credit: Brian Kakuk and Nancy Albury.

Crocodile Fossils

Fossils of the Cuban crocodile (*Crocodylus rhombifer*) have been found throughout The Bahamas, Cayman Islands, and Cuba. Today, this small species of crocodile is found living only in Cuba, but fossil records suggest it was widespread throughout the West Indies long ago.

Despite its modest size (7 feet in length) it is a highly aggressive and dangerous animal. It is the most terrestrial crocodile on earth. In Cuba, their preferred habitat is freshwater marshes where they feed on turtles and hutia. Captive crocodiles have displayed cooperative hunting behaviour and can be taught tricks. The Cuban crocodile is critically endangered and its numbers are dwindling due to continued hunting by humans.

Fossils of Endemic Animals

Long ago, The Bahamas supported many species of animals that included flightless birds such as the Bahamas Caracara, (*Caracara creightoni*), a flightless rail (*Rallus cyanocavi*), and the Giant Barn Owl (*Tyto pollens*). On Abaco, over 40% of the species found as fossils (tortoise, snakes, lizards and birds) are extinct or are *extirpated*, meaning they are no longer found in the Bahamas.

Did you know?

The Chickcharney is a mythical creature well known by Bahamians through its legendary folklore. The story behind the legend of the Chickcharney says that it lives in the pine forest in Andros, and it is not found on any other island. Chickcharnies are described as being able to rotate their heads, having three fingers and toes, red eyes and a long tail (The Legend of the Chickcharnies, 2021). To make their nests, legend says that they join two pine tree tops together, and use their three toes to hang upside down from pine trees (The Legend of the Chickcharnies, 2021). Residents of Andros may tell you to wear bright colours when walking through the pine forest if you want to attract them. Should you stumble upon the Chickcharney and treat it with respect, legend says good luck will come in your life. However, be sure not to upset the Chickcharney, as if you do, bad luck will follow (The Legend of the Chickcharnies, 2021).

Figure 10. A comparison of the Barn Owl (left) and mythical animal known as the Chickcharney (right). It is believed that the myth of the Chickcharney is based on this particular owl. Credit: Dr. Ancilleno Davis, Science and Perspective, Illustration Credit: Ozeke Swain.

It is believed that this myth is based on the giant barn owl, or Chickcharney owl (*Tyto pollens*) which dates to the Pleistocene through Holocene (present) periods. The Chickcharney owl was found on several islands of the Great Bahama Bank and has some features in common with the mythical being: they were large feathered creatures with great range of motion in their neck (like most owls), and they had red eye shine.

<u>Trace Fossils</u>

Trace fossils are formed through the biological activity of living animals, such as moving and eating. Trace fossils include footprints, bite marks, and coprolites (fossilised dung). Crocodile bite marks are numerous on tortoise fossils and show the presence of crocodiles even in the absence of fossilised bone material of the crocodile. Crocodile bite marks on about a third of tortoise specimens from The Bahamas show us that crocodiles preyed upon living tortoises or scavenged dead tortoises, sea turtles, and other animals along the coast with some regularity.

Figure 11. An example of two trace fossils, bite marks in the tortoise shell fossil (left) and coprolite, which is fossilised dung (right). Credit: Nancy Albury.

Lucayans

Caves and blue holes were important sites of ritual for the Lucayan-Taíno, the prehistoric people of The Bahamas and today are important to the archaeological record. Cultural materials recorded from Bahamian caves include human remains, pictographs, petroglyphs, faunal bone and botanical remains. Examples of Lucayan artefacts found preserved in caves include ‘duhos’, which were ceremonial seats for the ‘cacique’ or chief (Moyes & Clottes, 2014).

Caves were important in Taíno mythology and cosmology. The Lucayan-Taíno religion is related to the mythology of Amerind of Amazonia and the Orinoco River (Carr et al. 2012). “Caves were believed to be the origin or birthplace of humans and the place from which the sun and moon emerged” (Moyes & Clottes, 2014). The Taíno conceived the universe to be composed of three tiers – the celestial vault above the earth and a watery vault below the earth called “Coaybay, were the house and dwelling place of the dead, and the earth surface contained portals to Coaybay” (Moyes & Clottes, 2014). The underworld was home to the ancestral spirit called opía. Placement of the dead into caves and blue holes was believed to facilitate the access to Coaybay for the deceased.

Railroads

During the mid-to late 1800s some companies built railroads to move heavy, bulky sisal in Little Abaco. In the early 1900s, steam locomotives were purchased by the Bahamas Timber Company for operation at Wilson City, which operated from 1906-1917. During this time, blue holes were used as water sources to power the steam engines.

Harvesting of pine trees began in 1908. Wilson City had running water, electricity, an ice plant, railroad and hospital. It employed 12% of the Abaco population (375-540 people). Operators were required to leave all trees under 7 inches in diameter (Williams 2007).

Figure 12. Wilson City was the centre of operations for early logging works on Abaco. Credit: Albert Lowe Museum archives, Green Turtle Cay.

Guano Harvesting

In the mid to late 1800's bat guano, also known as "cave earth" became a popular export from The Bahamas. This guano, likely also including some seabird excrement. was known to be an effective fertiliser due to high concentrations of nitrogen, phosphorus, and potassium.

Ecological Role

<u>Water Table</u>

The fresh water lens provides drinking water for the people of Abaco.

<u>Climate Change Reference</u>

The fossils recovered from Bahamian blue holes suggest that the plant and animal communities of The Bahamas have changed dramatically through time. For example, in Abaco fossil evidence paints a picture of a grassy pineland as the dominant plant community on the island in the Late Pleistocene, with a shift towards more coppice (tropical dry evergreen forest) in the Late Holocene (Steadman et al. 2007). Fossils of extinct and extirpated species reinforce strong connections between the vertebrates of Cuba and The Bahamas.

The presence of speleothems in blue hole systems also indicate climate change. Their growth is an indicator of rainfall and changes in growth patterns indicate periods of drought as well as periods of heavy rainfall. Scientists can date the layers in a speleothem by measuring the amount of uranium that has decayed into thorium. This is called uranium-thorium radioisotopic dating. The newest layers of the speleothem contain little to no thorium (Riebeek 2005). Scientists are able to create a rough record of ground water levels over time.

Animal Habitat

Caves throughout The Bahamas provide a stable environment for roosting sites for bats, shielding them from natural disruptions like hurricanes. These caves also serve as significant hubs of biodiversity. Apart from housing bats, they offer refuge to various creatures such as shrimp, copepods, annelids, amphipods, isopods, insects, and fish, some of which are exclusive to The Bahamas (Speer et al., 2015).

Economic Value

Ecotourism

Blue holes contribute to the country's ecotourism. Tourists who visit may participate in eco-tours which include visiting blue holes and swimming in them. There are also persons who travel to The Bahamas to become certified cave divers with world renowned instructors like Brian Kakuk of Bahamas Underground in Abaco.

The National Geographic Series on Bahamian Blue holes and underwater caves shined a light on these once under-appreciated but important ecosystems.

Fresh Water

In The Bahamas, fresh water is a limited resource. As you move down the chain of islands the availability of water becomes more scarce. In the past, fresh water was harnessed from the aquifers of Andros and barged to New Providence. In Abaco, water is harnessed from the aquifers to service the island.

Threats

Blue hole ecosystems are threatened by human activity such as pollution, construction and illicit diving activities.

Pollution

Due to misconceptions of blue holes being bottomless pits, people have used them for dumping. It is unfortunate that this practice is still being carried out today. Persons have dumped an array of debris from household items to derelict vehicles into these blue holes; this can damage delicate cave features, disrupt the unique cave ecosystem, and pollute our fresh water lens.

Illicit Diving Activities

Cave diving is an extremely dangerous activity that should only be done by those certified to do so. Even those persons that are trained know the danger they face when diving in these underwater caves can be fatal.

Another issue faced is that blue holes are the homes to rare artefacts. The blue holes and their content are managed by the Antiquities Monuments and Museums Corporation of The Bahamas. Persons who dive in these blue holes and/ or recover artefacts without permission are doing so illegally.

Deforestation

The unique chemical composition of waters in blue holes is due in part to the decaying plant matter that falls into blue holes (from their surroundings). If vegetation near blue holes is lost that could disrupt the conditions that have resulted in extremely well-preserved fossils to date.

Development
Blue holes and caves may exist in a complicated underground matrix. If excavation, drilling, or other development activities take place too near blue holes and caves it can cause the ground to slump or sink and may result in the cave system falling in.

Conservation and Management

Blue holes that contain artefacts or objects of prehistoric, historic, archaeological, paleontological significance are protected by the Antiquities, Monuments and Museum Corporation. Diving is restricted in some blue holes in order to maintain the conditions that are preserving fossils in the blue holes.

A number of blue holes and caves are protected by the Bahamas National Trust Park system: Andros (Andros Blue Holes National Park), Grand Bahama (Lucayan National Park). The South Abaco Blue Holes Conservation Area was designated and declared in August 2015. The area encompasses an extensive cave system that includes Dan's Cave, Ralph's Cave, Nancy's Cave and Sawmill Sink. The area boasts the greatest biodiversity of any submarine cave systems in the world and has been featured extensively in National Geographic and on many nature documentaries.

Fun fact
Many Bahamians incorrectly cite Dean's Blue Hole as the deepest blue hole in the world. The world's deepest blue hole is currently Dragon Hole, South China Sea: 300 m (987 ft). The second deepest blue hole is currently Dean's Blue Hole: 202 m (663 ft). (Note: we say "currently" because those are the explored depths of the cave. Some caves have passages that are yet unexplored and as such their true depths are unrecorded.)

Did you know?
- Sawmill Sink is the site of the most significant fossil find in the history of the West Indies with the most complete tortoise fossils.
- A human tibia and sacrum of a juvenile about 13 years old, found in Sawmill Sink, represent the earliest human occupation in the northern Bahamas (~1050 – 920 BP)
- Dan's Cave is the longest underwater cave system in The Bahamas - over 13 miles of underwater cave passages!

classroom activities

Discussion
Discuss with your class the anthropogenic threats to blue holes.
Ask them what are some ways caves and blue holes can be protected from human destruction (graffiti, illicit dumping, diving, etc.), but also available to the public for recreation and enjoyment, such as swimming and site-seeing?

Discuss the nature of limestone bedrock with students. Limestone is porous like a sponge. Water (and sometimes, pollutants) passes through holes and cracks in the bedrock and collects in layers underground.
Ask them: Given the nature of limestone bedrock, why would it be important to be careful where homes are built and dumps are placed?

Limestone Activity
Summary: Students will learn how easily both water and pollutants can move through limestone bedrock.

Level: Any age

Prep time: 5 minutes

Duration: 8 hours

Setting: Classroom

Objectives: Students will understand how easily pollutants can get into our water table through our limestone bedrock.

Materials:
- White limestone rock
- Container (could be a tupperware container, bowl etc.)
- ½-1 cup of water, depending on size of container
- Food colouring (any colour)

Procedure:
1. Place water in a container with a few drops of food colouring.
2. Put white limestone rock in the container.
3. Monitor its absorption of the colour throughout the day. Have students check hourly if possible, or during break/lunch times to observe change.
4. Record observation notes on a piece of paper/in a notebook.

field trip activities

Comparative Analysis between two field trip sites

Observation is an important part of the scientific process. Scientists often identify new species of plants and animals by comparing collected species from the cave or blue hole to existing species. This is called comparative analysis.

Materials:

- Measuring tape
- Clipboards (or something to press on in the field)
- Pencil
- Observation sheet (1 per location)

Procedure *(this may need to happen over the course of two field trip periods based on locations)*

1. Visit a local cave or blue hole in a remote location (ie, not frequently used/visited by tourists or locals). If you are unsure of the location of a cave or blue hole, ask someone local to point you in the right direction.
2. Once you arrive at the location, locate the opening of the blue hole.
3. Have students measure and mark the area that is 10 feet from the opening.
4. Within that 10 feet, have them record species name, description and abundance on their observation sheet.
5. Answer the remaining questions on the observation sheet.

field trip activities

Blue Hole Field Trip Observation sheet

LOCATION # 1

Name: ______________________________

Date: ______________________ **Time:** ____________

Location Name: ______________________________

List the different plant and animal species found within 10 feet of the blue hole opening in the table below:

Species Name	Description (colour, patterns, size etc.)	Abundance (high, medium or low)

Would you say this location has a high biodiversity, meaning that there are many different species existing here? Why or why not?

____

____

____

____

Other Observations (human impacts, strange items observed, etc.)

____

____

____

field trip activities

LOCATION # 2

Name: ______________________________

Date: ____________________ **Time:** ______________

Location Name: ______________________________

List the different plant and animal species found within 10 feet of the blue hole opening in the table below:

Species Name	Description (colour, patterns, size etc.)	Abundance (high, medium or low)

Would you say this location has a high biodiversity, meaning that there are many different species existing here? Why or why not?

____

____

____

____

Other Observations (human impacts, strange items observed, etc.)

____

____

____

____

Compare the two sites using the table below:

Location #1. Site Name: ____

Observation	**Rating (high, medium or low)**
Human impact	
Overall biodiversity	
Amount of plant species	
Amount of animal species	

Location #2. Site Name: ____

Observation	**Rating (high, medium or low)**
Human impact	
Overall biodiversity	
Amount of plant species	
Amount of animal species	

Lesson Objectives

Identify a blue hole and their distribution.
State the importance of the presence of blue holes.
Identify features found in underwater caves.
Express an appreciation for blue holes and underwater cave systems.

Sandy Beaches

by Neil Sealey

Chapter Objectives

- Understand the origins of Bahamian sand
- Know where beaches form in The Bahamas
- Identify typical beach zones
- Learn causes of beach erosion
- Understand the importance of sandy beaches
- Discuss threats to and protection measures of sandy beaches

All Bahamian islands, and even many small cays, have a beach. Unlike some countries the beaches are nearly always of sand, as opposed to shingle or mud; and unlike some other Caribbean beaches on volcanic islands, they are never black. Beaches occur on the exposed Atlantic shores of islands, and also on the more sheltered western shores.

Sandy beaches are dynamic landscapes and subject to changes in temperature and tide, and pressures from wind and waves. The sandy beach consists of the foreshore and backshore and lies between the Mean Low Water mark and the foredune. The presence of beach features, as well as flora and fauna will depend on which zone of the beach it is found, as well as other environmental characteristics (see Figure 1). For example, no plants will be found in the foreshore as it is very salty, wet, and under constant influence from the sea. Some plants will settle in the back shore, specifically the "pioneer zone", helping to stabilise and trap sand. The majority of beach vegetation will be found on or behind the dune.

It should always be remembered that while a sandy beach is an ecosystem in itself, it is also part of the larger ecosystem that stretches from offshore to the land behind it. Any changes, whether natural or manmade, that occur offshore, such as to a bounding coral reef or the shallow water in the nearshore area, or seagrass beds, will affect the sand supply. Similarly the presence of a sand dune or structures behind the beach will also have an impact, most notably under stormy conditions.

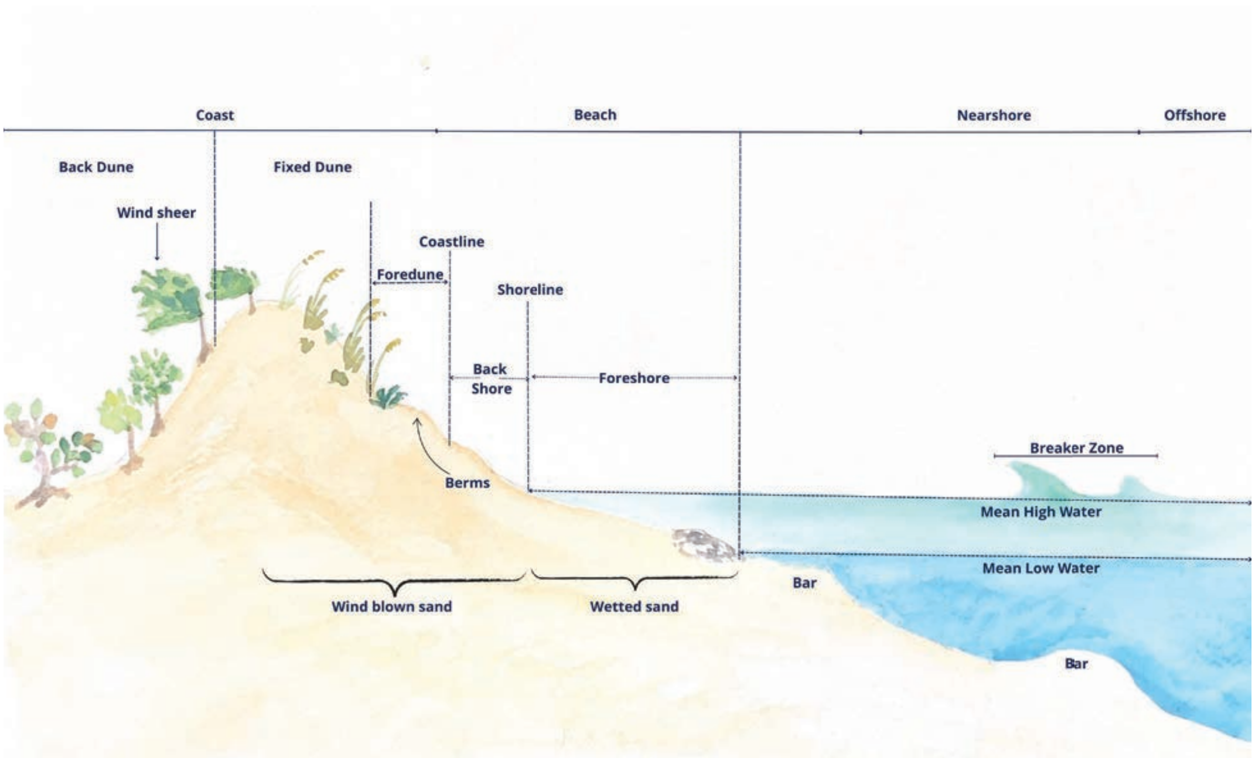


Figure 1. A cross section of a typical Bahamian beach ecosystem. Credit: Olivia Patterson Maura for Friends of the Environment.

Source of Sand

There are two main types of sand: abiogenic - sands that come from mineral sources, and biogenic - sands that come from plant and animal sources. All Bahamian sand comes from the sea, which is notable as rivers are often the source of sand for beaches in many countries, such as Jamaica. Bahamian sands come from two main sources: chemical precipitation which causes the formation of oolite grains, and coral reefs and other abundant marine life that produce sand through a variety of biological and physical processes. The shallow offshore waters of The Bahamas are a huge sand factory.

Skeletal sand comes from the remains of plants and animals, for example the minute shells of dead foraminifera. Some of the Atlantic species are pink in colour, hence the pink sand of Harbour Island and some other beaches in Eleuthera. Much sand is produced by the erosion (wear and tear), and death and disintegration, of coral reefs and their abundant marine life. Some is produced by parrotfish which graze the coral for algae and inadvertently scrape its surface, digesting and excreting the material as sand. More is produced by worms and other filter feeders which digest the sand to extract nutrients.

The well known aragonite sand, also known as oolite, is produced in a quite different way. The salty sea contains calcium carbonate as well as sodium chloride (salt), and when the shallow seas are heated up this precipitates out in very much the same way that salt is deposited in a salt pan. The result is tiny spherical grains, individually known as ooliths, which are widespread in certain areas, such as the Bimini Islands, Ragged Islands, and eastern Grand Bahama. However, while the beaches in these areas may be entirely oolitic, there is always some oolite produced on other beaches, so most Bahamian beaches are a mixture of the two sources.

Figure 2. Sources of sand, from left to right: Foraminifera (alex7370/Shutterstock.com), parrotfish (BEP-Foundation), and calcareous algae (Pavaphon Supanantananont/Shutterstock.com).

Figure 3. Oolitic sand being formed in the Schooner Cays west of Eleuthera. Credit: Neil Sealey.

Beach locations and shapes

Many beaches are just long stretches of sand facing the Atlantic, but sooner or later they will be interrupted by a headland. When headlands are fairly close together we get a crescent beach, and smaller versions that contain a pocket beach are usually called coves. Those facing the ocean and the trade winds can be quite wide, 100 feet or more is not uncommon. These beaches are nearly always sheltered by a coral reef up to a mile away, and it is from the reef, and the lagoon between the reef and the shore, that the sand is created and driven onshore by the waves. Waves are always wind-driven, and in The Bahamas wide beaches are mainly created by the persistent easterly trade winds, but winds from any other direction can form narrow beaches on shorelines facing the wind.

Figure 4. A typical Atlantic-facing beach on Guana Cay, Abaco. In the background invasive Casuarina trees line the shoreline. Credit: Neil Sealey.

Figure 5. A classic bay beach bounded by two headlands on the north coast of Rum Cay. Credit: Neil Sealey.

Beaches on the sheltered shores, such as the south side of New Providence, are usually quite narrow, but still 20-40 feet wide. These more sheltered beaches are less likely to be in bays or crescent in shape. They simply accumulate sand from the shallow banks, and in these areas the beach can be considered a drier version of the sea bed, which grades gently offshore.

Depending on the wave action, the shape, or topography, of a beach can vary. In many cases it will simply be a wide, slightly sloping, plain of sand, but if the waves strike the beach perpendicularly cusps can form, as on the well-known Cabbage Beach on Paradise Island. A narrow steep beach is usually found where there is little room in front of or behind the beach, as where there are cliffs behind and a steep profile offshore. A narrow beach is typical of sheltered shorelines such as along the coast and cays to the west of Abaco, or Andros.

Figure 6. Beach cusps (or scalloping) often form on Cabbage Beach on Paradise Island, Nassau. Credit: Neil Sealey.

Beach processes - Deposition and Erosion
Not only do beaches advance and retreat seasonally, but they are created and may be destroyed. Given that all the sand originates from the sea, it is evident that at some point in the past, the current beach did not exist.

As well as sand moving on and off the beach, there is a lateral movement of sand, known as longshore drift. If the waves strike the beach at an angle the effect is to push the sand along the beach, usually from east to west on windy beaches in most islands, but also south to north in summer. Other beaches in more protected areas are moved when the trade winds are replaced by winds from other directions, such as after the passage of a cold front in winter.

Under normal conditions sand that is formed offshore will be washed ashore by wave action. Waves, rather than currents, are the main transporting force. They are aided by tides, which in The Bahamas have a range of about three feet and change twice a day. The tidal current is not usually strong enough to move the sand, but the movement up and down allows the waves to act on a wide stretch of beach, not just remain static at the water line.

Constructive waves are those that wash sand up onto the shore.

Destructive waves are those that drag sand off the beach, and extreme events can cause massive erosion, and the creation of large piles of sand, seaweed, and other detritus called storm berms.

Beach Features

Not everything on a sandy beach is sand, and the sand may be laid out in a variety of ways. Common beach features in The Bahamas include the high water line, storm berms, beach rock, and sand.

The most common thing a beach walker will see is a line of seaweed and debris, usually marking the current high water line. Seaweed is actually an algae, not a plant, and there are thousands of species. Most common on our beaches is sargassum, a brown algae. Sargassum is produced in vast quantities in the Atlantic and has become a major nuisance on Caribbean beaches in recent years, although not in The Bahamas. Apart from abandoned shells in the seaweed zone, whole and shattered shells are a common feature throughout the sandy areas, being derived from creatures living in the beach itself and also from offshore. In the same way that shells end up on the beach, so do lumps of coral and seabed rock which are broken off under storm conditions. In large storms this material is usually pushed to the back of the beach creating a storm berm, but fragments of reef and rock can be found almost anywhere. Some will also come from adjacent headlands and rocky outcrops.

Figure 7. Large amounts of sargassum and other seaweed on the south-east coast of Acklins Island. Credit: Neil Sealey.

Figure 8. A large storm berm on the Atlantic shore of northern Cat Island. This berm is a few years old and already the sandy beach has re-established itself, and vegetation is colonising the pioneer zone. Eventually the berm will be incorporated into a new sand dune. Credit: Neil Sealey.

Among the seaweed is all sorts of litter, and perhaps some shells and dead marine life such as jellyfish, and maybe the Portuguese man o' war (which although it resembles a jellyfish is actually a colonial organism called a siphonophore).

Figure 9. Since Portuguese man o' wars have no means of propulsion they are often pushed by the wind and may end up on beaches. Caution: do not touch them as their sting persists even after the animal has died. Credit: Olivia Patterson Maura.

As for the sand itself, it is not static. Two things are commonly going on behind, or under, a sandy beach. As waves wash sand onto the beach, it dries out when the tide retreats and this allows the wind to blow it further onshore. The result is the familiar sand dune, an inevitable product of a healthy beach, and common throughout The Bahamas, but especially on the more exposed windy shorelines, those that face east or north. Beach rock is a type of sedimentary rock formed through a process known as lithology. This creates crystals of calcium carbonate that cement the grains of sand together. On recently eroded beaches fresh beach rock is often visible, but many beaches have exposed old beach rock in the intertidal area. In the early stages of formation you can break pieces off with your fingers, but as beach rock ages it becomes better cemented and harder. Both fresh sandy coloured beach rock and old algae-blackened examples are common around sandy beaches.

Figure 10. Beach rock exposed on Windermere Island, Eleuthera, after the passage of Hurricane Floyd. Beach rock can also be seen at the water line in Figure 11 below. Credit: Neil Sealey.

Ecosystem Flora and Fauna

Plant life is not possible below the high water mark as sea water is poisonous to most plants, and the sand is mobile. On a typical wave-formed beach the sand is sterile until the area above the high water mark is reached, and then a number of salt-tolerant plants will colonise the backshore. This is the initiation of a sand dune, as once some plants are established the sand starts to build up vertically, and the plants grow to accommodate it. The most common plants to grow on the beach are the pioneer plants, such as the railroad vine and sea bean. Once the dune has developed some elevation a much larger variety of plants appear, including sea lavender, inkberry, sea oats, and eventually leading to the nicker vine, spider lily, seagrape and fully grown trees, including the poisonous manchineel in some areas. These are what we consider to be native plants, and will be most common on uninhabited shores.

Figure 11. Railroad vine is a successful coloniser in the pioneer zone on Windermere Island, Eleuthera. Credit: Neil Sealey.

Within the beach is a myriad of life. Most common to the casual visitor is the ghost crab, and other crabs and their holes in the sand. Bahamian beaches host a variety of birds, including sandpipers and plovers. Plovers feed on the beach but are most likely seen running along it rather than walking like the sandpipers. Some resident birds (like Wilson's plovers) create a small depression in which they make a nest and lay their eggs. Other birds likely to be seen are terns, seagulls and herons, although they nest in other ecosystems. Sargassum occurs naturally on beaches. It contributes significantly to beach nourishment and stands as a crucial factor in maintaining shoreline stability. Plants within sand dunes rely on the nutrients provided by sargassum, while sea birds, among other species, rely on the marine life carried within the sargassum as a primary food source (Doyle & Franks, 2015).

Beaches are also the nesting grounds of turtles, and the common Bahamian species, the Green and Loggerhead, and the less common Leatherback, Olive Ridley, and Hawksbill, all leave the sea and crawl up the beach to lay their eggs. The babies will hatch on the beach and then trek to the sea. Hatchlings may be predated on by birds, crabs, or fish (when they reach the ocean). Other threats to hatchlings are anthropogenic in nature (including marine debris). Any eggs that remain unhatched provide a source of nutrients for dune plants and other life on the beach.

The other creatures living on the beach are less likely to be seen, being small and usually buried in the sand. These include several species of worms and insects, including flies that live on dead seaweed, and beetles and fleas.

spotlight species

Piping Plover

Scientific Name: *Charadrius melodus*
Conservation Status: Near threatened
Distribution: Breeding - Atlantic Coast of the U.S. and Canada, Great Lakes Shores
Non Breeding - Gulf of Mexico, the southern Atlantic coast of the United States and The Caribbean.

Figure 12. A Piping Plover with winter plumage. Credit: Christopher Johnson.

Piping plovers are sandy greyish brown birds with white underparts and a narrow, often broken collar with yellowish orange legs in all seasons (Cornell University, 2024). Their colouration helps them to easily camouflage in their surroundings if they are not moving. Piping plovers breed and nest in soft sandy areas along ocean and lake shores in their North American range. In the winter they migrate to The Bahamas utilising coastal beaches, sandflats, and mudflats for foraging and roosting (Cornell University, 2024).

spotlight species

Sea Oats

Scientific Name: *Uniola paniculata*
Conservation Status: Unknown
Distribution: Occurs throughout the Lucayan Archipelago, Caribbean region, North, Central, and South America

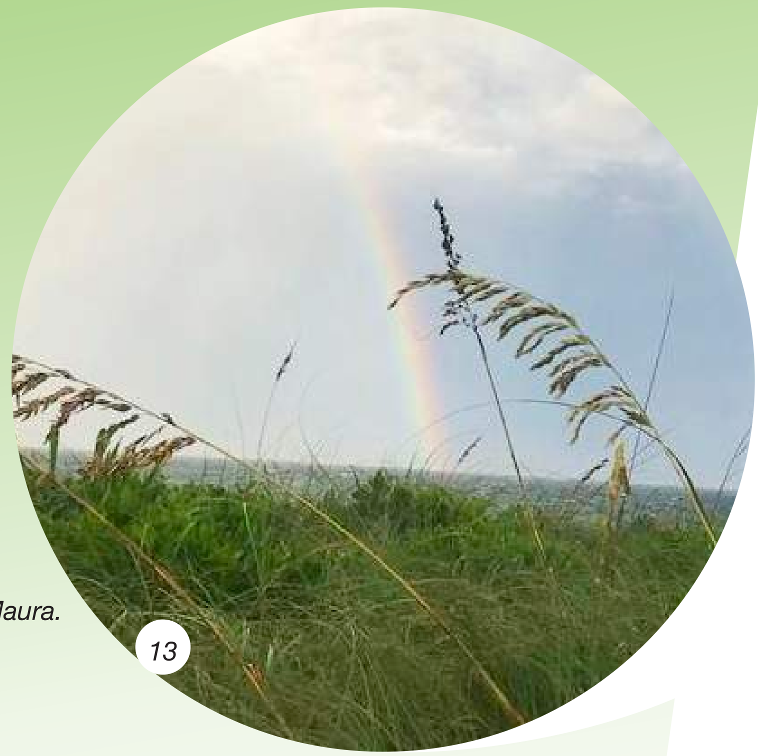


Figure 13. Sea Oats. Credit: Olivia Patterson Maura.

Sea oats are a vital dune plant with deep and complicated roots that hold sand in place, even during tropical storms and hurricanes. They thrive in sunny areas and prefer coarse sand. Once mature, this species can grow to be up to 6 feet tall, with their leaves growing up to 2 feet in length. The above ground parts of the plant also serve to trap wind-blown sand and when the base of the plant is covered by sand this can further stimulate growth of the plant. Similar to seagrasses, sea oats have rhizomes, which are horizontal plant stems that help the plant spread along the beach. In these ways, sea oats help to build dunes. Sea oats are protected by law; it is illegal to remove them (Fisheries Resources (Jurisdiction and Conservation) Regulations). In 2021, sea oats were also included on the Forestry (Declaration of Protected Trees) Order, Part II - trees of cultural, historical and economical significance.

Ecological Role

Sandy beaches play a crucial ecological role within coastal ecosystems, contributing to the overall biodiversity and functioning of these environments. Some key ecological roles of sandy beaches include:

Habitat Support
Sandy beaches serve as habitats for a diverse range of organisms, including various invertebrates and birds. These habitats provide shelter, breeding grounds, and foraging areas for many species.

Nesting Grounds for Sea Turtles
Several species of sea turtles like the green sea turtle rely on sandy beaches as nesting sites. Female turtles come on shore to lay their eggs in nests dug into the sand. The sandy environment provides a suitable substrate for incubating the eggs until they hatch.

Feeding Grounds for Shorebirds
Sandy beaches are often rich in invertebrates and other small organisms, attracting a variety of shorebirds. These birds feed on the abundant food resources found in the sand and nearby intertidal zones.

Buffer Against Storms
The dynamic nature of sandy beaches, with their shifting sands and dunes, can act as a natural buffer against storm surges and coastal erosion. They help dissipate wave energy and provide a level of protection to coastal areas.

Sand Dune Formation
Some sandy beaches support the formation of sand dunes. These dunes not only provide additional habitat for specialised plant and animal species but also contribute to stabilising the coastline and preventing inland erosion.

Water Filtration
Sandy substrates facilitate the percolation of rainwater and runoff, promoting natural filtration processes. This can help improve water quality by reducing pollutants and enhancing groundwater recharge.

Figure 14. Beachgoers enjoy a sunny day on Paradise Island Beach. Credit: Olivia Patterson Maura.

Threats

Invasive Plants

Invasive plants are typically non-native, and exhibit characteristics that help them succeed in their new environment, including being fast-growing, producing copious seeds, or suppressing the growth of other plants. Unfortunately, when the shoreline is disturbed, invasive plants will appear. These include the Brazilian pepper, Hawaiian seagrape, and the Casuarina. Brazilian pepper will take over the sheltered parts of a dune and suppress the local plants, but fortunately it is not yet widespread here in this ecosystem. Hawaiian seagrape also suppresses the local vegetation but can take over the entire dune. It is very aggressive and has been widely used by homeowners wishing to landscape their properties. The Casuarina, also known as the Australian pine, is another invasive but is rather more insidious. It suppresses the vegetation beneath its foliage which leaves the sand dune bare of cover and vulnerable to wind and wave erosion. Under storm conditions the Casuarina shoreline is washed away and the trees collapse, wash offshore and damage reefs. But being resilient to the coastal environment they return even stronger, leading to many miles of coastline being enveloped in Casuarinas and eroding the beach as a result. The heavily inhabited shores of Grand Bahama, Abaco, Eleuthera and Exuma are particularly infested in places. In New Providence many areas have been cleared of Casuarinas, but Scaevola is abundant.

Figure 15. Invasive Hawaiian seagrape (Scaevola taccada) has taken over the native vegetation on this low dune at the back of the beach at Orange Hill, Nassau. Credit: Neil Sealey.

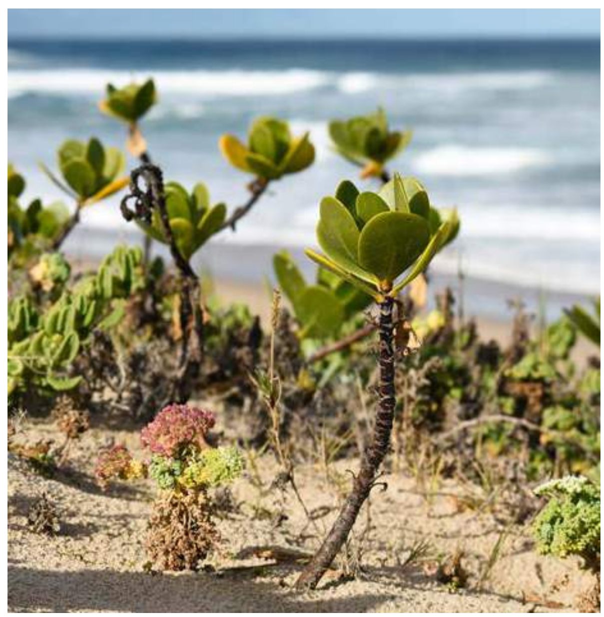


Figure 16. Inkberry (Scaevola plumieri) is native to The Bahamas and should not be removed. Credit: JJ van Ginkel/Shutterstock.com.

In order to encourage native species to flourish and maintain a healthy beach some form of restoration is often attempted. This can be done by removing invasive plants and replanting with native species, e.g. sea oats, which are relatively cheap, or installing sand fences which trap sand and allow miniature dunes to form.

Figure 17. Sand fencing and vegetation planting on Montagu Beach, Nassau. The beach has also been reclaimed with sand from Exuma, and mushroom groynes (background) constructed to preserve the new beach. Credit: Neil Sealey.

Pollution

Trash on our beaches is probably the single greatest threat to both marine life and the tourist trade. There are many types of litter, but plastic is the most widespread. A study from San Salvador from 1998-2004 revealed that the dominant material category across beaches and years was plastic (White & Curran 2006). As this is a sparsely settled shoreline with no tourist activities it is reasonable to assume that all of this washed up from other places. Large plastic items, such as water bottles, will eventually break into tiny pieces known as microplastics, however plastic does not break down entirely. Microplastics are easily carried into the sea from a beach and can enter the food chain. Microplastics are also known to attract other pollutants and as such can become a vector for introducing those pollutants to the food chain.

Among the litter washed up among the seaweed will sometimes be oil, usually in the form of black tar. On beaches it may be seen as tar balls, and some resorts provide baby oil for cleaning off the sticky tar from their guests. More typical is oil on the rocks which lasts longer as it is not mobile. There are two common sources of oil/tar. It may be local, such as the notorious leaks from the Clifton power plant in Nassau, but more widespread is the waste from oil tankers cleaning crude oil from their tanks at sea. This was common and legal until the 1970s, when it was banned from large tankers, but illegal washing and discharge from small vessels still releases large amounts of crude oil into the oceans, and ultimately this reaches the beaches.

Figure 18. Oil tar and marine debris along the South Abaco coast. Credit: Diane Claridge.

Figure 19. This road on the west coast of San Salvador has led to the destruction of the beach, once like the shore in the background. This has led to road damage and now the construction of a sea wall to protect the road. Credit: Neil Sealey.

Beach modification

Many beaches are abused by man made structures. As we have seen, a beach is part of an ecosystem that stretches from the sea to the back of a sand dune. Anything inserted into this system will have an impact on the whole system. A typical example is the building of roads along the shore. As there was often swampy land behind a beach/dune system many roads were built along the dune itself, which resulted in dune destruction.

Anything that projects into the sea from a beach will affect longshore drift. Groynes are created deliberately to use this effect and collect sand in one place, but they will always prevent it from reaching other areas downwind, which results in some degree of beach erosion. The same effect applies to canal entrances that are protected by groynes to keep the channel clear, as they also interrupt longshore sand movement. Docks, marinas, jetties, and wharves all have similar effects.

Another structure that causes sand loss is the sea wall, often built to protect a road or property that was originally protected by a sandy beach, but that same structure has now been destroyed. Unfortunately it is not usually realised that waves hitting a sea wall will scour any remaining sand from the beach and make matters worse, in many cases leading to the destruction of the sea wall itself, in turn leading to the building of an even bigger wall!

Figure 20. The groyne-protected entry to this marina on San Salvador has caused the loss of the entire sandy beach to the south (top of picture), but widened the beach in the north. Long-shore drift on the SW coast of San Salvador is from north to south in this location. Credit: Neil Sealey.

Sand Mining

While most sand for construction is obtained by dredging far offshore, or from onshore quarries, on many Family Islands there is no organised supply and local contractors simply load up from the nearest dune. Initially this may seem harmless as the sand is replaced in the normal way, but under stormy or hurricane conditions the dune can be breached and serious flooding of property behind the dune is likely, as well as the destruction of the dune itself. The Mining Bill, 2023 prohibits the excavation of sand from any beach or sand dune without permission from the appointed regulatory bodies.

It may be many years before a dune can be rebuilt naturally, but the process can be hastened through sand-scraping, which utilises sand that has accumulated in the foreshore. In more extreme cases where a beach has been washed away it can be rebuilt. This requires suitable sand from another area to be placed on the eroded surface, and then protected by a combination of groynes and breakwaters, the most common form being the mushroom groyne as used at Montagu and Saunders beaches in Nassau.

Figure 21. Sand scraping on Elbow Cay, Abaco, after Hurricane Sandy. Bulldozers or bobcats pushed foreshore sand up the beach to replace sand eroded from the dune face. Ideally houses should not be built on sand dunes. Credit: Neil Sealey.

Climate change

The impact of climate change on a beach is difficult to forecast until we have more evidence. The two most likely effects are a rise in sea level, and an increase in storm severity.

As sea level rises the sea can penetrate further inland if the shoreline is low-lying. In the case of a narrow beach it may be swamped and disappear if it is backed by structures like roads or houses, but not necessarily so. If there is an abundant source of sand offshore it is quite likely that more sand will accumulate on the beach, raising it as sea level rises. On a natural coast with a low landscape the beach may stay intact, but retreat landwards.

One effect of climate change seems to be the increased severity of hurricanes – in other words more high category storms, but not necessarily more storms. The waves generated by hurricanes are always destructive, and beach sand will be swept offshore. If there is no nearby drop-off this sand will be available for beach reconstruction once calmer conditions, and constructive waves, return. This is what facilitates beach scraping as practised by homeowners near the beach on Elbow Cay, or by hotels like Atlantis on Paradise Island. In some cases the wind itself may be more damaging than the waves, as was the case with Hurricane Sandy in 2012. For three days the beach sand was blown ashore along the north coast of Nassau, filling properties and car parks with sand and overwhelming sea walls, vegetation, and dunes.

CONSERVATION AND MANAGEMENT

The Bahamas Public Parks and Public Beaches Authority

According to The Ministry of The Environment and Housing, The Bahamas Public Parks and Public Beaches Authority was created to control, plan, and design, develop, administer, manage, and maintain, public parks and public beaches. Their responsibilities include conserving natural beauty and features of public parks and beaches, protecting and preserving flora and fauna in public parks and beaches, preserving objects of aesthetic and historical value, general cleanup, maintaining public access to beaches and providing lifeguard services, maintaining green verges, roundabouts, and open green spaces, ensuring that parks and beaches have sanitary and clean conditions.

National Parks

Examples of sandy beaches are found in a number of National Parks throughout the country. For example: Grand Bahama (Lucayan National Park, Peterson Cay National Park), Andros (Andros West Side National Park), Exuma (Exuma Cays Land & Sea Park, Moriah Harbour Cay National Park), Inagua (Little Inagua National Park), Conception Island (Conception Island National Park).

Protection of Coastal Vegetation

A number of coastal plants are listed on the Forestry (Declaration of Protected Trees) Order, Part II - trees of cultural, historical and economical significance, including sea oats, railroad vine, and inkberry. Harvest of protected plants is prohibited, except by permit from the Forestry Department.

classroom activities

Objectives

Identify the different zones of a beach and describe various visual characteristics.
Understand that the zones of the beach are affected by weather, waves and human activities.
Understand why beaches are important.

Classroom Discussion

1. Lead a class discussion with the following questions/prompts:
2. If you had to come up with a dollar value for the importance of a beach in The Bahamas, what features and services would you consider and why?

   Each student could select their own beach (there could be some variation in features and services), or the whole class could talk about the value of beaches in general.

Classroom Activity

Zonation fill-in-the-blank answer sheet. Have students refer to figure 1 in the chapter to be able to fill out this sheet on their own. Could be a classroom activity or homework assignment.

classroom activities

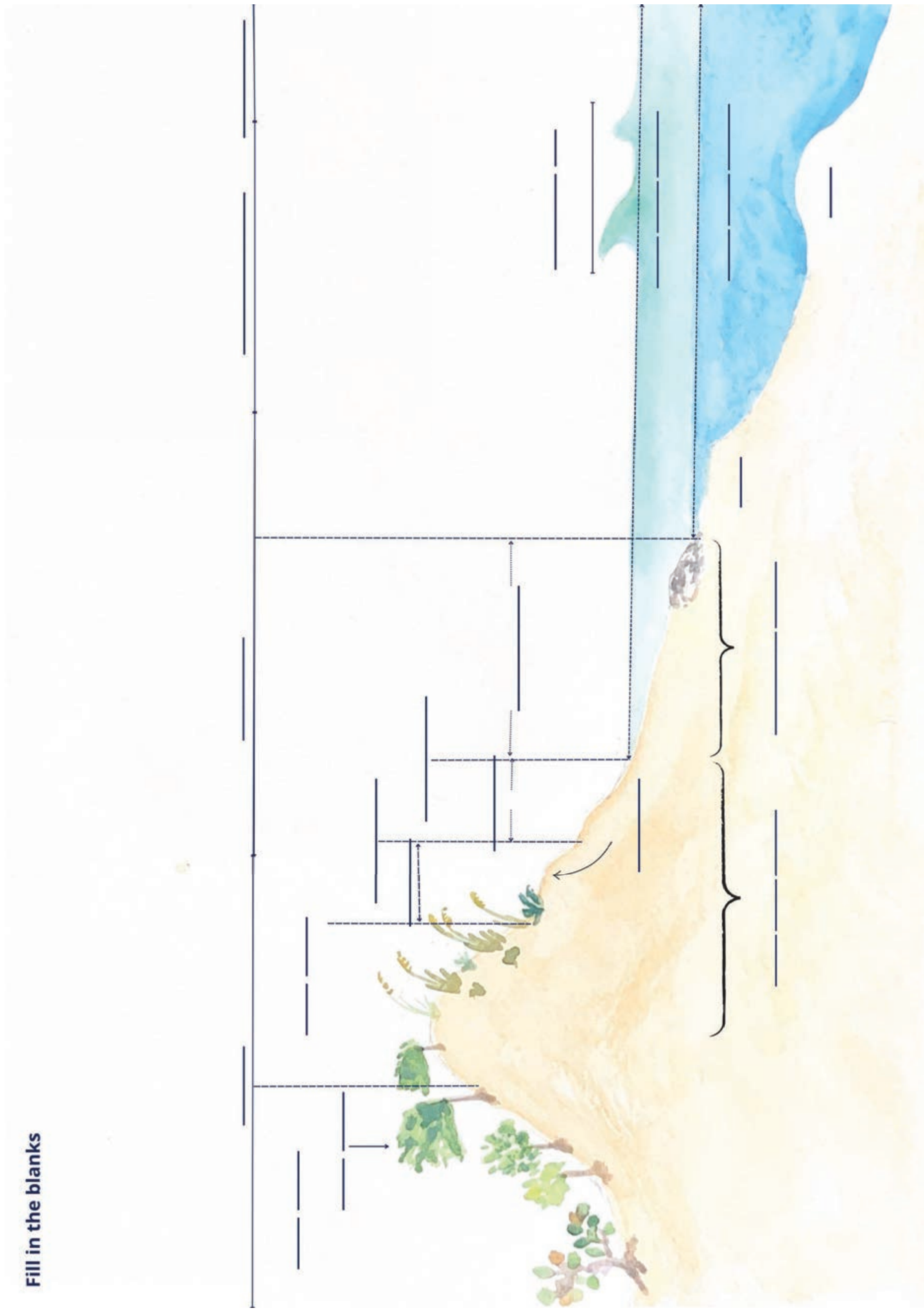


Figure 22. Fill in the blank beach profile sheet.

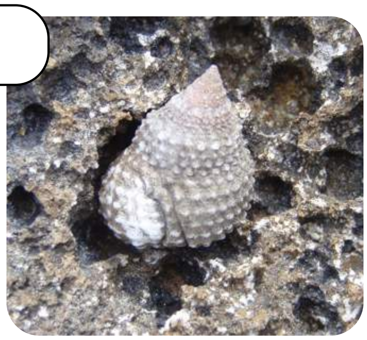
classroom activities

Sea Shore Expedition

The rocky shore is home to a number of molluscs, crustaceans, fish, birds, and plants. **(1)** Check the organisms that you find and **(2)** indicate which phylum they belong to and **(3)** describe the habitat you found them in. (Example Phyla - Arthropoda, Mollusca, Chordata, Echinodermata, Porifera)

Some species you may encounter:

Beaded Periwinkle



Phylum?	
Habitat?	

Dwarf Cerith

Phylum?	
Habitat?	

Bleeding Tooth

Phylum?	
Habitat?	

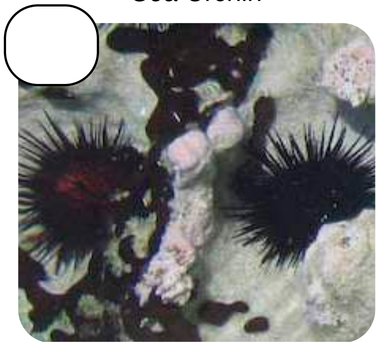
Hermit Crab

Phylum?	
Habitat?	

Fuzzy Chiton

Phylum?	
Habitat?	

Sea Urchin



Phylum?	
Habitat?	

Figure 23. Seashore expedition work sheet

field trip activities

Field Trip #1
Figure 23. Insert Seashore expedition sheet from GEF Grant highlighting different organisms on the sandy beach (full page)

Field trip #2 (Upper High)
Sandy Shore Beach Profiling

This activity was adapted from the Exploring Our Fluid Earth, a product of the Curriculum Research & Development Group (CRDG), College of Education. © University of Hawai‘i.

Materials

- Table 1 (Common beach feature. Not all beaches will have all of these features)
- Table 2 (Sample beach profiling data sheet)
- Figure 1 (Profile of typical coastal features)
- Three one-metre sticks or two transit poles
- Tape
- Marker
- Transect line or long rope marked at regular intervals
- GPS (optional)
- One flag or stake per transect (optional)
- Level (optional)

Background
A transect is a straight line that cuts through a natural landscape so that standardised observations and measurements can be made (Morris, 2021). This can be made from a long rope with marked intervals (ie., make a marking every metre) or a tape measure.

Pre Field Trip Activity:
Discuss coastal features and potential beach hazards.
Determine locations to lay your profile transects (Step 3). (Your plan may change when you arrive at your location based on factors like water conditions.)
Practice making a beach profile (Step 5) at school on a slope or stairs.

Safety Note: Take safety precautions around the water. Bring water, sunscreen, a hat, and other things that will keep you hydrated and safe. Be aware of the tide and whether the water is rising or falling.

Field Trip Activity:

1. If using metre sticks, attach two one-metre sticks together to make one two-metre high transit pole.
2. Hold the first metre stick perpendicular to the ground with the zero centimetre mark toward the sky. These values are positive; label this metre stick “positive”.
3. Hold the second metre stick in line above the first metre stick so that the centimetre

field trip activities

marks are facing the same side and the zero centimetre mark is toward the ground. These values are negative; label this metre stick "negative". The point where the metre sticks join is the zero mark. This is the point you will align to the horizon.

4. Attach the metre sticks together with tape.
5. Select locations for your profile transects.
6. Observe the beach. Consider the following questions.
   a. Can you observe high or low tide water levels?
   b. Where are the boundaries between coast, beach, and water (the shoreline and coastline)?
7. Transects will be run perpendicular to the water's edge.
8. Work with your classmates to decide where to place your transects. You may choose to place them at regular intervals across the beach, or arrange the transects to map specific features of the beach in more detail.
9. Decide how far from the shoreline you will lay your transects.
10. Use flags or other objects to decide where you will lay your transects; these can be easily moved around the beach while you finalise your transect locations.
11. Lay your transects perpendicular to the shoreline.
12. Your transect should run from the shoreline (mean low tide level) to a pre-determined location, such as a certain number of metres onshore or to the vegetation line. However, you may have to start your transect at a higher water line depending on the tide and water conditions.
13. The zero centimetre mark of the transect line should be at the edge of the water.
14. Record the distance between each transect line and between each transect line and a reference point, such as a tree, so that you can easily find the location of your transect line again.
15. Take GPS points to mark the location of each transect line. (can be done on a phone via google or apple maps)
16. Draw your study location, including the location and distance of each transect line, the features at the beginning and end of the transect lines, the water conditions, and other coastal features.
17. Measure the beach profile at regular intervals using a two person method. These directions are written starting at the coastal edge of the transect and assume a transect length of 20 m and interval of 1 m. You may use smaller intervals if your beach is narrow. Your transect length may be longer or shorter than 20 m. If the tide is rising, start at the edge of the transect next to the water.
   a. Person A stands at the end of the transect (20 m from the waters' edge) and holds the single metre stick or a transit pole vertically. You can use a level to make sure the pole is vertical.
   b. Person B puts the second transit pole one metre away (at 19 m) on the transect. If you do not have a commercial transit pole, this person would hold the taped-together metre sticks as a transit pole, with the "positive" side towards the sand. The measurements on this transit pole should face Person A's transit pole. Use the horizon, where the water meets the sky, to determine the vertical distance the beach slopes between the two transit poles.

field trip activities

c. Person A will look along the top edge or through the sighting hole of the transit pole or metre stick to the horizon. This point is the zero point. If you are using a metre stick, and your stick has a hole on one end, you can use it as your sighting hole for this activity.
d. Person B will move their finger on their transit pole until his or her finger aligns with the horizon and the top of Person A's metre stick (Fig. 5.14).
e. If Person B's finger moves down on the transit pole, the value read is positive (e.g., +5 cm). You will get positive readings if Person B is higher than Person A.
f. If Person B's finger moves up, the value read is negative (e.g., –5 cm). You will get negative readings if Person B is lower than Person A.

18. Record value on the beach profile data sheet.
19. Continue to collect data every metre along your transect, always keeping the metre sticks one metre apart. For example, for the next measurement person A, holding the single metre stick, would stand at 19 m and person B, holding the transit pole, would stand at 18 m.
20. Take any other measurements or make other observations that may be related to beach shape at this location.
21. Graph your beach profiles on graph paper, with height on the y-axis and distance on the x-axis. Multiple transect lines can be plotted on the same graph, or on separate graphs taped together to show the slope of the beach profile.

Activity Questions:

1. Why is it important to run transects perpendicular to the shoreline?
2. In your own words, describe the elevation change at your site.
3. Was the elevation change uniform from one end of the beach to the other? Explain why you think this is.
4. How do the beach profiles you created compare to your observation of the beach? Label beach features on your beach profile.
5. Which coastal features that are defined with respect to changes in the level of the tide did you observe (refer to Table 1 and Fig.1)?
6. Were there any beach features that you missed when you conducted your beach profile? If so, why?

field trip activities

Table 1. Common beach features

Term	Definition
Backshore	The beach area between the foreshore and the foot of the dunes. This zone is between the shoreline and coastline. Normally the backshore is dry; waves only reach this area during storms.
Bar (Sandbar)	An embankment of sand, gravel, or other particles deposited in shallow water by waves and currents that are parallel to the shore. Bars may be submerged or emerged. There can be several rows of bars.
Beach (Shore)	Zone of loose sand, gravel, and other material that extends landward from the low tide waterline to the coastline.
Beach Berm	Long wedge of sand parallel to the shoreline that is normally in the backshore of the beach. Berms have different slopes on their seaward and landward sides; the steep side of a berm faces the ocean, the side that faces land has a more gentle slope or is flat. Beach berms are formed by waves depositing material. Berms can resemble terraces, with several beach berms on a beach. Or, a beach may have no berms.
Breaker Zone	Area where deep-water waves touch bottom and become shallow-water waves, changing from rounded swells to unstable, peaked waves that start to break.
Coast	A strip of land of indefinite width (up to several miles) extending from the coastline inland toward the first major change in land features that are not influenced by coastal processes.
Coastline	The line that forms the boundary between the coast (land) and the beach (shore). It is marked by the start of permanent vegetation or where there is a marked change in substrate or landform morphology (shape), for example, from a relatively flat beach to hilly dunes.
Dunes	Ridges or mounds of loose, windblown material, usually sand. Dunes are often vegetated, that is, they have plants growing on them.
Foreshore	That part of the beach (shore) between the water level at low tide and the upper limit of the wave wash at high tide (the shoreline).
High tide	The highest water level of each rising tide.
Low tide	The lowest water level of each falling tide.
Nearshore	The zone extends seaward from the water level at low tide (the foreshore) to beyond the breaker zone. This area is indefinite and is affected by nearshore currents.
Offshore	The direction seaward of the nearshore zone.
Shoreline	The line formed when the water touches the beach at high tide. The shoreline divides the beach into the foreshore and backshore.

field trip activities

Table 2. Sample beach profiling data sheet

Beach Profile Data Sheet

Transect #				**Transect #**		
Starting Point (m)	Elevation Change (m)	Cumulative Elevation (m)		Starting Point (m)	Elevation Change (m)	Cumulative Elevation (m)
20				20		
19				19		
18				18		
17				17		
16				16		
15				15		
14				14		
13				13		
12				12		
11				11		
10				10		
9				9		
8				8		
7				7		
6				6		
5				5		
4				4		
3				3		
2				2		
1				1		
0				0		

Rocky Shores

Chapter Objectives

- Identify the zones relevant to the rocky shoreline
- Describe abiotic and biotic factors affecting animal distribution
- Discuss adaptations to life on the rocky shore

The Bahamian Rocky Shore is an important marine shoreline ecosystem where limestone rock has become exposed. Within the rocky shore, nooks and crevices are formed over time by erosion creating liveable spaces for many different animals and some plant species. Limestone is an incredibly permeable and soft rock that only stays intact due to an important algae that lives within the surface of the rock - called **endolithic** algae. Areas become eroded when this algae layer is removed, likely due to a combination of wind and wave action. Rocky shores are a type of **intertidal** system – an area between the high and low tide mark. Therefore, the fauna and flora is naturally divided into distinct vertical zones determined by the tidal movement of the ocean.

Different species inhabit different zones due to the ***abiotic*** (non-living) and ***biotic*** (living) factors.

Abiotic factors include wind, heat, salinity, and ultimately the vulnerability to **desiccation** due to time exposed by air.

Biotic factors include predation, food availability, and competition for space.
Feeding and reproduction are mostly limited to times when the organisms are covered in water and so inhabitants of the rocky shore exhibit cyclic behavioural patterns. At low tide, small pools are created within the divots of the rock (tide pools), where fish and other animals get stuck as the tide goes out. This concentrates food for birds to feast on.

Rocky Shore Zones
Organisms that use the rocky shore as their habitat are often found in one primary zone; however, their range may encompass different zones depending on their ability to survive and navigate certain environmental conditions such as slope, rock size, and exposure. Thus various organisms are more common in some zones than in others due to their ability to adapt to different conditions.

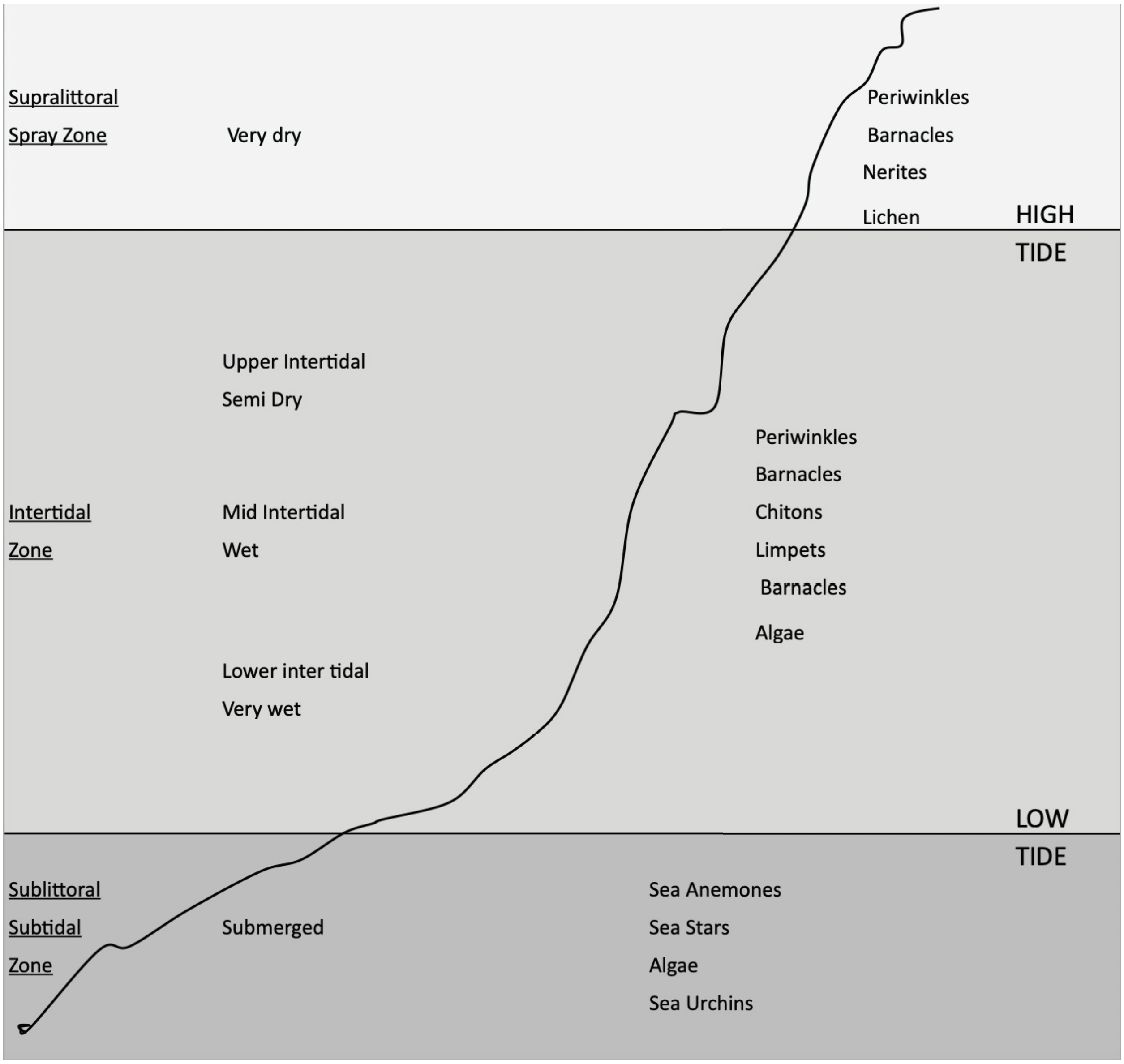


Figure 1. This diagram shows rocky shore zonation and where you would find certain animals. Credit: Joy Chaplin.

Supratidal or Splash Zone

This highest zone is only covered during exceptionally high tides and is moistened by spray from breaking waves. It is exposed to air for most of the time.

Intertidal Zone

This zone is between the high and low tides. The intertidal zone can be further divided into three zones: the upper intertidal zone, the middle intertidal zone, and the lower intertidal zone.

1) The upper intertidal zone is usually exposed to air with the exception of during extreme high tides. Tide pools are puddles of saltwater left behind when tide falls; they start to appear in the upper intertidal zone.

2) The mid intertidal zone is exposed to air and water for approximately equal durations of time.

3) The lower intertidal zone is almost always exposed to water except for at extreme low tides.

Organisms in the upper and mid intertidal zones are more affected by abiotic factors such as temperature and desiccation in comparison to those in the lower intertidal zone. They are also affected by biotic factors such as species competition and the predators with organisms in the lower zone being more susceptible to marine predators.

Subtidal or Sublittoral Zone
This zone is permanently covered in water and therefore more stable than the intertidal zone as organisms do not have to face the challenges of desiccation and extremes of temperature. Like the intertidal zone, competition for food and habitat and predation are still very important for all species to survive in this environment.

Ecosystem Flora and Fauna

Table 1. Examples of types of algae found along the rocky shore.

Common Name	Scientific Name	Green Algae (Chlorophyta)	Red Algae (Rhodophyta)	Brown Algae (Phaeophyta)
Mermaid's wine glass	*Acetabularia caliculus*	√		
Sea Pearl	*Valonia ventricosa*	√		
Pink bush alga	*Wrangelia penicillata*		√	
White Scroll alga	*Padina jamaicensis*			√
Bristle ball brush	*Penicillus dumetosus*	√		

*Various species of **crustose coralline algae** (Rhodophyta) form stains like coatings and "tar spots" on the rocky shore.

Figure 2. Stains from crustose coralline algae, a red macroalgae that grows encrusting over a substrate, appearing to look like tar spots. Credit: Olivia Patterson Maura.

Table 2. Native and invasive plants commonly found along rocky shores

Common Name	Scientific Name	Gymnosperm	Angiosperm		Native or Invasive
			Monocotyledon	Dicotyledon	
Hawaiian Seagrape/ Hawaiian Sea Lettuce	*Scaevola taccada*			√	Invasive
Australian Pine	*Casuarina equisetifolia*			√	Invasive
Seagrape	*Coccoloba uvifera*			√	Native
Buttonwood	*Conocarpus erectus*			√	Native
Sea Purslane	*Sesuvium portulacastrum*			√	Native
Bay Cedar	*Suriana maritima*			√	Native
Sea Ox-eye / Bay Marigold	*Borrichia arborescens*			√	Native

Table 3. Typical Fauna found along rocky shores

Phylum	Description	Examples
Annelida	segmented worms	bristle worms, tube worms, feather dusters
Arthropoda	external hard shell (exoskeleton), jointed legs, bilateral symmetry, segmented bodies	barnacles, crabs, crawfish
Cnidaria	Stinging cells, radial symmetry, polyp & **medusa** forms	Anemones, corals, jellyfish
Coelenterata	radially symmetric with simple internal cavity	jellyfish, hydroids, corals, sea anemones, sea fans
Echinodermata	radial symmetry, spiny skin, tube feet, water vascular system	sea stars, sea urchins, sea cucumbers, sand dollars, sea biscuits
Mollusca	external shell, rasping tongue like structure (radula), muscular foot, bilateral symmetry, complete gut	sea hares, octopus, conch, clams, limpets, nerites, chiton, periwinkles
Porifera	Sessile animals attached to the rocks, no definite symmetry, filter feeders	sponges
Protozoa	minute animals, free living or attached	foraminifera
Vertebrates	vertebral columns	Frillfin goby, juvenile school masters

spotlight species

Bleeding Tooth Nerite

3

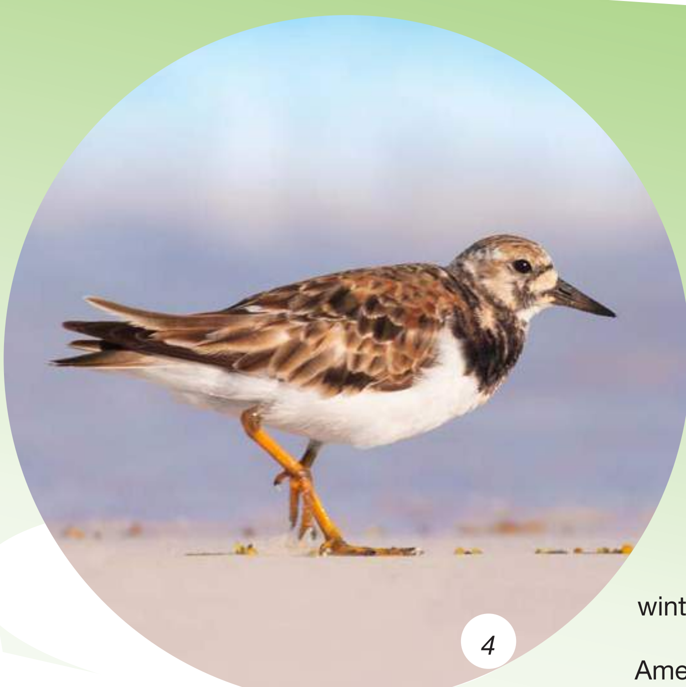
Scientific Name: *Nerita peloronta*
Conservation Status: Unknown
Distribution: Florida, Caribbean

Figure 3. As its name implies, this marine gastropod appears to have a bleeding tooth at the opening of its shell, which makes it easily identifiable. Credit: Lianna Burrows.

The bleeding tooth nerite is a marine gastropod, more commonly referred to as a sea snail. They are often found in the intertidal zone of the rocky shore, mainly living just above the high tide line. Bleeding tooth nerites feed on **diatoms** and other algae closer to the water (Sprung, 2003). They get their name from the tooth-like structures at the opening of the shell that have an orange/reddish colour.

spotlight species

Ruddy Turnstone



4

Scientific Name: *Arenaria interpres*
Conservation Status: Least concern
Distribution: The Ruddy Turnstone nests in North America in the tundra, and spends its winters along the coasts of 6 continents including Asia, Africa, Australia, North America, South America and Europe. They frequent The Bahamas and other areas in the Caribbean.

Figure 4. A Ruddy Turnstone. These unique birds travel thousands of miles annually for breeding and feeding, across six continents. Credit: Christopher Johnson.

The Ruddy Turnstone is well known for its feeding habits of using its bill to flip over shells and rocks for food. Sometimes, several of them work together to flip over large objects. They have a bright, multicoloured pattern of light brown and white in the summer months and a dark brown coat in the winter. Their diet consists of insects, mollusks and crustaceans and varies based on different seasons.

Habitat Adaptations

Wave Action Stress

Waves are formed by energy passing through water, causing it to move in a circular motion. This energy often comes from the wind and can also be formed by underwater disturbances such as earthquakes or volcanic eruptions. Waves are also caused by the gravitational pull of the sun and the moon—tides. Manmade objects can also create waves.

Waves are constantly buffering the rocky shore so organisms that inhabit this ecosystem must have adaptations to secure themselves to avoid being displaced.

Bivalves, such as mussels attach themselves with threads (*byssal threads*). Limpets and periwinkles clamp down into indentations in the rocks with the aid of a large foot. The chiton (curb) has armoured plates to withstand wave pressure. Algae develop large holdfasts to anchor themselves, and many other rocky shore animals have hard shells to help them withstand wave action.

Figure 5. This fuzzy chiton has found a crevice to hide in. Credit: Enie Hensel.

Temperature Stress

Many animals such as the periwinkle have shells with ridges or knobs on them which help to reflect and radiate heat. Lighter coloured shells do not absorb as much heat as the darker shells do; for example bleeding tooth nerites have a lighter coloured shell which aids in limiting the absorption of heat since they live predominantly in the upper to mid intertidal zones.

Figure 6. Notice all the ridges found on the periwinkle shells that allow them to reflect heat and maintain a good internal temperature. Credit: Olivia Patterson Maura.

Desiccation Stress

Desiccation is the state of extreme dryness, or the process of extreme drying. Organisms are threatened by desiccation being out of water, at low tides or when they are positioned in the high intertidal zones.

To avoid drying out when the tide goes down some organisms like nerites and limpets will take in a drop of water before clamping down tightly onto the rock surface. Activities are restricted during the time the animal is uncovered by water and this slows its metabolism.

Some sea anemones produce a mucus which covers them and slows down desiccation. Some algae are able to lose 80 to 90% of their water content during low tide and then recover when the tide comes back in.

More mobile animals like crabs can move to rock pools or travel down the shore line as the tide drops to stay covered with water.

Predation Stress

Organisms are exposed to predation in all zones of the rocky shore ecosystem. Characteristics such as a hard shell or the ability to hold tightly to the rock protect animals like the limpets, nerites, chitons and periwinkles from **predation** from other animals including brittle stars and snappers. **Calcification** and the production of noxious chemicals help to protect several species of algae.

Ecological Role

Rocky shores provide a habitat for marine organisms such as limpets, periwinkles, nerites, West Indian top snails (whelks), chitons (curbs), and crabs to name a few.

Rocky shores are also important nursery areas for several species of fish and birds (e.g. white tailed tropicbird, brown noddy). For example, many juvenile coral reef fishes live in the subtidal zone for their first few months. The subtidal rocky shore creates tons of refuge for these fish while there is little exposure to potential predators. During a snorkel along the rocky shores within The Bahamas, one is likely to see juvenile grunts, butterflyfishes, and parrotfishes.

Figure 7. White tailed tropicbirds soar near the rocky shore. Tropic birds nest on the rocky shore so it's important to have food sources nearby. Credit: Olivia Patterson Maura.

Economic Value

Coastal protection

Rocky shores protect the islands from wave action and serious erosion by stabilising inshore sediment.

Food source

Whelks and curbs are considered a Bahamian delicacy. They are harvested from the crevices in the rocks that are in the supratidal zone. Whelks and curbs can be found in salads and stews.

Figure 8. Curb salad is a tasty favourite in The Bahamas. Credit: Lisa Hall.

Threats

Dredging/Coastal Development

Major threats to rocky shores include human activities such as dredging and coastal development. Dredging is the operation of removing material (typically sediment and rock) from one part of the water environment and relocating it. This process produces silt which can smother coastal organisms. Careless building practices can cause erosion or the complete loss of coastal habitats like the rocky shore. Rocky shores are also considered not as aesthetically pleasing as sandy beaches; thus, large developments often perform beach reclamations, moving sand from another area to create a beach over the rocky shore.

Climate Change

Climate change and the predicted rise in sea levels will have a serious effect on the Bahamian coastline, therefore affecting the different zones of the rocky shoreline.

Invasive Species

Indigenous coastal vegetation is being replaced by invasive species such as Casuarina. With its shallow root system the Casuarina does not stand up well to tropical storms and hurricanes and is easily uprooted with damaging consequences to the shoreline.

Pollution

Pollution from oil spills can coat intertidal organisms and smother them. Plastic garbage, fishing lines and nets and other debris collect on shores and harm marine organisms. Sewage discharge is unsightly and changes the ocean chemistry.

Conservation and Management

You are never far from the shoreline in The Bahamas, being a nation of islands. Whereas private ownership of land may mean there is limited access to the shore from the land side, the high tide mark is the end of the private property, so access from the sea side is mostly unrestricted.

Some communities have guidelines for the distance you can build from the rocky shore and permits are required to make any changes to the rocky shore.

Many national parks in The Bahamas include rocky shore habitat. Examples include Andros (Andros North Marine Park, Andros South Marine Park), Abaco (Pelican Cays Land & Sea Park, Fowl Cays National Park, Tilloo Cay Reserve), Exuma (Exuma Cays Land & Sea Park, Moriah Harbour Cay National Park).

Did you know?

Seaweed is not a specific type of plant. It is the common name given to the combination of seagrass and algae (often sargassum) that washes ashore or floats around on the ocean's surface.

classroom activities

Objectives:

- To explore the value of the many services and products the rocky shore provides.
- To discover and understand the features and organisms that live in this ecosystem.
- To learn about equipment used to survey this ecosystem.

Brainstorm benefits derived from the rocky shoreline. This can be a writing assignment where students write about the benefits of the rocky shoreline, or a classroom discussion. Have students think about why the rocky shoreline is important, or from their perspective what is the most important part of it.

Prepare a cartoon showing benefits derived from the rocky shoreline using the template provided.

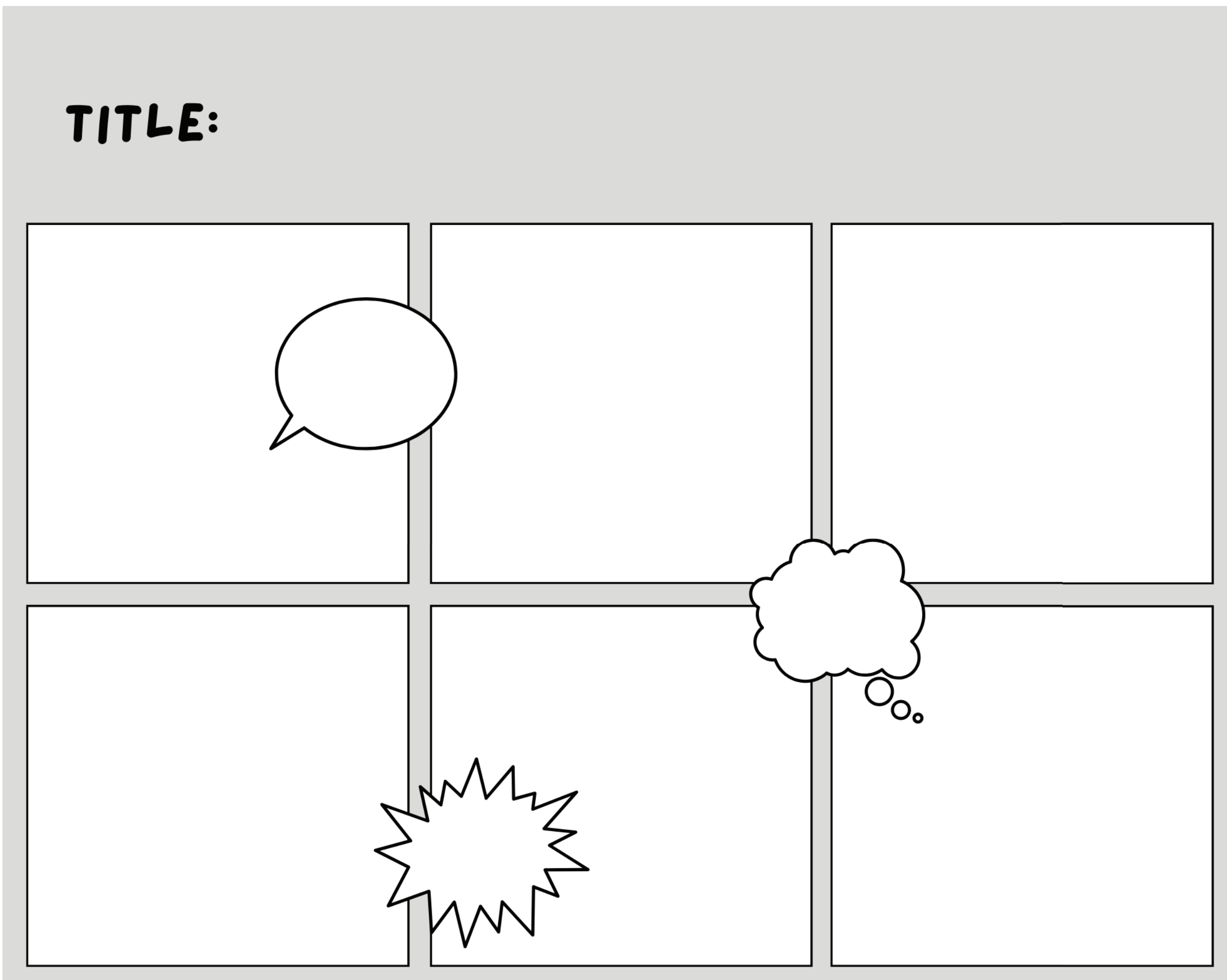


Figure 9: Template for classroom activity, "Brainstorm benefits derived from the rocky shoreline". Credit: Canva Create Studio.

field trip activities

Field Trip Activity 1: Measuring abundance of seashore organisms

Pre-field trip
1. Discuss what quadrats, line transects, and measuring tapes are and how we can use them on a rocky shore to study abundance.
2. You may have to create your own quadrat before this field trip.* Please see below the activity on how to make your own! Please note, building a quadrat can be a separate in-class activity.
3. Review photos of some of the common organisms found on the rocky shoreline - both plants and animals.
4. Take note of where these organisms are generally found.
5. Check the tides. Ensure that you will be exploring the rocky shore at LOW tide. Tide charts can be found online.

Level: Grades 10-12, this activity is recommended for BGCSE coursework.
Duration: 60 - 90 minutes
Objectives: Students will learn tools to scientifically measure abundance of seashore organisms using the quadrat and line transect method.

Materials:
- 2-3 Quadrats (see below on how to make your own quadrat).
- Transect line (soft tape measure)
- Pencil
- Paper/notebook
- Camera (optional)
- GPS / Phone for location (optional)

Instructions for field trip:
1. Travel to a rocky shoreline near you.
2. Divide students into groups of 2 or 3 depending on how many quadrats you have. Each group should have 1 quadrat.
3. Using your transect line (soft tape measure), have two students measure from approximately the high tide mark to the coastline.
4. If possible, rest the transect line on the ground for reference.
5. In groups, rest the quadrat on the ground at each 5 metre mark of the transect line (for example, 5m, 10m, 15m, and so on).
6. In your notebooks/on paper, set up a table with the following columns:
   Column 1: Point on Transect Line (ie. where your quadrat was placed. Example - 5m, 10m, etc). OR use your GPS / Phone to record coordinates of where your quadrat was placed.
   Column 2: Animals in this quadrat
   Column 3: Plants in this quadrat
   Note: it is important to record "0" if there are no plants or animals in this column.

field trip activities

If you do not know what the species is, describe its colour, behaviour and size, or take a photo to identify it later.

Column 4: Total organisms in this quadrat (total the amount of animals and plants)

7. Once the quadrat is rested on the ground, fill out all the columns on your worksheet and repeat every 5m from the high tide mark to the coastline of the rocky shoreline.

Post-field trip Discussion Questions

1. Which area of the rocky shoreline had the highest abundance of organisms total?
2. Which area had the highest abundance of animals?
3. Which area had the highest abundance of plants?
4. Why do you think location along the rocky shoreline affects abundance of certain organisms?

***Creating your own Quadrat for measuring abundance in the field**

Don't have a quadrat? Creating your own can be simple! Follow these steps to create your own before heading into the field.

Materials (can be found at a local hardware store)

- (4) PVC pieces cut into 1 metre (3.2 feet) - or whichever size is feasible. The 4 pieces must be equal.
- (4) PVC 90° pipe elbows
- Regular clear PVC cement
- Measuring tape or ruler
- String or fishing line

Instructions for assembly

1. Apply the clear PVC cement to the edge of the first 1m PVC pipe.
2. Once the cement is applied, attach one of the 90° pipe elbows to the pipe. Make sure the pipe is pushed all the way into the elbow.
3. Follow this procedure with the remaining three 1m PVC pipes to form a square.
4. Using a sharpie and ruler / measuring tape, mark 10 cm intervals along each side of the quadrat to create the inner grid.
5. Use a fishing line or string to tie each 10 cm interval together, creating 25 squares within the quadrat.

Reference: *Building a Quadrat.* GVC Science 20F. (n.d.). Retrieved March 29, 2023, from http://gvcscience20.weebly.com/building-a-quadrat.html

field trip activities

Field Trip Activity 2: Explore the Rocky Shore

Level: Grades 10-12
Duration: 60 - 90 minutes
Objectives: Students will be able to use observational skills to explore the rocky shoreline.

Materials:

- Rocky Shore Expedition field sheet
- Pencil
- Clipboard (or something to press on)

Pre-field trip:

Review Rocky Shore Field Trip Rules with students:

1. Check the tides. Ensure that you will be exploring the rocky shore at LOW tide. Tide charts can be found online.
2. Protect your feet—Wear appropriate footwear. The rocky shore is tough on the toes. Old shoes and water shoes work.
3. Wait for it—Be patient while you search for creatures in a tide pool. Observe and move around slowly.
4. Look out below—Rocky shore creatures don't prefer to sunbathe. Look under seaweed, rocks, and overhangs.
5. Easy does it—Be very gentle when holding rocky shore creatures and return them exactly where you found them.
6. Don't move—Rocky shore creatures like sea stars and limpets hold on tight. Do not move them, you'll hurt them.
7. Resist temptation—Taking objects from the rocky shore can impact the ecosystem negatively. Take photos instead.
8. Move slow—Expect to slip every step, step to the lowest point every time, and lean forward and not backward.
9. Bring a bin—Bring a plastic container to observe creatures more closely and for extended amounts of time. Collect clear sea water for the animals. Make sure to return them back to their habitat before the end of the field trip.

During field trip:
Travel to rocky shore with students and volunteers.
Explore the rocky shore and fill out the field trip activity sheets.

field trip activities

Rocky Shore Expedition Sheet

Name: ____

Describe the field trip site: ______________________________

Date: ______________________ Time: ______________

Tide State:________________ Weather Conditions:____________

Visible Human Impacts?:______________________________

____

Other observations: _________________________________

____

Native beach vegetation helps stabilise the shoreline by holding the soil and acts as a natural windbreak and home for native animals. Non-native invasive plants grow quickly and displace native plants. These invasive species often grow together in clumps, creating a "monoculture" (one type of plant). This reduces the natural diversity of an area and can affect the health of an ecosystem.

List any native and invasive plants you see in the proper columns.

Native Plants	Invasive Plants

List some of the organisms that you see on your expedition.

Common Name	Phylum	Habitat

Mangrove Forests

Mangroves are trees that grow along the sea-land interface in tropical and subtropical climates. Since mangroves can tolerate salt water, they are known as halophytes. Their distribution is limited by major ocean currents and water temperature (20°C) but they cover ~137,600km^2 globally (Alongi, 2009; Bunting et al., 2018). The most diverse mangrove forests can be found in the Indo-West Pacific (Tomlinson, 2016). In The Bahamas, three species of mangroves are found: red, black, and white mangroves.

Ecosystem Flora

Mangrove species In The Bahamas:

Red Mangrove (*Rhizophora mangle*):

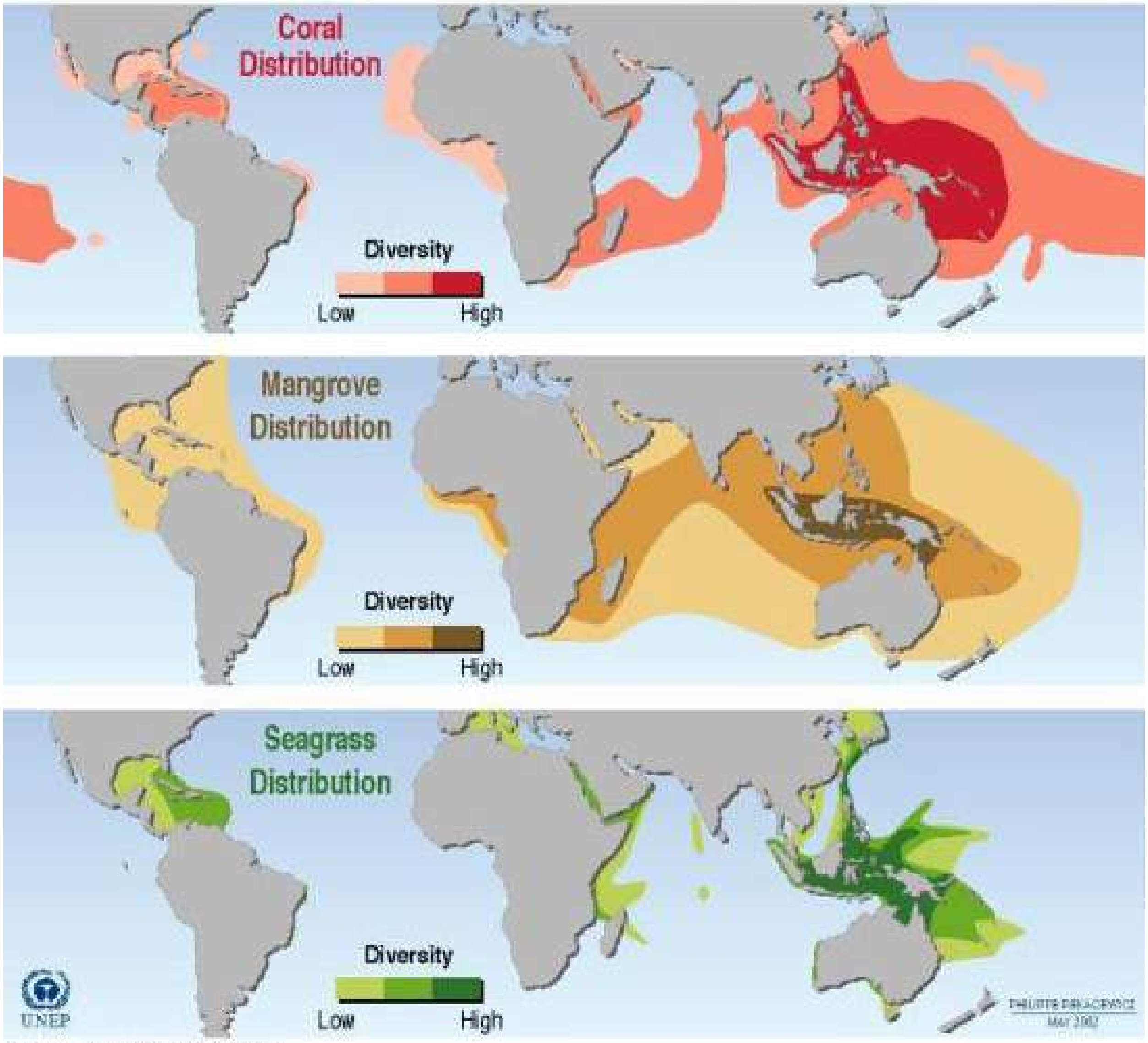
The red mangrove can be identified by its bright green leaves and reddish coloured arching prop roots (Tomlinson, 2016). Often, prop roots are tangled together making it difficult to distinguish individual trees. Typically, red mangroves are located closest to the water and can be found fringing creeks all throughout The Bahamas. Red mangroves are viviparous, meaning the seed actually germinates on the parent tree and forms a propagule. Once propagules are large enough, they drop off the parent tree and float in the water until they settle on suitable substrate.

Chapter Objectives

- Be able to identify the three types of mangroves and one mangrove associate found in The Bahamas.
- Be able to identify important animal species that live within Bahamian mangroves
- Demonstrate awareness of the ecosystem services of mangroves
- Understand the importance of mangrove ecosystems in relation to ecosystem connectivity
- Demonstrate awareness of threats that mangroves face
- Understand the importance of the conservation and management of mangrove ecosystems and what they can do as individuals to help

Figure 1. Red mangrove anatomy. (a) Full plant (b) Leaf (c) Propagule (d) Prop and drop roots. Credit: Friends of the Environment.

Global Distribution of Coral, Mangrove and Seagrass Diversity



Source : UNEP-WCMC, 2001.

Figure 2. Map showing the global distribution of mangroves, seagrasses and coral reefs. Credit: Hugo Ahlenius, https://www.grida.no/resources/7766

Black Mangrove (*Avicennia germinans*)
The black mangrove can be identified by its smaller, silvery green leaves that often have salt crystals on the underside (Tomlinson, 2016). Rather than prop roots like the red mangrove, the black mangrove has a more typical tree structure with one main trunk but sends out pencil-like sticks from its roots called pneumatophores to aid with air exchange when the forest is flooded. The black mangrove produces tear-drop shaped propagules that drop off the parent tree and float in water until settling on a suitable substrate.

Figure 3. Black mangrove anatomy. (a) Full plant and pneumatophores (b) Leaves and flowers (c) Propagules. Credit: Friends of the Environment.

White Mangrove (*Laguncularia racemosa*)

The white mangrove can be identified by its rounder and leathery green leaves that have two glands at the base of the leaf (Tomlinson, 2016). These glands are called nectaries and excrete sugar. Typically the white mangrove inhabits land higher than the red and black mangrove and does not necessarily require **adaptations** for being regularly flooded. If they are located in an area that does flood regularly, White Mangroves will send out pneumatophores like the black mangrove. White mangrove pneumatophores are often rounder, peg-like structures. The white mangrove produces flattened and ribbed, pea-green coloured propagules that contain dark red seeds within each rib.

Figure 4. White mangrove anatomy. (a) Full plant (b) Leaf (c) Propagule. Credit: Friends of the Environment.

Table 1. Characteristics of Bahamian mangroves

	Red Mangrove	Black Mangrove	White Mangrove	Buttonwood
Leaves	Large, broad leaves (~13 cm or 5 in), elliptical shape, end in blunt point Waxy, dark green on top; pale yellow underneath Oppositely arranged leaves	Oblong-shaped (~8 cm or 4 in) More narrow than red mangrove leaves Green, shiny upper surface, often coated with salt crystals Underside coated with dense hairs Oppositely arranged leaves	Broad, flat, oval (~7.5 cm or 3 in) Rounded at both ends, leathery, flattened Two glands at the base of each leaf that excrete sugar Oppositely arranged leaves	Pointy, oblong-shaped leaves Dark, shiny green upper surface; paler, smooth, hairy under surface Two salt-excreting glands at the base of each leaf Alternately arranged leaves
Roots	High prop roots from trunk grow downwards	Aerial roots (pneumatophores) grow upwards from ground Extensive network of finger-like projections around base of the tree	Can have prop roots or pneumatophores; many have neither In oxygen-deprived environments, will develop peg roots (short, stout pneumatophores)	Low-branching and multi-trunked
Bark	Grayish-brown bark; covers dark red wood	Dark brown, scaly bark	Reddish-brown, ridged and scaly bark	Dark-brown to black, rough bark with interlacing ridges Often covered in epiphytes
Location	Shoreline, from upper subtidal to lower intertidal zones	Immediately inland from red mangroves	Prominent in high marsh areas; typically upland of both red and black mangroves	Silty, muddy shorelines of tidal bays; generally the most landward of the mangroves
Size	Tallest (24.4 metres or more; 80+ ft)	Second tallest (reach a max of 19.8 m; 65 ft)	Second smallest (reach a max of 15 m; 50 ft)	Smallest (reach a max of 12.2 m; 40 ft)

Mangrove Associates

Mangrove associates are plants that are commonly found in or near mangrove forests, but are not true mangroves.

Buttonwood (*Conocarpus erectus*)

Buttonwood is often found associated with mangrove communities but is not a true mangrove (Tomlinson, 2016). It can be identified by leathery leaves with pointy tips and smooth edges. Like the white mangrove, buttonwood also has two glands at the base of

Figure 5. Buttonwood anatomy. (a) Full green buttonwood tree (b) Full silver buttonwood tree (c) Leaf (d) Flowerheads. Credit: Friends of the Environment.

each leaf. However, on the buttonwood, these glands excrete salt. Buttonwood does not produce propagules, instead it produces seed cases. Buttonwood gets its name from the way its flowers form dense clusters that look like old-fashioned round buttons. Another way to tell buttonwood apart from a mangrove is that its leaves alternate whereas mangrove leaves are opposite each other.

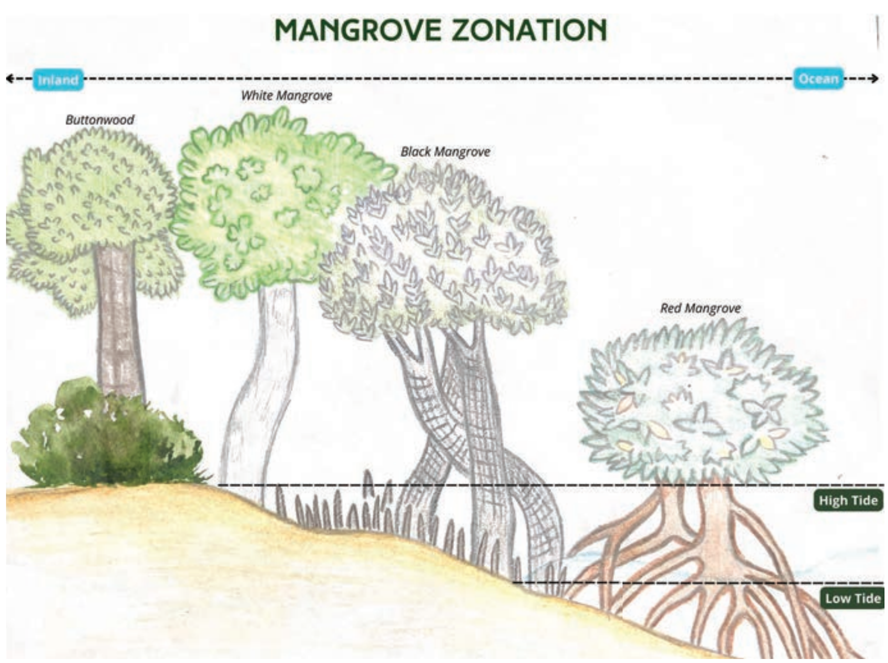


Figure 6. Mangrove zonation describes how mangroves and mangrove associates are found in order from sea to land based on elevation and inundation. Credit: Lyndeisha Curry for Friends of the Environment.

Mangrove Zonation

Often these mangrove species occur in a regular zonation pattern (Snedaker, 1982). Typically red mangroves are closest to the water followed by black mangroves; white mangroves and buttonwood are the most landward. This zonation pattern results from differences in elevation and inundation (flooding) - red mangroves and black mangroves are the most adapted for regular inundation due to prop roots and pneumatophores, respectively. In addition, this zonation pattern is important for the high diversity of fauna that live within these mangroves.

Mangrove Morphology

In The Bahamas we often see stunted or shrub-like red, black and white mangroves. The waters in The Bahamas are oligotrophic (very low in nutrients) so the mangroves may not receive enough nutrients, especially phosphorus which is essential to growth. Additionally, mangroves that grow on karst substrate are limited in the depth roots can reach. Since The Bahamas is mostly composed of limestone, much of the mangroves in The Bahamas inhabit karst substrate (Twilley et al. 2018). Karst is a type of limestone that is the remnants of coral reefs of the past. Karst is very porous, which allows water to flow directly through the land. This affects the architecture of the plant and can also contribute to stunting in mangroves.

Figure 7. Dwarf mangroves in Central Abaco. Credit: Lianna Burrows.

Ecological Role

Mangroves, especially red mangroves, are considered foundation species (Ellison et al. 2005). Foundation species create habitat and thereby help form entire communities (Angelini et al., 2011).

What Animals Use Mangroves?

Many commercially and recreationally important species utilise mangroves as a nursery habitat and/or permanent habitat. Lemon sharks, barracuda, grunts and snapper are some of the common fish species that have been shown to specifically use mangrove habitat as a nursery and for protection (Beck et al., 2001; Murchie et al., 2010). In addition to marine species, mangroves provide important habitat for avian species such as the Antillean nighthawk, White-crowned pigeon, and Gray kingbird (Chacin et al., 2015).

spotlight species

Caribbean Spiny Lobster

Scientific Name: *Panulirus argus*
Conservation Status: IUCN - Data Deficient **Distribution:** United States (Texas, Louisiana, Florida), Bahamas, Turks and Caicos, throughout The Caribbean and parts of Central and South America.

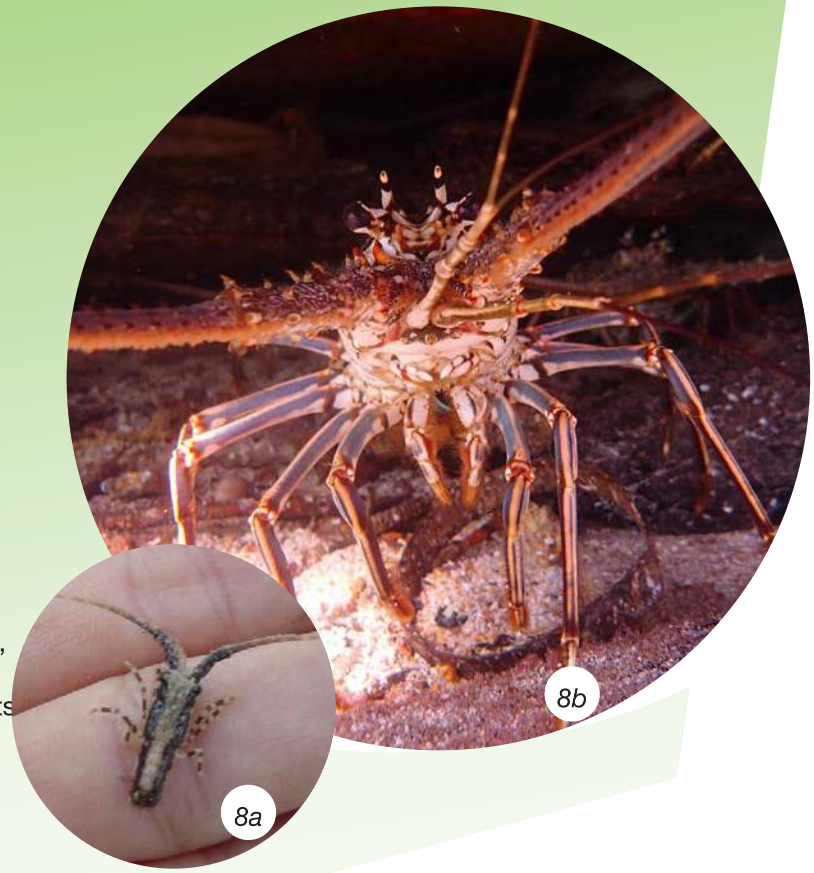


Figure 8. (a) Spiny lobster in its puerulus post-larva stage. Credit: Lory Kenyon. (b) Adult spiny lobster hiding under a shelf. Credit: Enie Hensel.

In early stages of life, crawfish larvae float freely in the open ocean. The larvae are attracted to certain chemical cues from specific algal species that are often found in mangroves and seagrass beds. Because of this, mangroves and seagrass beds are critical nursery habitat for crawfish, and without them crawfish populations would suffer drastically (Bahamas National Trust, 2013). In their juvenile stage, you can likely find crawfish in mangroves, seagrass beds or shallow reefs, as they prefer shallow waters. In shallow reefs, crawfish find crevices or holes to hide in during the day and forage mainly at nighttime out in the open. If startled, crawfish use their tails to swim backwards at a quick pace. Crawfish are a food source for many important species, such as large groupers, octopus, sharks as well as humans (Bahamas National Trust, 2008). The Caribbean spiny lobster industry is a multimillion dollar industry within The Bahamas (Bahamas National Trust, 2008).

Crawfish have size regulations as well as a closed season in The Bahamas to ensure a sustainable fishery. Size limits are 3 ¼ inches carapace length or 5 ½ inches tail length, and possession of egg-bearing females is prohibited. The season is closed from April 1st-July 31st. To further support the sustainability of the spiny lobster fishery The Bahamas has achieved marine stewardship council certification for the condo/casita fishery. This certification and the related requirements help ensure that the annual catch does not exceed the ability of the population to replenish itself.

spotlight species

White-crowned Pigeon

Scientific Name: *Patagioenas leucocephala*
Conservation Status: Near threatened
Distribution: Northern and Central Caribbean islands and some areas of North and Central America

Figure 9. White-crowned pigeon perched in a tree. Credit: Valerie Hudson.

White-crowned pigeons feed almost exclusively on fruit found in the coppice forest; poisonwood berries are an important food source. Other fruits they are known to consume include pigeon plum, gumelemi, and mastic. White-crowned Pigeons nest in mangroves and nearby coastal coppice, but will forage throughout the coppice and pine forest.

The White-crowned pigeon is considered a game bird in The Bahamas, however there is a limited hunting season (September 29th - March 1st) to protect the birds while they are nesting and to allow the population to replenish. The daily bag limit is 50 birds, as stated in the Wild Birds Protection Act (Bahamas National Trust, 2013). White-crowned pigeons are threatened by hunting out of season, hunting over restricted bag limits, and by habitat destruction.

ECOSYSTEM SERVICES

In total, mangrove ecosystem services have a value of $194,000.00/hectare/year (Costanza et al., 2014)

Nursery Habitat

In The Bahamas, juvenile Nassau grouper and spiny lobster are two important commercial species that often use mangroves during juvenile stages.

Figure 10. A juvenile lemon shark in a mangrove ecosystem. Credit: Enie Hensel.

Coastal Protection

The many branches and roots of a mangrove forest can slow the flow of water, allowing sediment to fall out and increase the height of land, and prevent further erosion. For these reasons mangroves are often the first lines of defence from storm activity and waves. The complex, dense structure of red mangroves in particular can help slow and reduce wave height (McIvor et al., 2012). Storm surge can also be reduced with the presence of mangrove cover because the many branches and roots slow down the velocity of the incoming water, thus reducing further inland flooding. In addition to reducing impacts of waves and storm surge, mangroves can also reduce erosion and dampen effects of sea level rise. Since mangroves help slow water flow, sediment suspended in the water can settle out and over time increase the height of the land.. This aids in sediment accretion and helps mangroves keep pace with sea level rise while combating erosion. (McLeod and Rodney, 2006).

Carbon Sequestration

In addition to the coastal protection benefits, mangroves are also important sinks for carbon. Mangroves sequester carbon through **biomass**, or the trees themselves, and in soil. In fact, mangroves are better at **carbon sequestration** than a tropical rainforest. The fact that mangroves can store this much carbon is great, however, this means when mangroves are deforested, there is a massive release of carbon into the atmosphere.

Recreation and Tourism

Since mangrove forests provide essential habitat for many marine species, they are important for recreation and tourism. Mangroves are critical habitats for many important commercial and sport species in The Bahamas like conch, grouper, crawfish, snapper and grunts. Mangrove creeks adjacent to tidal flats are utilised by bonefish and fishermen. Mangroves hold value for other types of ecotourism such as nature tours, kayaking, and birding.

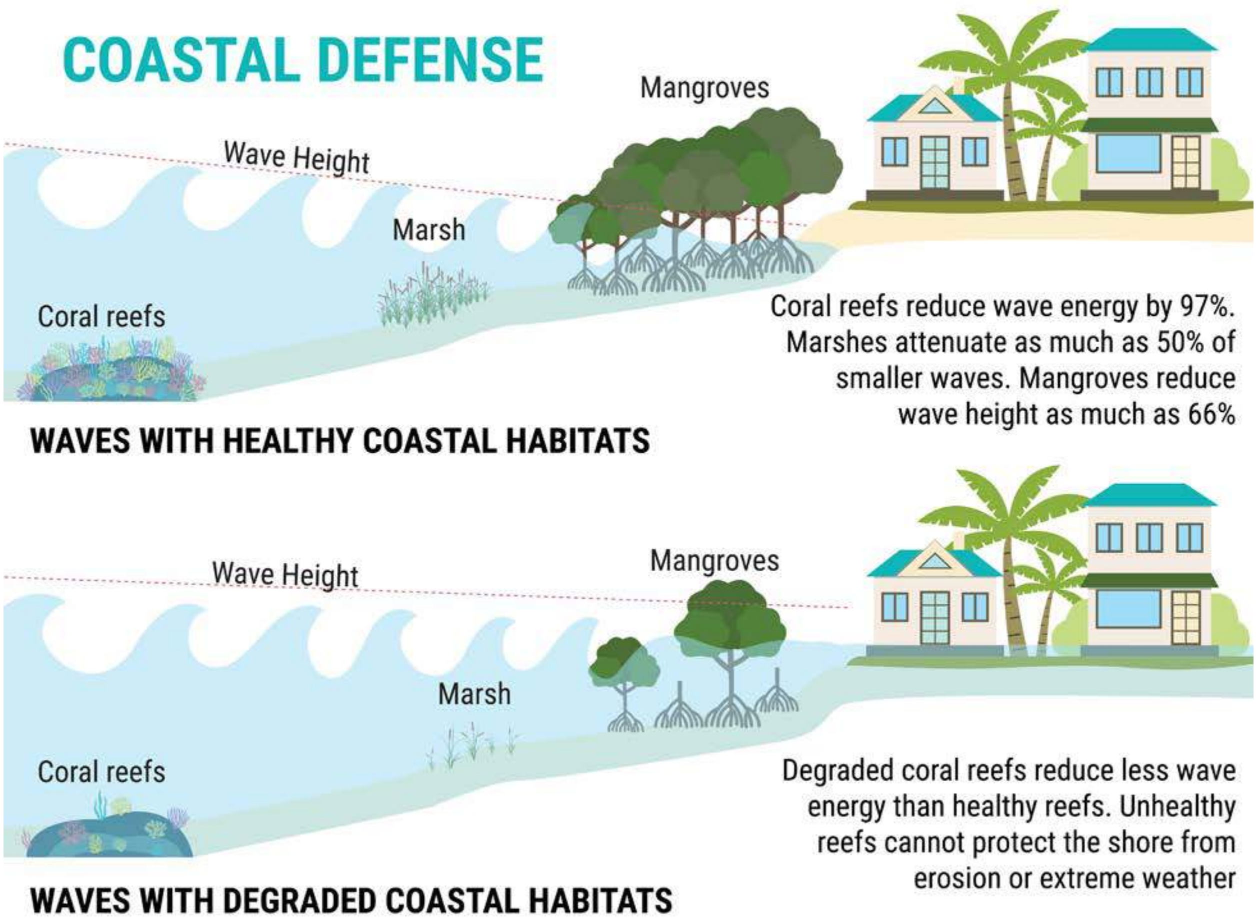


Figure 11. Mangroves, coral reefs and other near shore habitats help reduce wave action. In The Bahamas, seagrasses take the place of marshes as indicated in this diagram Credit: m.malinika/Shutterstock.com

Threats

Anthropogenic Threats

Humans are the biggest threats to mangroves. On a global scale, conversion of mangrove forest to shrimp aquaculture is one of the greatest threats mangroves face (Alongi, 2009). However, destruction of mangroves for coastal development is one of the most common human threats mangroves face in The Bahamas.

Climate Change and Sea Level Rise

As the climate changes, severity of hurricanes is likely to increase. Mangroves are generally resilient to hurricanes, but the more severe a hurricane is, the more potential for extreme leaf loss that the plant may not be able to recover from. Changes in precipitation are also projected to occur with climate change which could lead to more frequent drought periods. Reduced precipitation increases salinity which can negatively impact mangrove productivity and the health of entire mangrove forests. Changes in temperature may also lead to introduction of different species and potentially expansion of mangrove into different habitats. The effect of sea level rise on mangroves is highly site specific since it depends on the elevation, erosion, and ability of the mangrove to trap sediments to accrete soil. If the sea is rising faster than the mangrove can trap sediments, then it is likely that the mangrove forest will expand landward and to higher elevation areas (Lovelock et al., 2015). Although mangroves can trap sediment and themselves increase land height, the accelerated rate of climate change and sea level rise are expected to outpace the increased land accrual by mangroves in the next ~50 years (Lovelock et al., 2015).

Multiple Stressors
Mangroves that are experiencing multiple simultaneous stressors are more susceptible to factors that by themselves would not typically cause major harm. For example, insect damage and disease are typically not drivers of major mangrove loss, but, when mangroves are already impacted by human development or climate change, insect damage and disease can cause more harm than originally thought (Rossi, 2018).

Conservation and Management

Despite their extreme importance for the environment, **biodiversity** and humans, mangroves are among the most threatened ecosystems globally. Every bit counts to help reduce threats and stresses to mangroves to give them a better chance at combating climate change and sea level rise.

- Keep mangroves forests clean - don't dump waste into mangroves
- Advocate for protection of mangrove forests to help prevent unnecessary development in mangrove forests
- Restore natural water flow to mangrove forests that have been cut off from regular tides (e.g., insert culverts under a roadway to restore connection of a fragmented mangrove).
- Restoration can be an effective tool to increase mangrove cover if done well. A successful restoration will ensure the proposed restoration site has suitable substrate and is slightly protected from major storm events to allow the seedlings to establish.

Figure 12. Culverts were installed to restore natural water flow to the mangroves previously impacted by the construction of a road accessing the coast near Broad Creek in Abaco. Credit: Lianna Burrows.

In response to the devastation of Hurricane Dorian in 2019, the Northern Bahamas Mangrove Restoration Project began. Scientists estimate a 40% loss of mangroves in Abaco's Marls ($88km^2$) and 74% loss of mangroves across Grand Bahama ($91km^2$) due to impacts from Hurricane Dorian. Many national and international entities are collaborating in this effort, including: The Nature Conservancy, Bonefish and Tarpon Trust, Perry Institute for Marine Science, Waterkeepers Bahamas, Bahamas National Trust, The Bahamas Forestry Unit, Blue Action Lab, The Bahamas Agriculture and Marine Science Institute (BAMSI), University of The Bahamas and Friends of the Environment in response to impacts caused by Hurricane Dorian in 2019 on the islands of Abaco and Grand Bahama. The goal of this partnership is to restore the ecosystem function of priority mangrove areas on hurricane impacted islands, while developing a framework for continued mangrove restoration, conservation, and education in The Bahamas.

Figure 13. Bonefish guides and other community members are an important part of the mangrove restoration project.. Credit: Justin Lewis, Bonefish and Tarpon Trust.

Mangroves are now formally protected in The Bahamas under the Forestry (Declaration of Protected Trees) Order, 2021. Specifically, mangroves are listed under Schedule 2 which recognizes trees of cultural, historical and economic importance. It is illegal to remove any protected tree without approval from the Forestry Unit. Application may be made online.

Mangrove forests are included in a number of National Parks across the country, including Grand Bahama (Lucayan National Park), Abaco (Black Sound Cay National Reserve), Andros (Andros Crab Replenishment Reserve), New Providence (Bonefish Pond National Park), Inagua (Union Creek Reserve), Exuma (Exuma Cays Land & Sea Park, Moriah Harbour Cay National Park), Conception Island (Conception Island National Park).

classroom activities

"Stringing it Together"

This activity is a component of the Mangrove Ecology Curriculum, which was created by Amy Heemsoth from the Khaled bin Sultan Living Oceans Foundation (KSLOF). It was originally designed for secondary school students participating in the KSLOF's mangrove education and restoration program, "Bahamas Awareness of Mangroves (B.A.M.)," which KSLOF has implemented in Abaco in collaboration with Friends of the Environment since 2015 (to learn more about the program, visit www.lof.org/BAM). However, it can be adapted for other educational contexts. The KSLOF and authors assume no responsibility for any injury or damage resulting from the implementation of this activity. These materials may be reproduced for educational purposes. When utilising this activity, please ensure to include the following attribution: "Khaled bin Sultan Living Oceans Foundation Mangrove Ecology Curriculum www.lof.org." Looking for additional educational materials? Visit us at www.lof.org/edportal for lesson plans, quizzes, and educational videos designed to teach marine ecology to middle and high school students.

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Summary: Students will become part of the mangrove food web to learn about how all of these species found within the ecosystem are connected.

Level: Any

Duration: 20-30 minutes

Setting: Indoors or outdoors

Objectives:

To teach students that few animals rely on a single source of food and that interlocking food chains become food webs.

To teach students that food webs are part of every ecosystem.
To have students represent different species within a mangrove ecosystem and work together to create a food web.
To leave students with an understanding of the interconnectedness of species and why it is important to conserve these vital organisms.

Materials

- Species identification sheets, printed* (28 total)
- String or ball of yarn
- Scissors
- Hole puncher

classroom activities

***To create your own species identification sheets if you don't have access to a printer:**

- String or ball of yarn
- Hole puncher
- Construction paper or letter sized (8.5 x 11") white paper
- Scissors
- Glue
- Printed pictures of the following (**optional** - you can also just write the names of the following on the paper): Barnacle, Barracuda (juvenile), Blue crab, Great blue heron, Grey snapper, Grouper (juvenile), Land crab, Loggerhead sea turtle, Macroalgae (seaweed), Mangrove tree crab, Microorganisms (bacteria, fungi, protists), Osprey/hawk, Oyster, Phytoplankton, Raccoon, Red Mangrove tree, Sea anemone, Seahorse, Sea star, Sea urchin, Shark, Shrimp, Spiny Lobster (juvenile), Sponge, Sun, Turtle seagrass, White mullet, Zooplankton.

Instructions to making your own species identification sheets:
Disregard if you have access to a printer and can print them yourself

- Use scissors to cut paper in half
- Hole punch two holes on the top of the cut paper
- Use the string / yarn to thread through two holes, making a knot at the end of each string. Ensure the yarn is long enough to hang as a necklace
- On the front side of the paper, write the item in bold letters (example, SUN, CRAB etc.) on the top of the paper.
- Underneath the word, use glue to paste the printed picture of the item

On the back side of the paper, write talking points related to the item found in the table below.

Organism	**Energy Comes from (what it eats)**	**Highest Possible Trophic Level**
Barnacle	Phytoplankton, zooplankton	Secondary consumer
Barracuda (juvenile)	White mullet	Tertiary consumer
Blue crab	Zooplankton, red mangrove (leaf litter)	Detritivore
Great blue heron	Blue crab, white mullet, grey snapper, grouper (juv.), shrimp, barracuda	Quaternary consumer
Grey snapper	Blue crab, shrimp, zooplankton, seahorse	Tertiary consumer
Grouper (juvenile)	White mullet, shrimp, blue crab, zooplankton, sea horse	Tertiary consumer
Land crab	Red mangrove (leaf litter)	Detritivore
Loggerhead sea turtle	Blue crabs, detritus (dead animals)	Tertiary consumer
Macroalgae (seaweed)	Sun	Primary producer
Mangrove tree crab	Red mangrove (leaves)	Primary Consumer

classroom activities

Organism	Energy Comes from (what it eats)	Highest Possible Trophic Level
Microorganisms (bacteria, fungi, protists)	Red mangrove (leaf litter)	Decomposer
Osprey/hawk	White mullet, barracuda, grey snapper, grouper (juv.)	Quaternary consumer
Oyster	Phytoplankton, zooplankton	Secondary consumer
Phytoplankton	Sun	Primary producer
Raccoon	Blue crab, land crab, mangrove tree crab	Tertiary consumer
Red mangrove tree	Sun	Primary producer
Sea anemone	Phytoplankton, zooplankton	Secondary consumer
Seahorse	Phytoplankton, zooplankton	Secondary consumer
Sea star	Oyster, barnacle, sponge	Tertiary consumer
Sea urchin	Macroalgae, turtle seagrass	Primary consumer
Shark	Snapper, white mullet, blue crab, grouper (juv.), raccoon, barracuda, great blue heron	Quaternary consumer
Shrimp	Other shrimp, detritus (leaf litter & dead animals)	Detritivore
Spiny lobster (juvenile)	Sponge, sea urchin, macroalgae, turtle seagrass, shrimp	Tertiary consumer
Sponge	Phytoplankton, bacteria	Secondary
Turtle seagrass	Sun	Primary producer
White mullet	Turtle seagrass, zooplankton, phytoplankton, macroalgae, red mangrove (leaf litter)	Detritivore
Zooplankton	Phytoplankton, red mangrove (leaf litter)	Primary consumer

Background
The mangrove food web is not as well studied as other food webs. Most scientists believe that it is detritus-based, but they are still trying to figure out the linkages of this ecosystem. There are many other organisms that exist in this ecosystem, these are just a few examples. The mangrove food web is much more complex than this.

Procedure for activity:
1. Explain to students that they are going to construct a food web. The students will need to work together as a group.
2. Hand out organism cards to students.
3. Ask the students to place the organism cards around their necks.
4. Have students stand in a circle about arm's length apart. NOTE: This activity is best conducted outside where there is more space.

classroom activities

5. Ask each student to introduce themselves as the organism that they represent.
6. Ask students, "Where should the food web begin?"

Students should realise that the food web begins with the energy from the sun. Ask the sun to stand in the centre of the food web. Students may have to adjust the circle that they are standing in.

7. Ask students to look around the circle and ask themselves, "Who will I eat and who might eat me?"
8. Hand the ball of yarn or string to the student that is the sun. Explain to students that in one hand they will hold the yarn and in the other they will throw the ball of yarn. Tell students that the yarn represents the energy that is being passed from organism to organism. The student will pass the ball of yarn to an organism that needs the energy. In other words, the animal that eats it.
9. Try a practice round with students so that they understand the rules.
10. Now have the students make a food chain, but do not tell them that is what they are doing. Ask the students to pass the ball of yarn until they get to a tertiary or quaternary consumer.
    a. When students get to the last organism in the chain ask students, "Why can you not throw the ball to someone else?" *Students should respond that the tertiary or quaternary consumer is the highest trophic level in the food chain (apex predator) and organisms in this trophic level do not have any natural predators.*
    b. Then ask students, "Does anyone know what this represents?" *Students should respond that it is a food chain. Fully explain the food chain to the students including the different trophic levels (primary producer, primary consumer, secondary consumer, etc.)*. Ask, *"Which direction would the arrows point?"*
11. Tell the students that they are going to start over again. Give the ball of yarn to the sun. Tell students that they need to throw the ball of yarn to different students this time. Allow students to create another food chain. Once they do, you can either cut the yarn or throw the ball of yarn back to the sun. If you want to reuse the string, do not cut it. Ask the students to create a third food chain. Suggest to students that they need to throw the ball of yarn to students who do not have any string. NOTE: some students will probably have to be a part of multiple food chains. Try to get all students to hold at least one string. Once completed, ask students:
    a. "Does anyone know what this represents?" *The student's response should be that it is a food web.*
    b. "Who is holding the greatest number of strings? Why?" *The students should respond that the sun is holding the greatest amount of string because all mangrove food chains begin with the sun.*
    c. "Why are there some students holding more than one string?" *Students should answer that in a food web, organisms can eat more than one organism and they can be prey to many others.*
    d. "Raise your hand if you are a producer." *These students should raise their hand: macroalgae, phytoplankton, red mangrove tree, turtle grass*.
    e. "Raise your hand if you are an herbivore." T*hese students should raise their hand: land crab, sea urchin, mangrove tree crab, microorganisms, and zooplankton*.

classroom activities

f. "Raise your hand if they are a carnivore." T*hese students should raise their hand: barracuda, shark, great blue heron, grey snapper, raccoon, osprey/hawk, and grouper (juv.).*

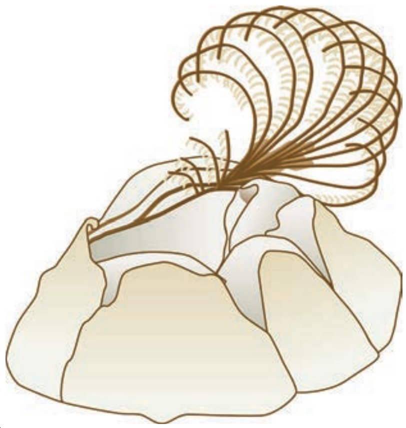
g. "Raise your hand if you are an omnivore." *These students should raise their hand: barnacle, blue crab, white mullet, oyster, sea anemone, spiny lobster, loggerhead sea turtle, sea star, sea horse, shrimp, and sponge.*

h. Pick one student. Ask that student to pull on the string. Then ask students to raise their hand if they are directly connected to that organism (i.e., eaten or eats). Ask the students:
   - "What happens if I remove _______ (the organism that you chose)? Who is affected?" Have the students who are directly affected tug on their string(s).
   - "Who is affected by this?" Continue to do this until all of the students' hands are raised.
   - "When one organism is removed from the food web, who is affected?" The students should answer that all organisms in the food web are affected.

12. Continue to create food webs until students fully understand the concept of food webs.
13. When finished, collect organism cards and yarn or string.

classroom activities

BARNACLE



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BARRACUDA

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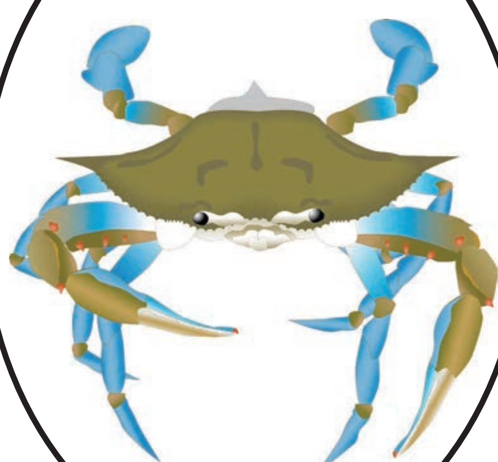
BLUE CRAB



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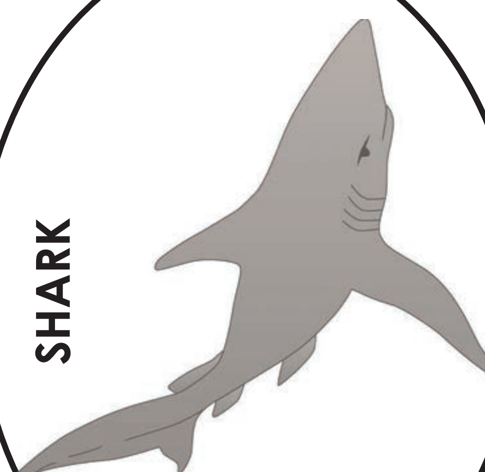
SHARK



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classroom activities

GREAT BLUE HERON

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LAND CRAB

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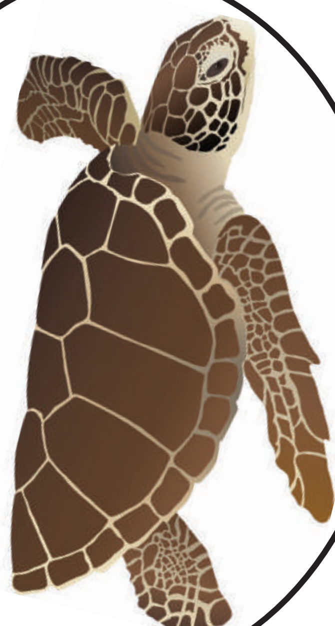
LOGGERHEAD SEA TURTLE



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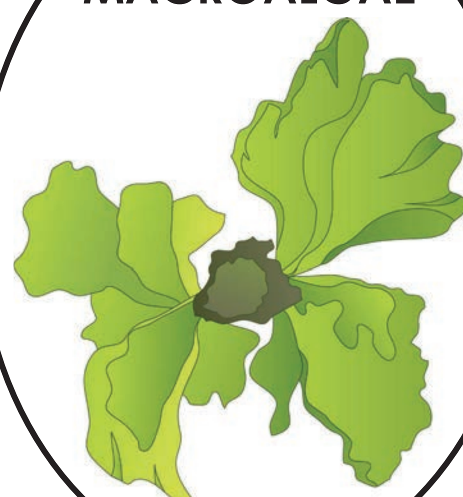
MACROALGAE



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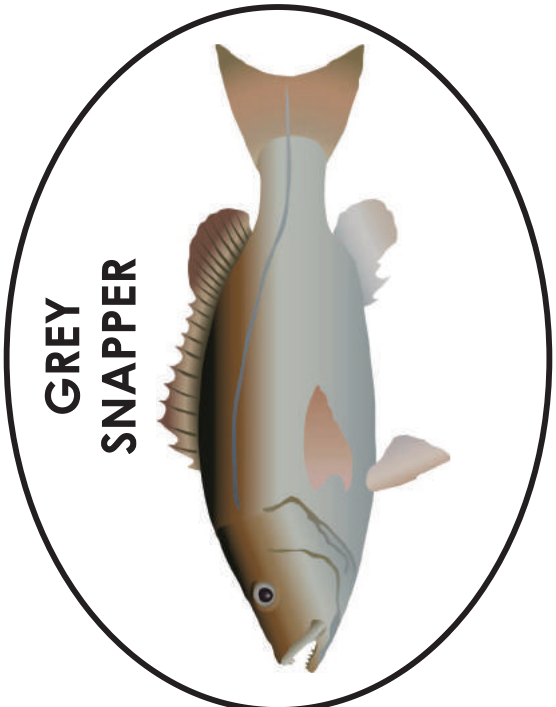

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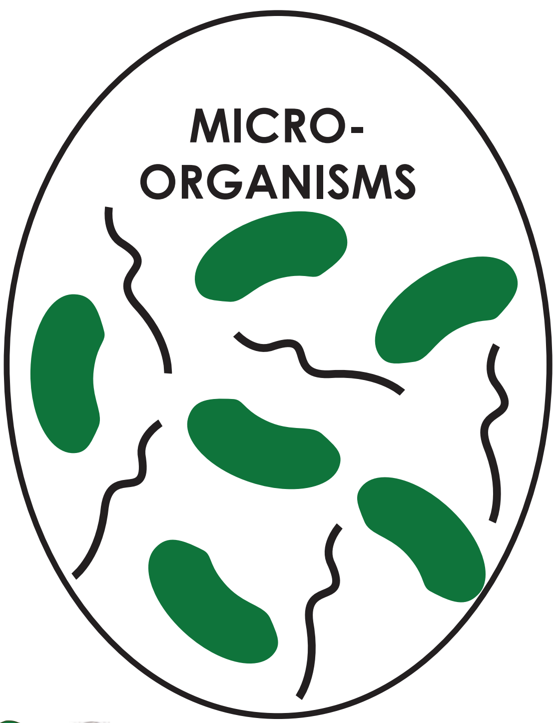

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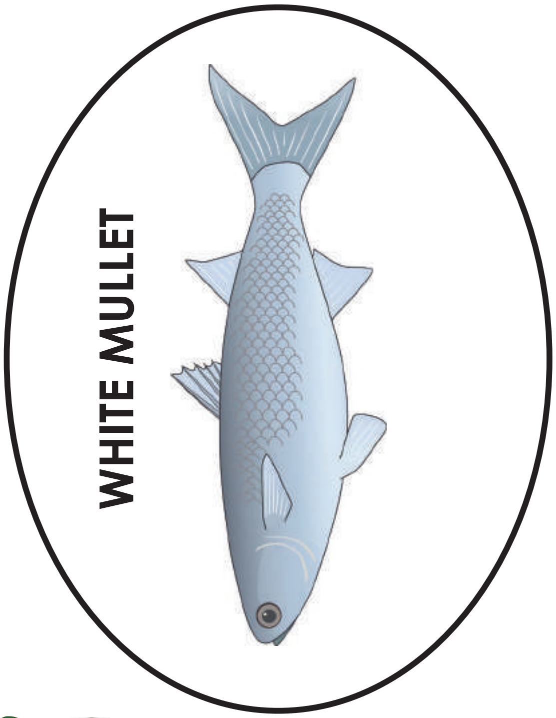
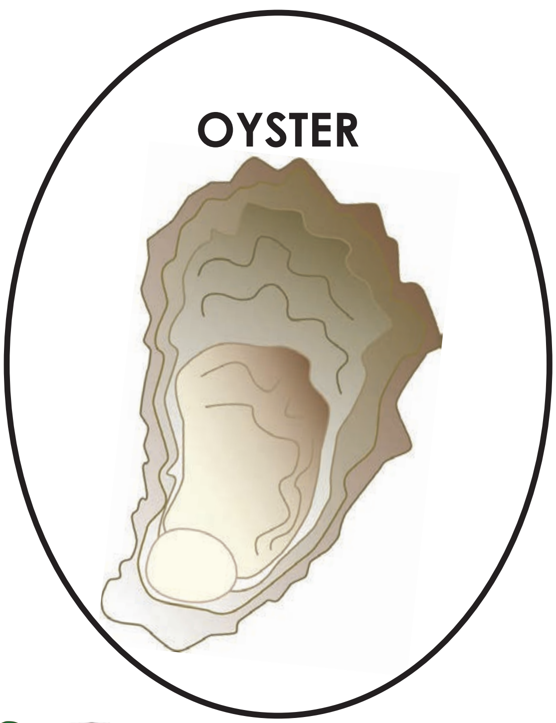
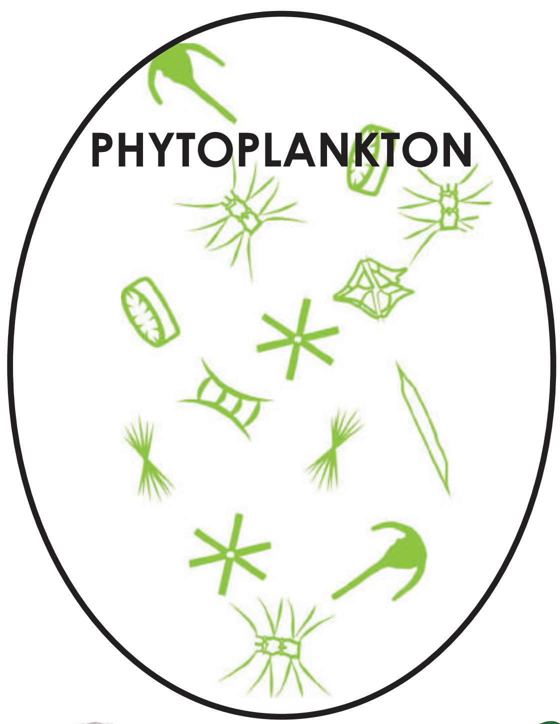


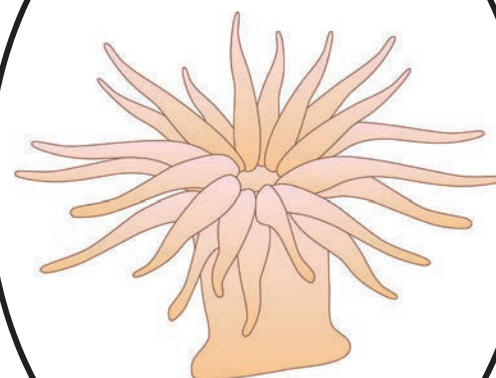




classroom activities

RED MANGROVES

SEA ANEMONE



SEA HORSE

SEA STAR

classroom activities

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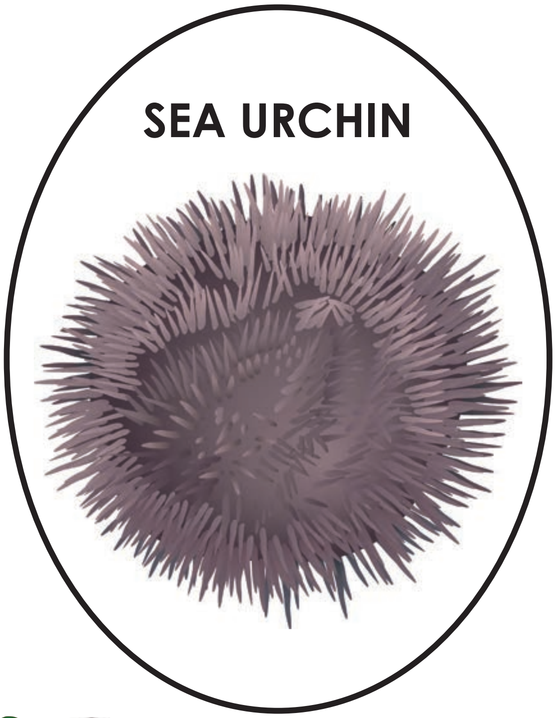

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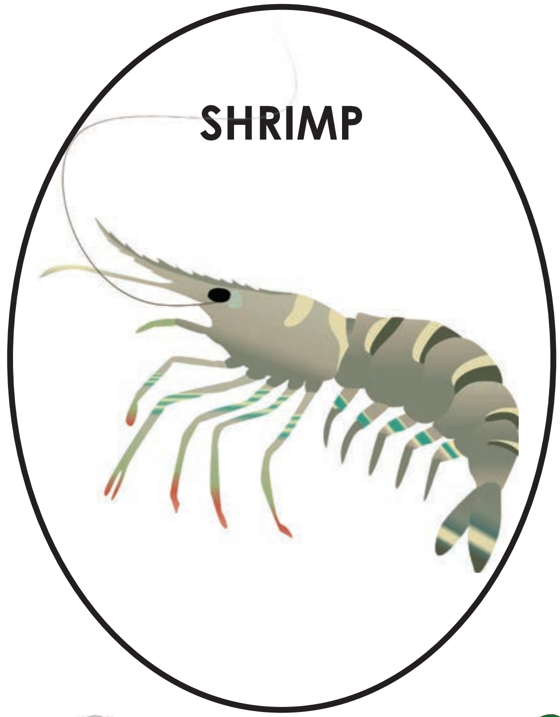

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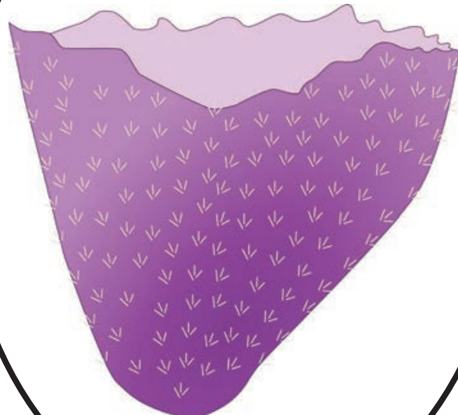
SPONGE



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SUN

Mangrove Ecology Curriculum - Stringing it Together Appendix A

TURTLE SEAGRASS

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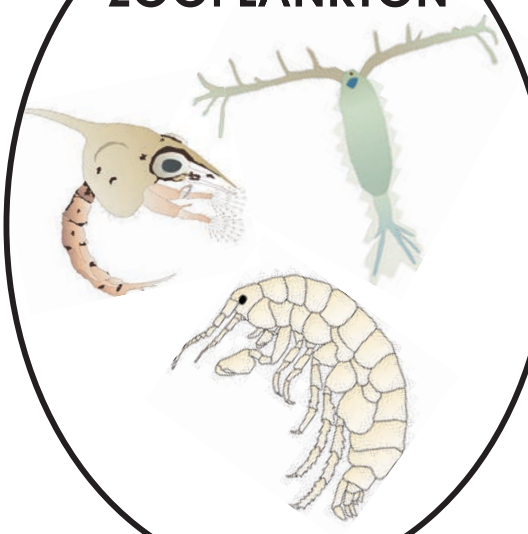
ZOOPLANKTON



field trip activities

Pre-field trip

You may have to create your own quadrat before this field trip. Please see the Rocky Shores chapter to see an easy way to create your own for your class, which can be used as an in-class activity in itself.

Field Trip Activity (good for coursework)

Level: Grades 10-12

Duration: 60 - 90 minutes

Objectives: Students will learn to identify and collect diseased mangrove leaves in the field to bring back to the lab/classroom for testing

Materials:

- Notebook (or worksheet)
- Pencil
- Ziplock bags
- Sharpie
- GPS device (or phone)
- Camera
- Quadrat (4 or 5)
- Marking tape (optional). 4 or 5 different colours

Field sampling protocol:

1. Record the mangrove location name, and the date and time that you started your survey.
2. Each group should be assigned a letter, A-E. These will be used for labelling diseased leaves that are collected.
3. Choose an area to place your quadrat. A quadrat, not a 'quadrant', is a frame used for sampling an area and it is usually square. Smaller quadrats present a smaller number of species to be identified. However, groups taking 10 samples each with 0.5 m x 0.5 m quadrats will collect information about a more significant sample of the area. You should place a quadrat into a randomly selected area in the mangroves or drop it over their shoulder, rather than throw it.
4. Look for diseased leaves in your quadrat. These leaves will have lesions on them. If you do not have any diseased leaves in your quadrat, search for leaves in the surrounding area. Do not sample diseased leaves in the other groups' quadrats.
5. Each person in your group needs to collect 1 diseased leaf. Place the leaf in a Ziploc bag and with a permanent marker, label the bag with the date, your group's letter (A, B, C, D, or E), and sample leaf number. For example, the first leaf that you collect will be Sample Leaf #1, the second Sample Leaf #2, etc.

Figure 15. Diseased Red mangrove leaf. Credit: The Abaco Scientist.

field trip activities

6. Use your GPS device (or teacher's phone) to find the latitude and longitude of the tree that the diseased leaf was on. Record this information.
7. This step is optional. If you are unsure about completing this step, ask your teacher. Tie marking tape around the tree branch that you took the leaf from. Next time you return, it will be easy to see where you sampled the leaf from. If you do this step, ensure that each group has a different colour of marking tape.
8. Write down any observations that you can about the site where you collected your leaf. For example, is it located close to a road? Near a development? Is it flooded or dry?
9. In your quadrat, conduct a visual survey for disease. This means record the number of diseased leaves that you see (0, 1, 2-10, 11-30, 31-50, or >50).
10. Look inside your quadrat one more time. List approximately how many dead trees that you see. If there are none, write zero.

Before leaving the site, make sure that the leaves you collected are stored in the Ziploc bag and that the bag is tightly sealed. We do not want to risk spreading the disease.

Lab Activity (compliments the field trip activity)

Mangrove Detectives, a citizen-science program for students, was created by Amy Heemsoth from the Khaled bin Sultan Living Oceans Foundation (KSLOF) and Dr. Ryann Rossi, formerly of North Carolina State University (NCSU), and was developed with support from the National Geographic Society. This particular lab activity is a component of the program and was designed primarily for use by secondary school students but can be adapted for use in other educational contexts. It is also used as part of KSLOF's mangrove education and restoration program, "Bahamas Awareness of Mangroves (B.A.M.)," which KSLOF has implemented in partnership with Friends of the Environment in Abaco since 2015 (*www.lof.org/BAM*).

Please note that neither the KSLOF, NCSU, nor the authors assume any liability for injuries or damages resulting from the implementation of this lab activity. However, these educational materials are authorised for reproduction for educational purposes. When utilising this lab activity, please ensure to provide the following attribution: "Khaled bin Sultan Living Oceans Foundation Mangrove Detectives, available at *www.lof.org/mangrovedetectives*."

Supplementary resources related to this lesson plan can be found at: *www.lof.org/mangrovedetectives*. You can also find additional marine ecology resources for middle and high school students and teachers, including lesson plans, quizzes, and educational videos, at *www.lof.org/edportal*.

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field trip activities

PREPARE POTATO DEXTROSE AGAR (PDA) MEDIA

Supplies:

- Scale
- Distilled water (250mL)
- ~9.25 g Potato Dextrose Agar (PDA) media* See below on how to make your own PDA if you do not have access to ready-made.
- Pot to boil the water
- Agar
- 3.5 mL Hydrochloric acid (HCl) also known as muriatic acid, (Optional)
- Petri plates (about 30)
- Graduated cylinder
- Lab goggles / protective eye covering
- Gloves
- Hand sanitiser
- Rubbing alcohol

Instructions:
1. To sterilise the area, wipe down the area of the table that you will use with rubbing alcohol.
2. Measure 250 mL of distilled water.

***Preparing your own PDA. Note: this makes 1L of PDA**
Supplies: 1 potato, 20 grams dextrose (if unavailable, you can use sugar), 15 grams agar, 1L distilled water, cheese cloth.
- Wash, peel and dice 200 grams of potato
- Add diced potatoes and dextrose to 1L distilled water
- Using a hot plate, boil for 20-25 minutes
- Let cool, then using a cheesecloth, collect the PDA extract
- Add agar to PDA extract

3. Mix the PDA with distilled water in a container that can be boiled. If necessary this can be done in a clean, non-stick pot.
4. Boil for approximately 15 minutes. Watch carefully if doing it on the stove. Do not cover with a lid in order to avoid spills.
5. Allow this mixture to cool for approximately 5-10 minutes.
6. Wearing gloves, add HCl to the PDA solution and swirl. If you do not have HCl, skip this step.
7. Gently pour the PDA into petri dishes. Pour enough to cover the bottom of the dish in a thin layer. Gloves should also be worn for this step.
8. After pouring, immediately cover each petri dish with the lid.
9. Swirl petri dishes to ensure even distribution of agar.

field trip activities

10. Let the liquid solidify on the tabletop for at least 30 minutes.
11. With the covers on, turn each petri dish upside down (once solidified), stack them, and place the bag into the petri dish bag OR into ziploc bags. Seal the bags with tape or the ziploc seal. Transfer bags to the refrigerator until further use. This prevents moisture from building up on the PDA which could be a source of contamination.

NOTE: These supplies will be enough to create 30 small plates.

PREPARE BLEACH SOLUTION
Supplies:
- Bleach
- Distilled water
- Graduated cylinder

Instructions:
If using 5% bleach:
1. Mix 1 part bleach to 9 parts water. To create a 5% solution, mix ~300 mL of bleach to 1,700 mL of water.

If using 8% bleach:
2. Mix 1 part bleach to 14 parts water. To create an 8% solution, mix 200 mL bleach to 2,800 mL of water.

ISOLATING DISEASE FROM LEAF:
Supplies:
- Potato Dextrose Agar (PDA) petri dishes (1 per student)
- Leaves (1 per student)
- Rubbing alcohol
- Hand sanitiser
- Sterile paper towels (covered in foil)
- Scissors or scalpel
- Bleach solution
- Bunsen burner
- Tweezers or forceps
- Saran wrap
- Tape

Instructions:
1. Using a piece of tape, label petri dishes with sample data including your group's letter (A, B, C, D, or E), and sample leaf number.
2. To sterilise the area, wipe down the area of the table that you will use with rubbing alcohol.
3. Sanitise hands with hand sanitiser or put on gloves.

field trip activities

4. Using scissors or a scalpel, cut the leaf into two small pieces at the margin of the lesion and green leaf. The leaf piece should contain a small portion of the lesion and adjacent green tissue. Leaf pieces should be no bigger than the size of a pinky nail.
5. Make sure to also label each piece as 1 and 2 on your petri dish. You will need to write on the underside of your petri dish because the lid could move from its original place.
6. Sterilise leaf pieces by placing them into a bleach solution for 1 minute. This prevents contamination from microbes living on the surface of the leaf – the microbe causing the lesion has penetrated the leaf so it will still grow when plated on the agar.
7. If you are not wearing gloves, sterilise your hands with hand sanitiser.
8. While leaf pieces are sterilising, sterilise tweezers with alcohol and flame for 5 seconds.
9. Use tweezers to transfer the sterile leaf pieces to a sterile water solution to rinse (approximately 5 seconds).
10. Remove one paper towel from the foil.
11. Use tweezers to transfer leaf pieces from sterile water to a paper towel and dab dry.
12. When dry, use sterile tweezers to place leaf on the PDA agar in the petri dish. Make sure the piece is inserted into the agar so that it is slightly buried, not just laying on top.
13. Close the petri dish lid and wrap it with saran wrap to help prevent contamination.
14. Store in a plastic container at room temperature and monitor samples for fungal growth after 3 days and one and two weeks.

Tidal Flats

The Bahamian archipelago is primarily made up of two carbonate banks, the Great Bahama Bank and the Little Bahama Bank, which were formed by a chain of carbonate platforms. These banks are part of the continental shelf, and while they are generally deep enough, there are some features such as shoals, sand bars, and tidal flats that can be a hindrance to navigation. Tidal flats are some of the shallowest areas within the Bahamian marine environment. Because of their proximity to the carbonate banks, tidal flats are commonly referred to as sand flats or sand banks. The banks in The Bahamas provide favourable conditions for marine life making them important fishing grounds. Tidal flats are found along the margins of these banks, particularly on the lee sides (the sides protected by the elevation of the island from the prevailing wind) of Bahamian islands (Carew & Mylroie, 2010).

Chapter Objectives

- Describe the characteristics of a tidal flat
- Be able to name typical flora and fauna found in tidal flats
- Understand the importance of Bahamian tidal flats and their connectivity with other ecosystems
- Discuss threats to tidal flats and learn conservation measures being taken in country

Tidal flats form from the ebb and flow of tides which deposit sediments near shore. The type of flat is partially determined by the amount of wave energy: low energy areas tend to deposit fine sediments like mud while high energy areas are more prone to deposit larger grained sediments like sand (Miththapala, 2013). Tidal flats are so shallow that areas which are flooded at high tide may become partially or fully exposed at low tide.

Tidal flats and mangrove forests are often intertwined because they both occupy the intertidal zone, thus, an overlap in ecosystem flora and fauna will be seen.

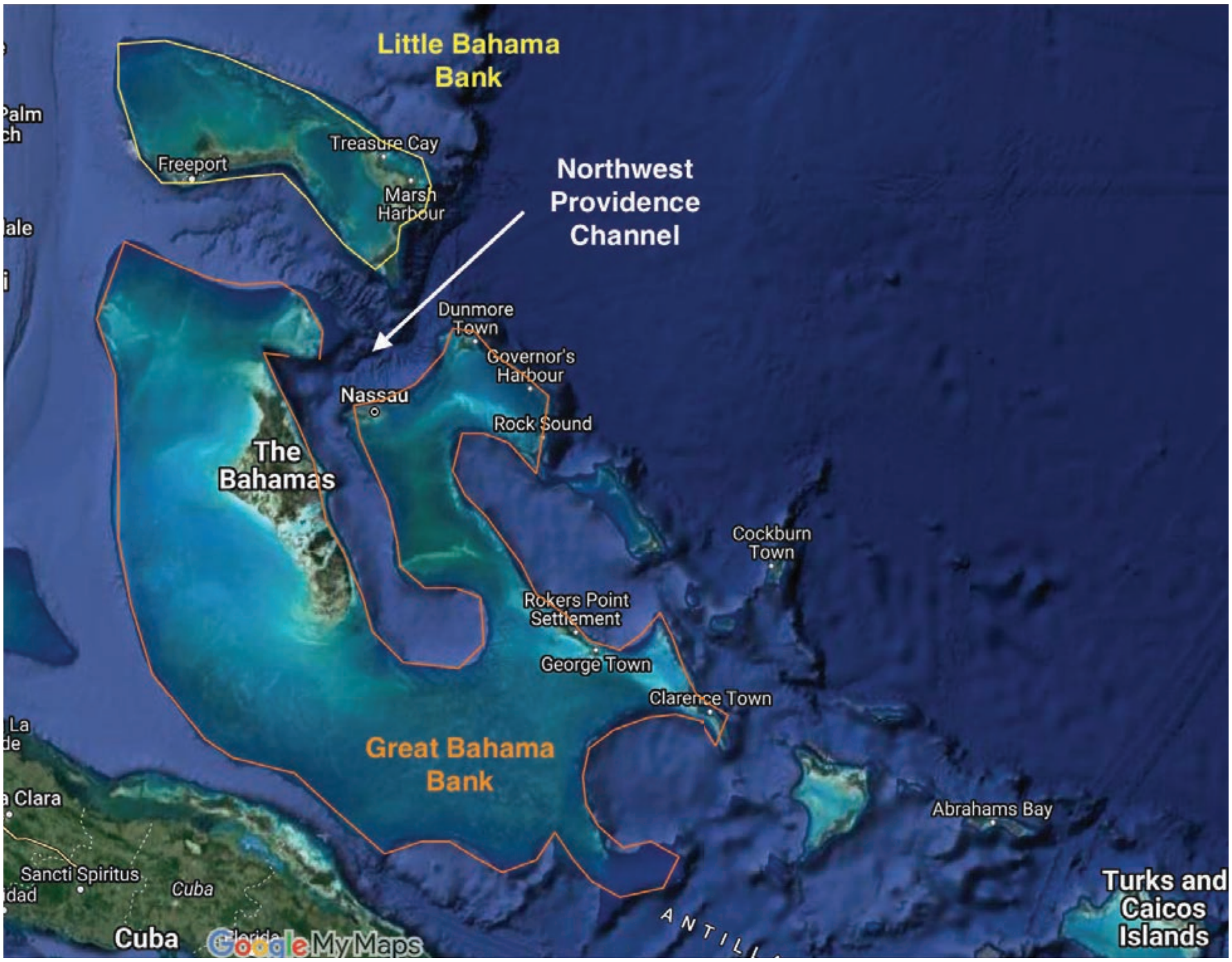


Figure 1. The Great Bahama Bank and Little Bahama Bank are separated by the Northwest Providence Channel. Credit: Google Maps with annotations by Friends of the Environment.

Figure 2. Cherokee Sound in Abaco has extensive tidal flats. Credit: Adrian Whylly/Shutterstock.com.

Ecosystem Flora and Fauna

Organisms that occupy tidal flats have to be adapted to the harsh conditions they may encounter there. In particular, they face extremes of wet and dry, or hot and cold, during the cycling of the tides. Organisms must be adapted to either survive through those changing conditions or leave the area temporarily while conditions are unsuitable. Factors that fluctuate in this ecosystem and that have major effects on the organisms include: 1) salinity, 2) evaporation and 3) dissolved oxygen in the sediment.

Table 1. Common organisms that utilise tidal flats.

Flora - Autotrophs					
Red Mangrove		Black Mangrove		Algal Mat	
Fauna - Annelida					
Polychaetes or Bristle Worms					
Fauna - Molluscs					
Horn Snails	Cerion	Punctate codakia		Queen Conch	
Fauna - Arthropoda					
Juvenile Spiny Lobster	Shrimps	Fiddler Crabs	Land Crabs	Barnacles	
Fauna - Fish					
Larval Fishes	Juvenile Reef Fishes	Juvenile Nassau Grouper	Bonefish	Nurse Shark	Lemon Shark
Fauna - Birds					
Frigate Bird	Osprey	Wading Birds	Flamingos	Piping plovers	Heron

Figure 3. A flamboyance of flamingos in flight on Long Island. Credit: Lianna Burrows.

spotlight species

Ragworms

Scientific Name: *Eumaeus atala*
Conservation Status: Unknown
Distribution: Across intertidal zones of the North Atlantic as well as north-west Europe

Figure 4. The bristle worm is one of the most interesting species to spot on a tidal flat. Credit: Elizabeth Stoner.

Ragworms, also referred to as bristle worms, can be found burrowing into the sediment of the tidal flats. Bristle worms move through the sand by using the parapodia (each of a number of paired muscular bristle-bearing appendages) on the side of their body, which also act as gills allowing the worm to breathe underwater. Using their net-like mouth and jaws, they eat tiny invertebrates, mud, detritus, phytoplankton and zooplankton. Bristle worms are important because they are a food source for many shore birds and fish. They eat upside-down jellies, as seen in the image.

Fun Fact: Bristle worms are typically reddish brown in colour but turn green during their spawning season.

spotlight species

Smalltooth Sawfish

Scientific Name: *Pristis pectinata*
Conservation Status: Listed as endangered for U.S. population as well as populations outside of the U.S. by the Endangered Species Act (ESA), critically endangered by IUCN Red List, in Appendix I of CITES, meaning species that are threatened with extinction, and in Annex II of Specially Protected Areas and Wildlife (SPAW), meaning species that are subject to the highest level of protection throughout the Caribbean region.
Distribution: South-west coast of Florida and throughout Caribbean regions, including The Bahamas.

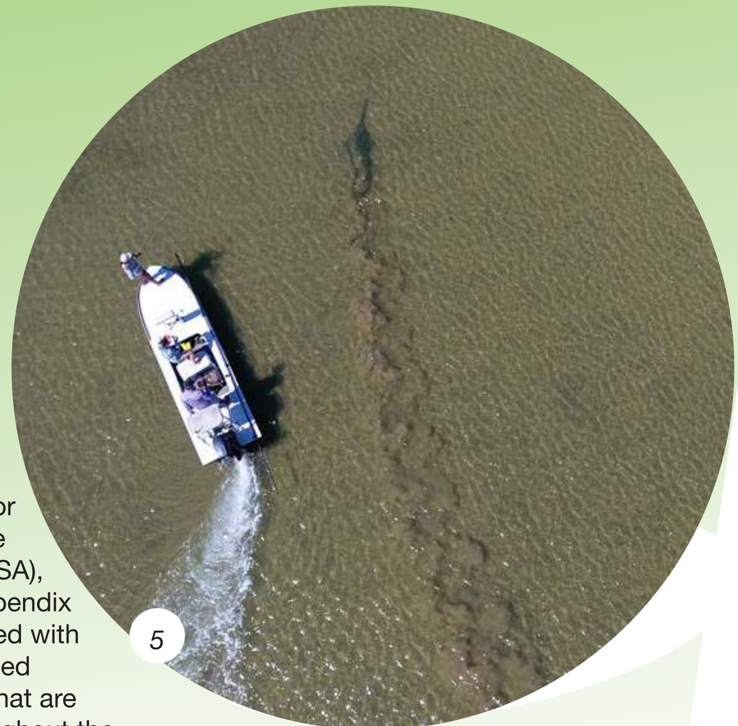


Figure 5. A rare sighting of a smalltooth sawfish in Abaco was captured by drone footage. Credit: Enie Hensel.

Smalltooth sawfish belong to a group known as elasmobranchs, meaning cartilaginous fish - or having cartilage as a skeleton instead of bone (NOAA, 2018). Elasmobranchs consist of rays, skates and sharks. Despite having a similar appearance to sharks, smalltooth sawfish are classified as rays since their gills and mouths are located ventrally (NOAA, 2018). Their snouts resemble a saw with teeth-like structures lining either side, which is how they got their name. These teeth-like structures are actually called denticles, which are a specialised type of scale (Gillett, n.d.). They use their snouts for both defence and feeding. Another name for their snouts is rostra (rostrum). Their diet consists mostly of fish, shrimp and crabs, and their rostra makes it easy for them to stun and impale their prey by thrashing it from side to side.

Smalltooth sawfish inhabit waters warmer than 64°F. Juvenile sawfish tend to have a preference for shallow and slightly warmer waters, around 70°F (NOAA, 2018). This is why they can be found in the tidal flats of The Bahamas. Sawfish will move out into deeper waters as they grow. Smalltooth sawfish populations are threatened by habitat loss and fisheries. Their impressive rostrum is easily entangled in nets and sawfish populations struggle to recover from excessive catches (whether intentional or not) as they have few young and only become mature around ten years of age (Save our Seas Foundation, 2017). They are the most threatened elasmobranch species worldwide as a result of their high exposure to coastal shallow-water fisheries and their large body size (Dulvy et al., 2014). As of 2023 this species was listed as critically endangered by the IUCN Red List.

Ecological Role

Tidal flats support coastal biodiversity

Tidal flats are highly productive, supporting very large numbers of microorganisms, bacteria, and **cyanobacteria** (in the form of algal mats), which are a major source of food for many invertebrates and fish, who in turn are prey for larger fish and birds (Miththapala, 2013). These areas are also important for coastal fisheries.

An **algal mat** is one of many types of microbial mat formed on the tidal flat beds. It is made out of blue-green cyanobacteria and sediments. In Bahamian tidal flats, the primary algal mat organism is *Scytonema* sp., which is a form of photosynthetic cyanobacteria which grows in filaments that form dark mats.

Algal mats have two important ecological roles within tidal flats. All algae contain chlorophyll; they play a vital role by forming the energy base of the food web for all the marine organisms. Since algae are **autotrophic** organisms, they convert water and carbon dioxide through the process of photosynthesis into glucose and oxygen. The oxygen generated contributes to the survival of fish and other marine organisms.

Tidal flats enrich nutrients in coastal waters

Due to their proximity to shore, tidal flats receive nutrients both from freshwater runoff and from tides; this encourages high levels of photosynthesis in the algae found there (Miththapala, 2013). The cyanobacteria in tidal flats perform a useful job by fixing atmospheric nitrogen and making it available for other organisms (Stal, Severin, & Bolhuis, 2010). Much of this material disperses into the nearby waters, and the regular movement of tides transports these nutrients into the adjacent coastal waters (Miththapala, 2013).

Tidal flats act as crucial breeding areas and nurseries for various fish species

Tidal flats offer safe havens, serving as spawning grounds and nurturing spaces for numerous commercially valuable fish and crustaceans, just like mangroves and seagrass beds. One of the key roles played by tidal flats is that they provide feeding areas for migrating birds, which frequently utilise these flats as rest stops during their journeys, such as piping plovers (Miththapala, 2013).

Figure 6. A banded piping plover eats a worm on Colonial Beach, Paradise Island, just weeks after hatching in Fire Island, New York. Credit: Ancilleno Davis, Science and Perspective.

Tidal flats are carbon sinks

Carbon sinks, like tidal flats, absorb (**sequester**) more carbon dioxide than they release into the atmosphere. Within tidal flats, various microorganisms, including cyanobacteria, exhibit high rates of primary production, leading to swift carbon sequestration. Research conducted in these areas has demonstrated rapid carbon storage, with a substantial amount being below the surface. The sulphates generated by cyanobacteria in tidal flats inhibit methane production, a greenhouse gas significantly more potent than carbon dioxide, commonly generated in wetlands through decaying matter (Miththapala, 2013).

Tidal flats provide protection from floods and storms

Tidal flats along with mangroves act as reservoirs for water retention, naturally functioning as a flood control system by absorbing and storing excess floodwater. (Miththapala, 2013). Tidal flats also act as buffers for strong wave action typically associated with storms.

Tidal flats prevent erosion

Tidal flats prevent erosion by increasing sedimentation. The cyanobacteria on the surface of the mudflat excrete substances that cling to mud particles, effectively preventing erosion (Miththapala, 2013).

Economic Value

Bahamian tidal flat ecosystems are critical habitat for bonefish (*Albula vulpes*), which also happen to be the basis of an important sport fishery. Bonefish rely on tidal flats for food; when the flats are flooded they forage for fish and small crustaceans like crabs and shrimp (Crabtree et al., 1998). Bonefish are considered "near threatened" by the IUCN Red List for endangered species. Although they are not protected, fishing for bonefish is regulated: it is illegal to catch bonefish by net, and sport fishing for bonefish is catch and release only. Some bonefish foraging and spawning habitat has been included in The Bahamas marine protected areas network. Bonefish have been recognized for their importance to The Bahamas through their appearance on the ten cent coin.

Figure 7. A bonefish swimming in the tidal flat ecosystem. Credit: Brian Grossenbacher.

Low fishing traffic and high quality habitat make The Bahamas a sought after fly fishing destination. According to the 2008 Bahamas Ministry of Tourism Visitor Expenditure Survey (The Bahamas Ministry of Tourism, 2009), "flats and offshore fishing were undertaken by 11% of all stopover visitors and accounted for 20% of the expenditures on all recreational activities". Flats fishing generates $141 million in total economic benefits to The Bahamian economy annually with nearly $70 million of that directly injected in island economies and supporting the equivalent of 2,500 full-time jobs from those direct expenditures (Fedler, 2010).

Figure 8. Guides and anglers handle bonefish carefully to help ensure their survival in the catch and release fishery. Credit: Bonefish and Tarpon Trust.

Did you know?

West Side National Park in Andros encompasses 1.5 MILLION acres of land consisting of tidal flats, tidal creeks, mangrove forests, pine lands etc. This expansive area supports an array of culturally, economically, and ecologically important species such as the endangered Andros rock iguana, West Indian Flamingo, queen conch, and spiny lobster (Bahamas National Trust, n.d.). This park is internationally recognized as a prime flats fishing area and also encompasses traditional fishing grounds for a number of marine resources (Bahamas National Trust, n.d.) Healthy populations of nurse sharks (*Ginglymostoma cirratum*), bull sharks (*Carcharhinus leucas*) and the critically endangered smalltooth sawfish are also found within Park boundaries (IUCN, 2014).

Figure 9. Established in 2002, West Side National Park in Andros is one of the largest protected areas in the Western Atlantic, encompassing the majority of the west side of Andros. Credit: The Bahamas National Trust (www.bnt.bs)

Threats

Habitat Destruction and Fragmentation

Habitat destruction and **fragmentation** is the greatest threat to tidal flat ecosystems. In The Bahamas, like many other small island developing states (SIDS), our coastlines have the greatest demand for development. With increasing populations and growing interest from local and foreign investors, our coastal ecosystems are being degraded or lost from the impacts of reclamations, dredging, filling and other processes employed in coastal development. Tidal flat ecosystems have been altered for the building of hotels, communities, roads, etc. In addition, fragmentation of tidal flat ecosystems may affect tidal flow, sedimentation and water flow. Common causes of fragmentation include dredging and cutting of channels for boat traffic. All these changes can have a devastating impact on these, and neighbouring, ecosystems.

Pollution

Tidal flats, like all other coastal ecosystems, are affected by pollution. Substances introduced to these ecosystems can negatively impact flora and **fauna**. The run-off from farms or sewage disposal can cause the overgrowth of algal mats leading to **eutrophication** in those ecosystems. The introduction of trash (plastics, metals and glass) from illegal dump sites can harm fauna living within these ecosystems.

Overexploitation
There are currently no rules on when or how often a tidal flat may be accessed. Excessive traffic could cause damage or disturbance to these habitats. Due to their proximity to shore, some tidal flats may be easily reached and therefore their resources easily exploited by humans.

Lack of Knowledge
A major indirect threat to tidal flat ecosystems is the lack of knowledge both publicly and scientifically (Miththapala, 2013). The public conception of tidal flats is often skewed similar to mangroves, with the belief that they are swamps or "wasteland". However, these ecosystems are filled with organisms which play a major role in supporting a healthy marine environment.

Conservation and Management
Establishment of National Parks
In efforts to conserve important Bahamian ecosystems, The Bahamas Government and Bahamas National Trust, with the assistance of other environmental non profit organisations and stakeholders, have established protected areas throughout The Bahamas encompassing large acreages of coastal wetlands and inland ecosystems. National Parks encompassing examples of tidal flats include West Side National Park (Andros), Union Creek Reserve (Inagua), Bonefish Pond National Park (New Providence), and Moriah Harbour Cay National Park and Exuma Cays Land and Sea Park (Exuma).

Education
Many organisations make it their mission to increase general awareness of the importance of all coastal ecosystems. Only through increased public understanding can there be more informed and effective management of these coastal areas.

Flats Fishing Regulations
There are regulations in place to manage both fishers and guides and how they operate in The Bahamas. The guiding industry is reserved for Bahamians with Bahamian registered vessels. Anyone over the age of 12 is required to obtain a licence to fish on the flats. Fines and penalties exist for anyone in contravention of the law. For more details on all the flats fishing regulations, review the Fisheries Resource (Jurisdiction and Conservation) (Flats Fishing) Regulations, 2017.

classroom activities

Lesson Objectives

Students will be able to:

- Identify characteristics of a tidal flat
- Identify organisms that inhabit this ecosystem
- Recognise challenges that organisms encounter in the tidal flat ecosystem and the different adaptations made to live there
- Interpret the interconnectivity of the tidal flats with other coastal ecosystems
- Determine the ecological and economical importance of the tidal flat ecosystems
- Identify the threats that these tidal flat ecosystems face

Classroom Discussions

1. Discuss what students know about tidal flats.

Ask students about the characteristics (what they look like) of a tidal flat. Ask them which organisms inhabit tidal flats. In addition, ask them to classify the organisms following the typical classification of living things (Kingdom, Phylum, Class, Order, Family, Genus, Species). As they suggest organisms which inhabit the tidal flat list them on the board for further discussion to verify if the information is correct. Explain that the next part of the lesson will help students to identify organisms that live in tidal flats, challenges they face, conditions of the tidal flat, importance of tidal flats and what threatens them. Explain to students that tidal flats are ecosystems which have many characteristics related to the coming and going of the tides. Teachers and students can briefly discuss tides at this time, and how the organisms may be affected.

2. Learn about the highlighted species.

Ask students if they know what the term '**species**' means. Provide students with the definition for species and discuss important factors of this classification group ex.fertile offspring. Introduce students to the various highlighted species mentioned.

3. Learn about the importance of tidal flats.

Ask students if they think tidal flats are important. Ask students who said "yes, they are important" why? Write the list of reasons for importance on the board. Share with the class the reasons why tidal flats are important ecologically. Ask students how the tidal flats ecological importance impacts us? Tell them why. Ask students how many of them have a relative who is a fisherman? Or someone who works in the hospitality industry -resorts, hotels, bonefish lodges, restaurants, tour guides, boat captains etc. Ask students if they believe that tidal flats have some economic value? Explain the economic importance of tidal flats.

4. Discuss the threats to tidal flat ecosystems.

Ask students what poses a threat to tidal flat ecosystems. Ask students what they believe would happen if tidal flat ecosystems continue to be destroyed? Discuss all major threats to tidal flat ecosystems. Ask students what can be done to protect/preserve tidal flat ecosystems. Discuss ongoing conservation methods. Present the various national parks that include tidal flats and laws and regulations to preserve tidal flats. Ask students whether they have ever visited a national park.

classroom activities

5. Discuss Tides

What happens at high tide? (Ans: Tidal flat is under water.)
What happens to the temperature when it becomes high tide on a hot day? (Ans: It decreases.) On a cold day? (Ans: It is a little warmer.)
Would a tidal flat be saltier at high tide or at low tide? (Ans: low tide as the salt is more concentrated)
What are three things that plants and animals have to deal with as the tides change? (Ans: Changes in water level, changes in temperature, and changes in salinity.)

6. Discuss common species found in the rocky shore habitat and how they are adapted to that environment

Classroom Activity

Objectives:

Students will compare the difference of tidal flats during low and high tide.
Students will gain experience in presenting their comparison work to the class.

Level: Grades 7-12

Duration: 30-60 minutes

Setting: Classroom

Materials

- Construction paper or butcher paper
- Cardboard (either a tri-fold poster or a broken down cardboard box)
- Paint
- Crayons
- Markers
- Corrugated cardboard

Procedure

1. Break students into two groups. One group will create a tidal flat mural at low tide, and the other will create one at high tide.
2. Assign different members of the group different roles to ensure everyone has a task. Some can create the artwork, cut out pieces of cardboard etc. Others can research a different tidal flat plant or animal. Ensure they determine how each plant or animal deals with the challenging conditions such as being fully submerged, high/low salinity levels, changes in temperature, lack of oxygen in the sediment etc.. Label this on the mural.
3. Once each group has completed their mural, have them present it to the class.

field trip activities

This lesson takes place in the field (with a trip to a tidal flat ecosystem) and will enable us to observe the interconnectivity of Bahamian coastal ecosystems while identifying organisms in their natural habitat.

Level: Grades 7-12

Duration: Half day of school (about 3 hours)

Setting: Outdoors

Objectives

• Students will be able to locate the various species of animals discussed in this chapter in their natural environments and to describe structures specific to their survival.
• Students will answer questions that require investigation and work on the field trip data sheet.
• Students will have fun and increase their enthusiasm for science!

Materials

- Clipboards (one per student if possible)
- Field trip data sheet (one per student)
- 4 Plastic containers/buckets to view specimens
- Camera
- School bus (or enough volunteer drivers with vehicles)

Procedure

Activity 1. Class Field Trip

1. Ensure each student has a partner.
2. Once at the field trip location, give students a safety briefing and clear instructions on expectations for the day's activities.
3. Allow students a minimum of one hour for exploration; ensuring that their observations are being recorded - written details and scientific drawings.
4. Students should be given a thirty minute warning to allow time for wrapping up the recording of observations.
5. Data sheets should be collected from students; if they are to be graded.

Activity 2. Follow up classroom activity

1. Discuss what was observed in the field with students.
2. What kind of species were recorded on their data sheet?
3. Did all members of the same species look the same, or were there noticeable differences?
4. Did they find more or fewer species than they expected? Were there more species found than they thought would be? Were there more of a particular grouping of animals than others (for example were there more species of crabs than snails)? Why might this be the case?
5. Were students able to identify any other ecosystems within the tidal flat ecosystem (e.g. tidal pools along a rocky shore)?

field trip activities

Tidal Flat Data Sheet

Name:____ Time:________________

Partner: ______________________________________

Location:______________________________________

Date: ____ Tide:________________

Tide Data For Today's Date:
-low tide at : ____:_____ (_____ft)
-high tide at: ____:_____ (_____ft)

Describe Weather and Ocean Conditions:

Instructions:
Record all species observed while in the tidal flats. Using the A.C.F.O.R scale to indicate how many organisms of that same species were present in the tidal flat ecosystem.

The A.C.F.O.R. scale is as follows:
A – The species observed is "Abundant" within the given area.
C – The species observed is "Common" within the given area.
F – The species observed is "Frequent" within the given area.
O – The species observed is "Occasional" within the given area
R – The species observed is "Rare" within the given area.

Organism (Common Name)	Scientific Name	Description	A.C.F.O.R

Seagrass Beds

Seagrass beds are important marine ecosystems around the world. Seagrass beds are primarily comprised of seagrasses, however various species of algae may also be found there. Seagrass beds are commonly found on sandy bottoms, however seagrasses may also grow among coral rubble. Seagrasses are vascular, flowering, monocotyledon marine plants that live in shallow areas of the ocean floor. Because seagrasses are flowering plants (also called **angiosperms**) they produce seeds, flowers, and fruits. This makes them unique in the marine environment because they are the only type of flowering plant that can live underwater.

Chapter Objectives

- Be able to classify seagrasses and seaweeds
- Be able to identify animal species that utilise seagrass beds
- Understand the value of seagrass beds to Bahamians

Seagrasses are often easily confused with seaweeds, although they possess significant differences in their structure, appearance, and ecology. While seagrasses are flowering plants, seaweeds are algae, which in itself poses many differences.

Seagrasses are far more complex than seaweeds. Their root structure, and specialised horizontal stems, called rhizomes, are responsible for not only anchoring the plant down on the seafloor, but also conduct nutrient intake from the sediment, similar to other **angiosperms** on land. The internal vascular system of seagrasses allows for transport of these nutrients as well as water throughout the plant.

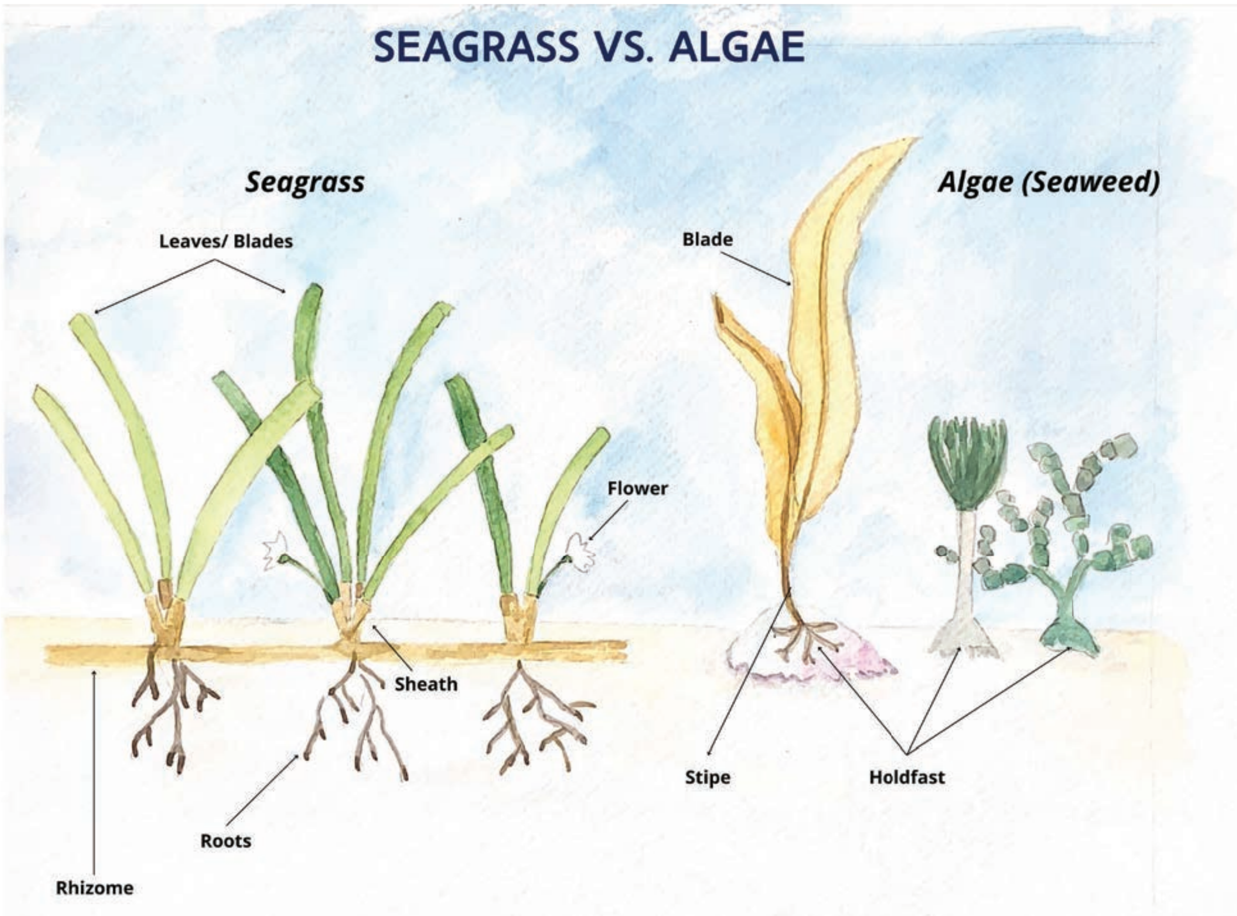


Figure 1. Seagrass and seaweeds (algae) have very different structures as shown in this comparison illustration. Credit: Olivia Patterson Maura for Friends of the Environment.

Table 1. Comparison of features between seagrasses and seaweeds.

Feature	Seagrass	Macroalgae (Seaweed)
Classification (Kingdom)	Plantae	Protista
Number of Species Worldwide	72	12,000
Habitat	Grow on all substrates.	Need something hard, like rocks or shells, to attach to.
Structure	Have specialised roots, leaves and underground stems (rhizomes).	Multicellular algae with no true roots, leaves or stems.
Reproduction	Produce flowers, fruit and seeds.	Produce spores.
Transport/Clarification	Have a vascular system that transports nutrients throughout the plant.	Use diffusion to extract nutrients from the water because they do not have a vascular system.

Source: Ocean Info, 2023 and Kvaroy Arctic, 2020.

A Closer Look
In addition to being part of an important ecosystem as a habitat for such a wide variety of animals, seagrasses can also be hosts to other organisms that grow on them, collectively called **epiphytes** or **epibionts**. Epiphytes consist mostly of micro- or macro-algae that grow on the surface of the blades, and epibionts include invertebrates like worms, barnacles, and sponges that live on the blades (Florida Fish and Wildlife, n.d.). Found on the outside of seagrass blades, epiphytes are an important food source for marine animals like the queen conch. The amount of epiphytes found on seagrass blades tell how healthy the ecosystem is. When nutrients are high in the surrounding water, epiphytes are more likely to grow on seagrass blades. Too many epiphytes can interfere with seagrass getting enough light and nutrients. A healthy seagrass ecosystem has a small amount of epiphytes (Florida Fish and Wildlife, n.d.).

Figure 2. A close up view of seagrass showing epiphytes. Epiphytes may include algae, hydroids, bryozoans, sponges, tunicates, bacteria and more! Credit: Olivia Patterson Maura.

Ecosystem Flora and Fauna

There are three main species of seagrass found in The Bahamas:
1. Turtle Grass (*Thalassia testudinum*)
Named after green sea turtles that graze on this species of seagrass, turtle grass is the most common amongst seagrasses in The Bahamas. Turtle grass usually grows in large meadows in shallow waters in depths up to 30 feet. Their broad blades make them easily identifiable from other species of seagrass.

2. Manatee Grass (*Syringodium filiforme*)
Manatee grass gets its name from the large marine mammals that enjoy grazing on this species of seagrass. This grass is normally found in small patches or within large

meadows of turtle grass. Their leaf blades' thin, cylindrical shape identifies them from other species. In The Bahamas however, Manatee grass is not very common and is usually found mixed in with other types of seagrass.

3. Shoal Grass (*Halodule wrightii*)
Shoal grass is able to tolerate harsh conditions in high salinity or air exposure and it can therefore be found in areas where other species of seagrass may not be able to survive. Their leaf blades are thin and narrow.

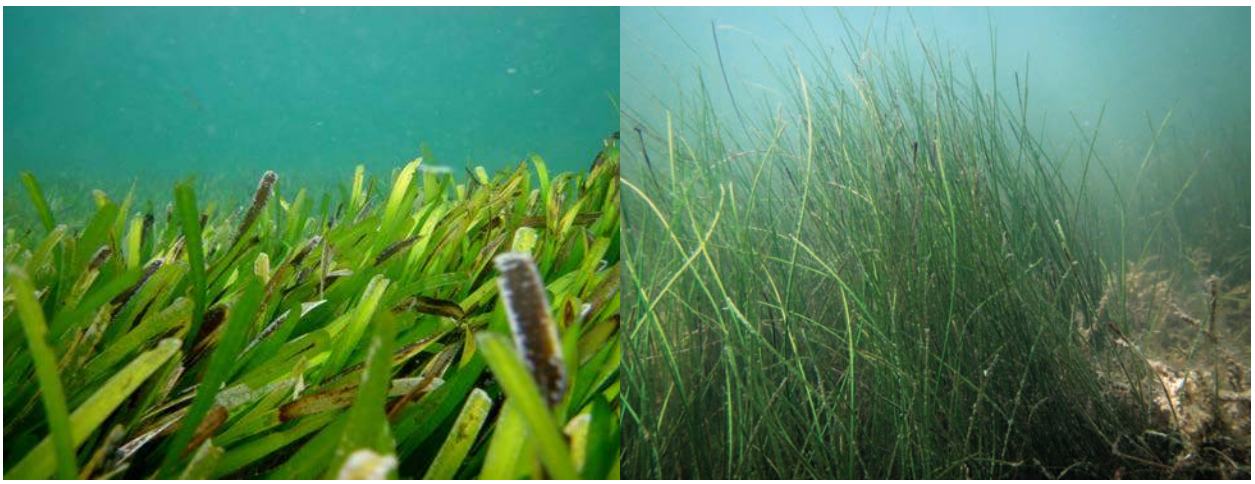


Figure 3. The two most common seagrasses found in The Bahamas. Left to right: Turtle Grass, Manatee Grass. Credit: Enie Hensel.

Seagrass Fauna
Seagrass beds are home to a wide variety of organisms inclusive of juvenile and adult fish, mollusks, bristle worms, and nematodes. Popular organisms found in seagrass beds are sea hares, sea stars, sea cucumbers, sea urchins, barracudas, queen conch, turtles, and manatees.

Figure 4. Queen conch (left), sea urchins (middle), and sea hares (right) make seagrass beds their home. Credit: Enie Hensel.

spotlight species

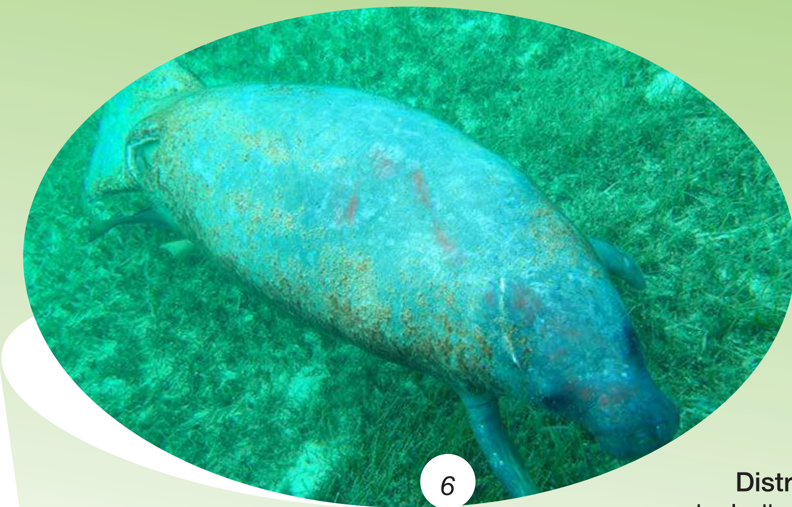
Green Sea Turtle

Scientific Name: *Chelonia mydas*
Conservation Status: Endangered
Distribution: Around the world in tropical and, to a lesser extent, subtropical waters.


5

Figure 5. Green turtles forage in seagrass beds. Turtle grass is the primary food source for adult green turtles, while juvenile green turtles are omnivores. Credit: Enie Hensel.

Green turtles were named as such because of the colour of their body fat, which is due to their diet. Juvenile green turtles (up to a year old) are carnivorous. However, adult green turtles are largely herbivorous, eating underwater grasses, especially turtle grass. Adults can weigh between 200 to 500 pounds, and reach full maturity around 27-50 years of age (Ernst and Barbour, 1989; Hirth, 1997). In addition to green turtles, The Bahamas is also home to hawksbill, loggerhead, and leatherback turtles, and more rarely olive ridley turtles. Traditionally, sea turtles were harvested for their meat, eggs, and shells, but now, nearly all species are listed as endangered. In 2009, The Bahamas passed laws making it illegal to harvest, possess, purchase, or sell sea turtles, their eggs, or any other by-products (e.g. shell). It is also illegal to disturb sea turtle nests.
However, globally, sea turtle numbers are still dropping. Turtles are threatened by nesting and foraging habitat loss as a result of coastal development, poaching, pollution and bycatch. The Bahamas Sea Turtle Network is a group of organisations and government departments that collaborates to monitor turtle populations, and keep records of stranding and nesting events. To report injured or dead turtles or turtle nesting activity, please email: bahamasseaturtlenetwork@gmail.com



spotlight species

West Indian Manatee

Scientific Name: *Trichechus manatus*
Conservation Status: Vulnerable
Distribution: Throughout the Caribbean basin, including the southeastern United States, eastern Mexico, eastern Central America, northeastern South America, and the Greater Antilles.

Figure 6. Randy is a manatee that is well-known in Abaco. This photo taken in 2018 shows that he looks fairly healthy, however he has suffered a major injury from a boat propeller near his tail. Thankfully, Randy has been sighted since then and has recovered from the injury, but his story helps us understand how important it is to reduce interactions between humans and manatees. Credit: Bahamas Marine Mammal Research Organisation.

Manatees are typically grey in colour, have large, heavy, seal-shaped bodies with paired flippers, and a round, paddle-shaped tail (National Wildlife Federation, n.d.). Sensory hairs cover their body. Manatees are able to inhabit salt, fresh, or brackish waters and feed on vegetation found there (e.g. turtle grass or manatee grass). The West Indian manatee has two subspecies, the Antillean manatee and the Florida manatee; according to The Bahamas Marine Mammal Research Organisation both subspecies may be found in the country but recent records are only of Florida manatees. There are only about 20 known manatees currently in the entire Bahamian archipelago with three - four of them resident to Abaco and Grand Bahama (Bahamas Marine Mammal Research Organisation.

Did You Know?
Manatees are a protected species in The Bahamas. Use your "Manatee Manners" if you spot a manatee like Randy by following these rules:
Do not feed them; food is readily available in our abundant seagrass beds and lettuce lacks the nutrition that they need to survive

Do not give them water to drink; they are incredibly resourceful and are capable of finding even the smallest freshwater source. By providing them food and water, we are encouraging them to spend time in marinas and harbours where they will eventually be hit by a boat and potentially fatally wounded by the propellers.

Please respect their space and do not touch, chase or follow them. Despite their gentle demeanour, they are large animals that can move very quickly when disturbed and you can get hurt.

Please mind your manatee manners and let's keep wild animals wild! Guidelines provided by The Bahamas Marine Mammal Research Organisation.

spotlight species

Queen Conch

Scientific Name: *Chelonia mydas*
Conservation Status: Commercially Endangered
Distribution: Throughout the Caribbean Sea from Venezuela to Mexico, Southern Florida, The Bahamas, and the Lesser and Greater Antilles.

Figure 7. A queen conch that is well camouflaged in a bed of manatee grass and shoal grass peeps out of its shell. Credit: Enie Hensel.

Adult conchs live in seagrass beds and on sand flats in depths of 2-30m where they feed on algae, detritus, and diatoms (unicellular algae) found on the blades of seagrass (*turtle grass*). The shells of adult conchs have a well formed lip, thick and flared, which continues to thicken as the conch ages. Studies have indicated that conchs are sexually mature when their lip is 15mm thick, typically around four years of age or older (BREEF, 2014).

Further Reading: BREEF. (2014). The Queen Conch True Bahamian Royalty: The Guide for Bahamian Schools.

Ecological Role

Seagrass Connectivity
Seagrasses are connected to all major ecosystems in the ocean, including coral reefs, mangrove wetlands, and the open ocean.

Habitat
Seagrass beds provide habitat for many important and vulnerable species in The Bahamas, most notably, the Queen Conch. The biodiversity in seagrass beds ranging from microorganisms on seagrass blades to macroorganisms existing in and around beds contributes to the overall biodiversity of our oceans.

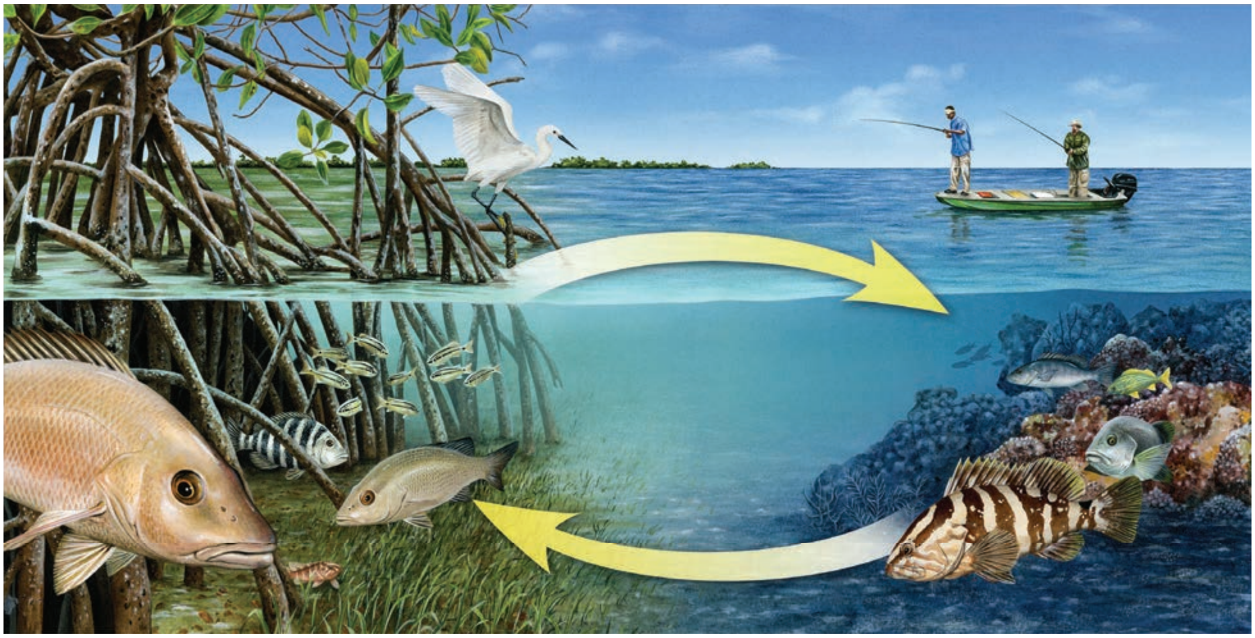


Figure 8. Seagrass beds are important habitat corridors, facilitating connections between other marine habitats such as mangroves and coral reefs. Credit: Dawn Witherington for Friends of the Environment.

Primary producers
Seagrasses are one of the main primary producers in our oceans, like other organisms such as phytoplankton. They are one of the main organisms that sit at the base of the ocean's food chain, making them essential in many life cycles of aquatic animals.

Nursery habitat
Many animals living in seagrass beds came from mangrove ecosystems. As they transition into a more open environment, seagrass beds still provide them with a protected area to reside, many of them hiding within the densely packed seagrass blades.

Sediment stabilisation and carbon sequestration
The complex structure of the roots of seagrasses helps to stabilise the sediment below it. The thick, horizontal structure of rhizomes on seagrasses adds to this stability. Sediment stabilisation is extremely important as it contributes to protection from storms/hurricanes and aids in preventing erosion. The structure of seagrass beds also facilitates storage of carbon, helping to reduce the atmospheric carbon dioxide levels and lessening the impacts of climate change.

Maintain water quality
In addition to helping stabilise sediment, the roots and rhizomes of seagrasses also improve water quality and clarity by trapping suspended particles.

Economic Value

Seagrasses are a key component of domestic, commercial, and sports fisheries due to their ecosystem service as a habitat for key fishery species like spiny lobster and queen conch. Seagrasses (and seaweeds) that wash up on our shores are sometimes collected as fertiliser for sandy soil. While this is still being realised in The Bahamas, the role of seagrass beds in carbon sequestration has been getting global attention and The Government of The Bahamas is investigating the idea of including our seagrass beds in the “carbon market” where other governments or large entities may provide financial compensation for the services of the seagrass beds in order to offset the carbon emissions those entities produce.

THREATS

There are many threats to seagrasses, many of which are **anthropogenic**.

Eutrophication

An oversupply of nutrients like nitrogen and phosphorus can be harmful to seagrasses. Instead of benefiting them, it directly harms them and promotes the growth of macro- and microalgae that cling to or float near the seagrass. This excessive growth shades the seagrass, limiting the amount of sunlight it receives for photosynthesis. As a result, the seagrass struggles to thrive. Additionally, decaying seagrass leaves and algae contribute to the proliferation of algal blooms, creating a cycle where the increased algae further exacerbates the issue, leading to a continuous and harmful loop.

In The Bahamas, a major source of the nutrients involved in eutrophication can be attributed to the presence of large golf courses at major hotels and resorts. Leaching and runoff of nutrients from farm lands and the improper disposal of waste also plays a part.

Dredging, Anchoring and Sand Mining

The process of dredging, anchoring, and sand mining leads to the physical removal and/or burial of vegetation. Increased **turbidity** and sedimentation also occur which can lead to the loss of these seagrasses due to their inability to photosynthesize.

Climate Change

Sea level rise is one of the consequences of climate change. As sea levels rise, the depths of existing seagrass beds will increase. As the water gets deeper a decrease in light available to the seagrass will limit photosynthesis - ultimately negatively affecting seagrass growth.

Conservation and Management

Protected Plants

All three species of seagrass are listed under Part 1 of the Forestry (Declaration of Protected Trees) Order, 2021, classifying them as “endemic or endangered or threatened protected trees”. It is illegal to remove a protected tree unless in possession of a valid permit from the department responsible for Forestry. Contravention of this law may result in a fine, imprisonment, or both.

Marine Protected Areas

Seagrass beds are included in a number of national parks across the country such as: Exuma (Exuma Cays Land & Sea Park, Moriah Harbour Cay National Park), New

Providence (Bonefish Pond National Park), Abaco (Fowl Cays National Park, Pelican Cays Land & Sea Park), Andros (Andros North Marine Park, Andros South Marine Park), Conception Island (Conception Island National Park), Inagua (Union Creek Reserve, Little Inagua National Park)

Regulations and Policies

Dredging must be permitted, but the distribution of seagrasses is not often reviewed as part of approvals. The use of siltation screens and turbidity monitoring sometimes is required by larger projects, especially those being developed in coastal areas. Moorings may be installed in protected areas and other anchorages to limit damage to seagrass beds and other benthic habitats.

classroom activities

Dried Seagrass Print

Duration: 1.5 hours

Grade Level: 7-12

Objective

- Students will collect seagrass and seaweed to create a dried print.
- Students will learn how to identify parts of seagrass and algae plants.

Materials

- Fresh seagrass and seaweed
- Shallow pan filled with water
- Cardstock
- Waxed paper or plastic film
- Old newspaper
- Permanent marking pen
- Plant Press (Optional)

Procedure

1. Collect various seagrass and seaweed specimens.
2. Fill a shallow pan with water.
3. Sink the cardstock to the bottom of the shallow pan filled with water.
4. Float a piece of seaweed or seagrass on top of the paper.
5. Once the seaweed/seagrass is properly positioned, carefully lift out the paper while allowing the water to run off, but keeping the seaweed or seagrass on the paper.
6. Place the wet paper and seagrass/seaweed on several sheets of newspaper to dry.
7. Cover the paper and seagrass/seaweed with waxed paper or thin plastic film.
8. Use the permanent pen to write a statement about the seagrass/seaweed or add additional design on the plastic film or waxed paper, if desired. (Name of seagrass or seaweed/ where it was collected/ date)
9. Repeat this procedure with other seagrasses/seaweeds, placing each piece of paper and seaweed on top of the first in a stack.
10. When all the seaweeds/seagrasses are stacked, cover with a thick layer of newspaper to absorb excess water.
11. Finally, put the whole stack of papers and seaweeds/seagrasses in a flat place with some weight on top (A rug or textbook etc).
12. Change the newspaper daily until the seagrass/seaweed is dry (about two weeks).
13. Peel the waxed paper or plastic film off of the paper and a pressed and dried seagrass/seaweed display will remain pressed to the cardstock.
14. Once the plant is dried and mounted, label the appropriate plant parts along with classifying the type of seagrass or seaweed
15. Display seagrass/seaweed print in a window or keep a collection of prints in a notebook.

Reference for above activity:

Modified from Deering Estate at Cutler. (n.d.). Sea grasses lesson plan . yumpu.com. https://www.yumpu.com/en/document/read/31803013/sea-grasses-lesson-plan-deering-estate-at-cutler.

field trip activities

Seagrass and Seaweed Scavenger Hunt

Duration: 1.5 - 3 hours, depending on field trip location
Grade Level: 7-12

Objectives:
- Introduce students to seagrass bed habitat
- Use observational skills to mark weather, human impacts and other characteristics of the field trip site
- Identify and list plant and animal species that are observed during the field trip

Materials
- Mask and Snorkel Sets
- Noodles
- Glass bottom buckets
- Buckets or Plastic containers
- School bus (or enough volunteer drivers with vehicles)
- Seagrass Expedition sheet (1 per student)
- Clipboard if possible (1 per student)
- Pencils

Procedure
Explore the Seagrass bed
1. Review Seagrass bed Field Trip Rules

- Check the tides— You can find local tide charts online. Seagrass beds are usually more accessible at low tide. Be sure to check if the tide is going down, and if there are rip currents to be aware of.
- Wait for it—Be patient while you search for creatures in the seagrass beds. Observe and move around slowly. Do not forget to note the different types of plant species you see.
- Look out below—Seagrass creatures are small and like to hide. Look within the seagrass blades and lookout for animals that appear to be rocks or organisms covered with sand and other loose debris.
- Easy does it—Be very gentle when holding seagrass creatures and return them exactly where you found them.
- Be careful—Please be careful when handling sea creatures like sea stars and sea urchins. They often have spiky appendages that can hurt you if you apply too much pressure and you also do not want to hurt them.
- Resist temptation—Taking objects from the seagrass bed can impact the ecosystem negatively. Take photos instead.
- Move slow— So that you are able to see all there is to see. If you are walking aim to disturb the settlement as little as possible and avoid stepping on sea creatures within.
- Bring a bin—Bring a plastic container to collect various plant specimens if you will be doing the seagrass print activity. Collect clear sea water for the plants.

field trip activities

2. Travel to seagrass bed ecosystems with students and volunteers. Ask local fishermen and naturalists for suggestions on possible field trip locations. An ideal site will be a sandy beach with prominent seagrass beds nearby. Visit the site prior to bringing students to ensure it is safe and to plan your field trip.

3. Explore the seagrass bed ecosystem and fill out the field trip activity sheets.

field trip activities

Seagrass Bed Expedition Sheet

Name: ________________________________ Date: ____________________

Describe the field trip site:

____

____

____

____

Time: __________ Tide State:__________ Weather Conditions:______________

Visible Human Impacts?:____

____

Other observations: ____

____

List all organisms that you have seen during your expedition.

Common Name	Phylum	Habitat

Coral Reefs

Coral reefs are often called “rainforests of the sea” due to their high biodiversity. Economically and biologically important, these ecosystems are highly productive and sustain the Bahamian way of life. Corals can often be overlooked in their important role to the health of our oceans and to the benefits they provide to us on land.

Coral reefs are home to a wide variety of flora and fauna and are often called “the rainforests of the sea”. Corals, although sometimes having the appearance of plants or very large rocks, are actually animals, made up of thousands of polyps that together form a colony. The majority of reef-building corals are found in tropical and subtropical latitudes because they require warm, sunlit, clear, clean and shallow saltwater to survive. Although these are optimum living conditions for the majority of corals, some species, collectively known as **deep water corals**, have been discovered in the depths of the ocean where sunlight does not penetrate. Deep water corals grow slower and form simpler reefs than corals that grow in the photic zone.

Chapter Objectives

- Learn the three major types of coral reefs.
- Learn optimum conditions that corals need to survive.
- Learn about fauna found on coral reefs.
- Connect cultural values as Bahamians with the importance of coral reefs.

Ecosystem flora and fauna

As previously mentioned coral reefs are made up of thousands of coral polyps; each individual polyp is a single animal, and is composed of a mouth, gastrovascular cavity, and tentacles that contain stinging cells, called nematocysts.

These polyps secrete the mineral calcium carbonate, which forms the corals’ hard skeleton. Corals require specific temperature, salinity, and water clarity in order to survive. These are known as **abiotic** factors, and help corals thrive. They thrive best in

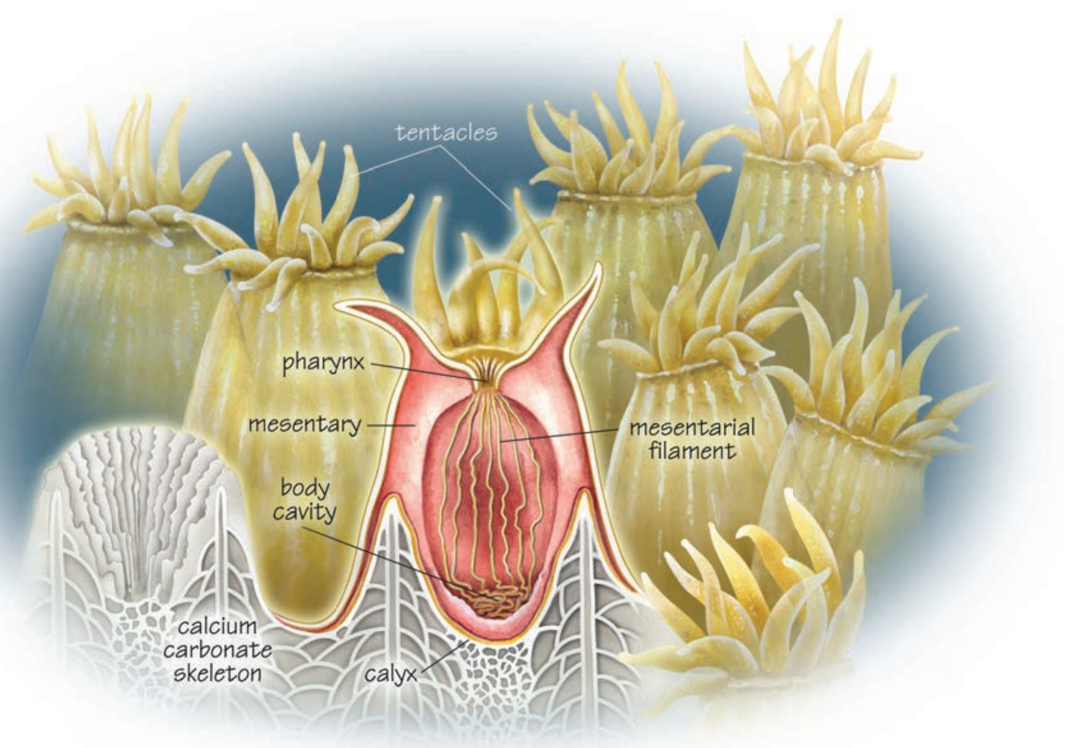


Figure 1. Illustration of coral polyp anatomy. Credit: Dawn Witherington.

shallow, clear water that is between 23°-29° C in temperature with a salinity around 35 ppt, meaning they are found mostly in tropical zones. Water clarity is important to allow sunlight to reach the single cell photosynthetic microalgae living inside their tissue, zooxanthellae.

There are two types of coral found in The Bahamas: hard coral (also known as stony coral) and soft coral. Hard corals are called **hermatypes**, which means they are reef builders. Their polyps secrete a calcium carbonate skeleton, giving them their hard, sturdy structure.

Figure 2. Hard corals (left) vs. soft corals (right) Credit: Enie Hensel (left), Olivia Patterson Maura (right).

Soft corals are called **ahermatypes**, because they are non-reef builders. Although their skeleton is still made of calcium carbonate, it is secreted in small, needle-like structures called sclerites. This gives soft corals their soft, bendable skeleton. Coral reefs have a symbiotic relationship with zooxanthellae, the microscopic algae living in their polyp tissues.

Coral polyps provide zooxanthellae with shelter as well as carbon dioxide from the photosynthesis process. In return, zooxanthellae provide corals with oxygen, carbohydrates, and their beautiful colour. This **symbiotic relationship** is known as mutualism, because both organisms benefit from each other.

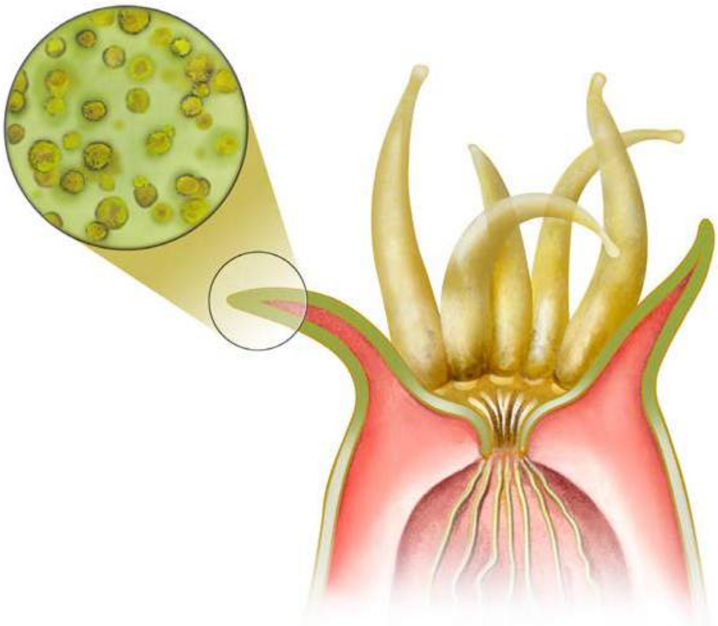


Figure 3. In this illustration, the magnified area is highlighting the zooxanthellae found within the coral polyp tentacle. Credit: Dawn Witherington.

Table 1. Typical species seen near at a coral reef.

<table>
<tr><th colspan="6">Primary Producers</th></tr>
<tr><td>Zooxanthellae</td><td>Phytoplankton</td><td colspan="2">Seagrass
(Turtle, manatee, shoal)</td><td colspan="2">Algae
(Sargassum, White Scroll alga, Sea Pearl, Mermaid's fan, Mermaid's wine glass, pink bush algae)</td></tr>
<tr><th colspan="6">Common species of soft corals</th></tr>
<tr><td>Sea Plumes</td><td>Common Sea Fan</td><td colspan="2">Wide-mesh Sea Fan</td><td>Long Sea Whip</td><td>Bushy Sea Whip</td></tr>
<tr><th colspan="6">Common species of hard corals</th></tr>
<tr><td>Staghorn Coral</td><td>Elkhorn Coral</td><td>Branched Finger Coral</td><td>Pillar Coral</td><td>Mountainous Star Coral</td><td>Boulder Star Coral</td></tr>
<tr><td>Lettuce Coral</td><td>Blade Fire Coral</td><td>Flower Coral</td><td>Lesser Starlet Coral</td><td>Mustard Hill Coral</td><td>Brain Coral</td></tr>
<tr><td colspan="3">Branching Fire Coral</td><td colspan="3">Massive Starlet Coral</td></tr>
<tr><th colspan="6">Important species of reef grazers (herbivores)</th></tr>
<tr><td colspan="3">Parrotfish
(striped, stoplight, blue, queen, redband)</td><td colspan="3">Surgeonfish
(ocean surgeonfish, doctorfish, blue tang)</td></tr>
<tr><th colspan="6">Scalefish</th></tr>
<tr><td>Nassau Grouper</td><td>Black Grouper</td><td>French Grunt</td><td>Yellowtail Snapper</td><td>Schoolmaster Snapper</td><td>Grey Snapper</td></tr>
<tr><td>Mutton Snapper</td><td>Hogfish</td><td>Angelfish
(Spongivores)</td><td colspan="3">Butterflyfish
(spotfin, banded, four-eyed)</td></tr>
</table>

Common reef fish					
Fairy basslet	Squirrelfish	Yellow goatfish	Bluehead wrasse	Filefish	Triggerfish
Trumpetfish	Porcupinefish	Yellowhead wrasse		Checkered pufferfish	
Common Invertebrates					
Caribbean Spiny Lobster	Banded Coral Shrimps	Orange Fireworm	Christmas Tree Worm	Social Feather Duster Worm	Flamingo Tongue
Caribbean Reef Squid	Caribbean Reef Octopus	Amber Penshell	Branching hydroid	Moon Jellyfish	Giant Anemone
Red-spot Comb Jellyfish	Swimming crinoid	Two-Spined Sea Star	Sponge Brittle Star	Long-Spined Urchin	Giant Tunicate
Common Sponges					
Giant Barrel Sponge	Branching Vase Sponge	Yellow Tube Sponge	Rope Sponges (lavender, scattered pore, erect)	Encrusting Sponges (pink, red, peach, star)	
Common Sharks & Rays					
Spotted Eagle Ray	Southern Stingray	Yellow Stingray	Nurse Shark	Lemon Shark	Bull Shark
Caribbean Reef Shark					
Sea Turtles					
Loggerhead Turtles		Green Turtle		Hawksbill Turtle	
Marine Mammals					
Bottlenose Dolphin					

spotlight species

Elkhorn Coral

Scientific Name: *Acropora palmata*
Conservation Status: Critically Endangered
Distribution: The Bahamas, Florida, and the Caribbean.

Figure 4. The branched structure of elkhorn coral provides important habitat for reef fish. Credit: Perry Institute for Marine Science.

One of the most important corals in the Caribbean, Elkhorn coral is a reef builder, making up a large percentage of the coral reef structure. Elkhorn coral colonies are golden tan or pale brown with white tips and they get their colour from the algae (zooxanthellae) that lives within their tissue. Individual colonies are able to grow to at least 6 feet in height and 12 feet in diameter (NOAA Fisheries, 2023). Elkhorn coral colonies have the ability to grow in dense " thickets" of overlapping branches, which provide important habitat for reef fish and other animals. When Elkhorn coral is approximately 2 square feet, it reaches reproductive maturity. As simultaneous **hermaphrodites**, each colony generates both eggs and sperm, although they typically do not self-fertilise (NOAA Fisheries, 2023). Elkhorn coral sexually reproduces annually following the full moon in late summer, releasing eggs and sperm into the water through a process known as "broadcast spawning" (NOAA Fisheries 2023). Elkhorn corals are threatened by climate change, coastal development, disease, pollution and other human impacts.

spotlight species

Staghorn Coral

Scientific Name: *Acropora cervicornis*
Conservation Status: Critically Endangered
Distribution: The Bahamas, Florida and the Caribbean

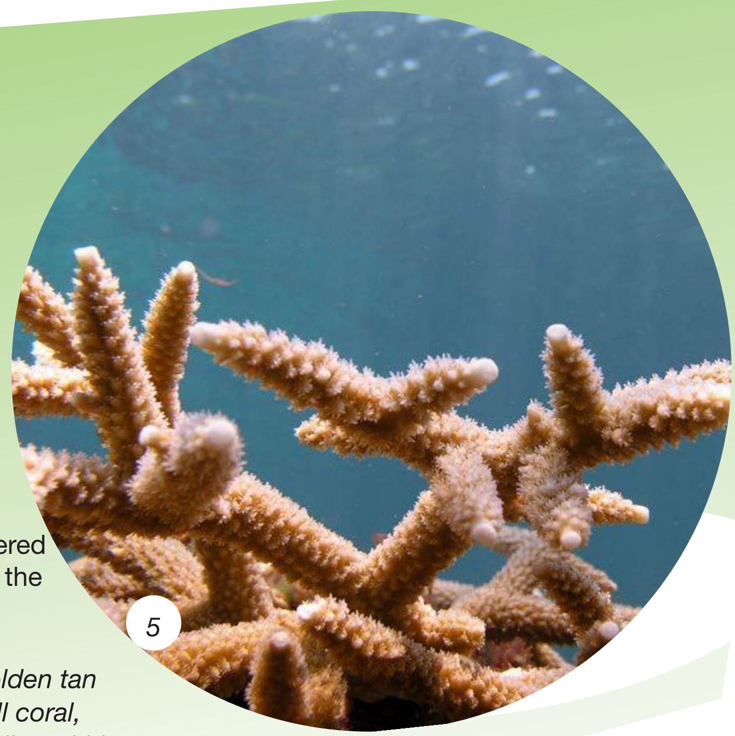
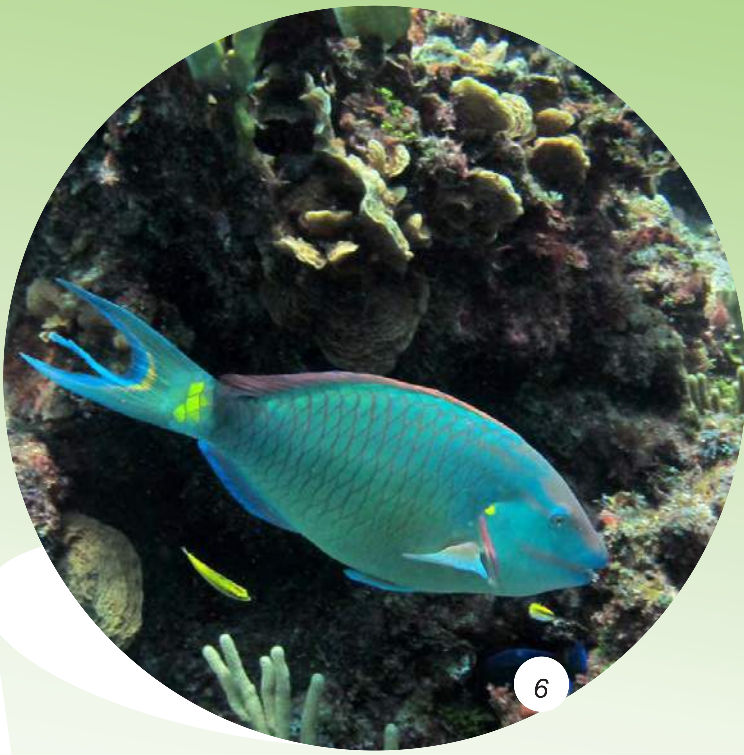


Figure 5. Staghorn coral colonies are golden tan or pale brown with white tips and, like all coral, they get their colour from the algae that live within their tissue. Credit: Tim Higgs.

Staghorn coral is also a reef builder. Staghorn corals have antler-like branches, which is how they got their name. Individual colonies are able to grow to at least four feet in height and six feet in diameter (NOAA Fisheries, 2023). Staghorn coral colonies can also grow into dense thickets. Because of their structure they provide great habitats for fish and marine organisms as well as serve as coastal protection from wave action. In the early 1980s, "a severe disease event caused major mortality throughout its range and now the population is less than 3 percent of its former abundance" (NOAA Fisheries, 2023). Staghorn corals are threatened by climate change, coastal development, disease, pollution and other human impacts.

spotlight species

Stoplight Parrotfish



Scientific Name: *Sparisoma viride*
Conservation Status: Least Concern

Figure 6. Stoplight Parrotfish - Terminal Phase. Credit: BEP Foundation.

Stoplight parrotfish are a very exciting species to see on the coral reef. They have an elongated body with a rounded head and most notably a beak-like mouth for which they were named. Stoplight parrotfish experience notable colour variations across their three main life stages: juvenile, initial phase and for some - the terminal phase. Juvenile stoplight parrotfish have three rows of white spots running the entire length of the body, over a dark reddish-brown body (Bester, n.d.). In their initial phase both male and female are "mottled reddish brown, often mixed with white scales, on the upper two thirds of the body while the belly is bright red" (Bester, n.d.) The terminal phase refers to the " supermale" - which is the primary male who leads reproduction in the school or "harem". In the event that there is a huge imbalance between the number of breeding males and females, female parrotfish are able to change their gender to ensure that their population remains stable. If there is no existing primary male to be the "supermale" the largest female parrotfish that undergoes this change becomes known as the "supermale". Terminal phase males are "green with diagonal orange bands on the upper half of their head, an orange crescent-shaped indentation is found on the caudal fin and they also have a yellow spot located near the top of the gill slit and another at the base of the caudal fin" (Bester, n.d).

Like other parrotfish, Stoplights are reef grazers, who eat the algae off of coral reefs. Sometimes, because their beaks are so powerful, they may bite off pieces of coral when feeding. Their digestive systems cannot break down coral, so it is excreted as sand. Parrotfish may produce as much as one tonne of sand per acre of reef each year, making them extremely important to sandy beaches (Bester, n.d).

Habitat adaptations

There are three main structures of coral reefs that exist in the world. These are **fringing**

reefs, barrier reefs and **atolls**. Fringing reefs are found parallel to the coastline and can stretch for miles. Barrier reefs are also found parallel to the coastline, but with a lagoon separating them from the shore. Atolls occur when a fringing reef forms around a volcanic island that subsides, leaving a lagoon in the middle. As the fringing reef grows, the volcanic island begins to subside completely below sea level, and the fringing reef turns into a barrier reef. Once the volcanic island has subsided, a lagoon is left in its place with the reef formation surrounding the lagoon. This process may take as long as 30 million years to grow which makes atolls a unique reef structure. The structural framework keeps them sturdy and allows for protection from natural threats such as hurricanes.

There is another coral reef structure known as **patch reefs**. Patch reefs have small scale characteristics of all three structures of reefs (fringing, barrier, and atolls), and therefore are not considered a major structure. In The Bahamas, we primarily have fringing, barrier, and patch reefs, the exception being Hogsty Reef in the southern Bahamas which is classed as an atoll. We have some of the largest barrier reefs in the world located in the waters surrounding Abaco and Andros.

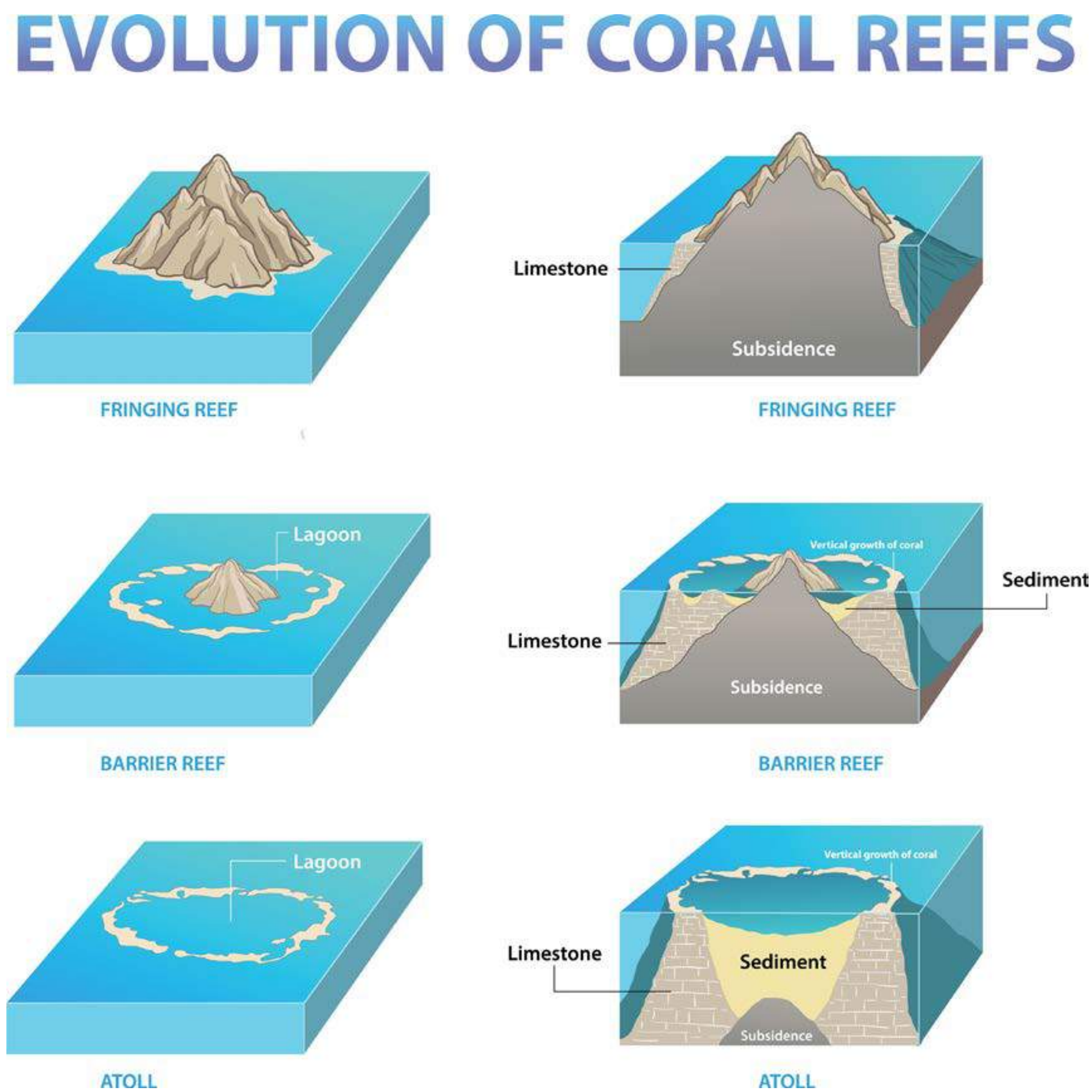


Figure 7. Three main types of coral reef structure: (a) fringing reef (b) barrier reef (c) atoll. Credit: zombiu26/Shutterstock.com.

Many fauna in a coral reef ecosystem have physical adaptations to help them thrive in this ecosystem. Many species of fish practice **camouflage** on a reef to hide from predators, changing their appearance to blend in or hiding amongst reef structures. Trumpetfish for example have a long thin body shape and unique markings that allow them to blend in with algae and soft corals on the reef.

Figure 8. The colouration and pattern of a trumpetfish help it camouflage on the reef. Credit: Tim Higgs.

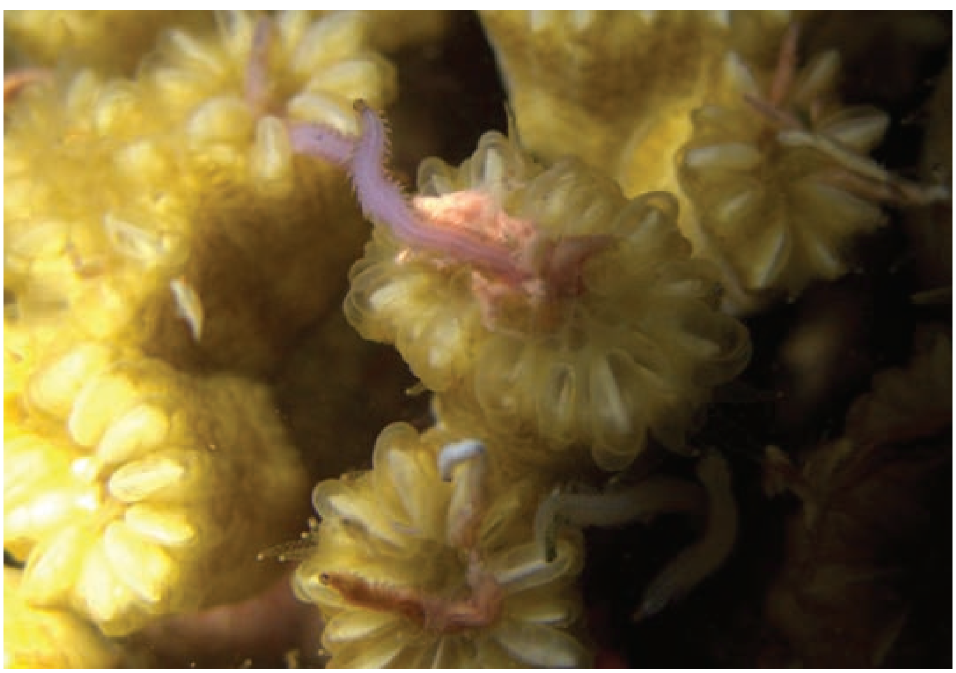


Figure 9. Flower coral (Eusmilia fastigiata) feeding at night. Credit: Perry Institute for Marine Science.

Feeding
Although corals get a major source of their food from zooxanthellae, some corals also filter feed. Since corals are sessile animals, filter feeding is another method used to obtain the nutrients they need. Filter feeding happens when the coral polyp extends from its skeleton and uses its tentacles to capture tiny animals suspended in the water column (called zooplankton) or phytoplankton. This typically occurs at night.

IMPORTANCE

Ecological role of the ecosystem

• Habitats for a high biodiversity of organisms
Scientists have not yet discovered all of the organisms that live in the ocean, much less on a coral reef. A coral reef is the best marine example of an ecosystem with many plants and animals living together in one place. This means that the ecosystem has high biodiversity, and this is important for the marine environment as it contributes to and diversifies food chains. It also means that it is a home to a wide variety of marine animals, providing them with shelter and a food source.

• Protect our coastline from waves
Coral reefs found along the coastline protect the shore from large waves from storms, especially hurricanes. They break big waves down before they reach the shoreline, preventing erosion and aiding in protection from flooding.

• Water quality
Coral reefs host organisms that are filter feeders (e.g. sponges) and suspension feeders (e.g. coral), which feed off of microscopic animals in the water column, as well as other bacteria and particles floating in the water. This helps with visibility in the water column and helps keep the ocean clean.

• Medicine
Due to the phylogenetic diversity of animals found on coral reefs as well as of corals themselves, it is thought that coral reefs can provide medicinal benefits to us (Bruckner, 2002). Many crucial functions of these animals, such as fighting off predation, feeding, and fighting disease require bioactive compounds found within the animal (Bruckner, 2002). These bioactive compounds are thought to be capable of creating life-changing medicines for cancers and other diseases, although research is still being done.

Economic Value

• Fishing
Fishing brings in millions of dollars a year in the Bahamian economy due to export. Not only are coral reefs important to sustain these species for export, but also to provide jobs for thousands of Bahamian fishermen who rely solely on fishing for their income. Seafood is an important source of protein for Bahamians across the archipelago; many rely on the sea for sustenance. Ensuring sustainable fisheries is critical to promoting food security in The Bahamas.

- Tourism
    - Snorkel/Dive Trips

The Bahamas is known for our beautiful waters worldwide. Tourists are attracted to our country because of our clear, turquoise waters, as well as our colourful and diverse coral reefs. Tourists travel from all over the world to experience these waters, and many come for snorkelling/scuba diving trips to see the coral reefs that make it possible. Not only do coral reefs bring tourists to our country, but they provide jobs for the staff who conduct these trips, i.e. boat captains, dive instructors, administrators, underwater photographers, etc.

- Research

Ecosystems are always changing. Today more than ever because of human impacts, coastal ecosystems like coral reefs are experiencing rapid change and degradation from human impacts. It is important to study these changes over time to monitor coral reef health and understand how human impacts are altering them. To do so, scientists conduct surveys of coral reefs, genetic testing, and more. From these efforts we now know that the amount of coral on reefs is in drastic decline. To help restore these ecosystems, scientists are conducting experiments and reef restoration projects, such as midwater coral tree nurseries, micro-fragmentation, and coral spawning assistance. These types of research projects are beneficial to The Bahamas because they provide access to new information, capacity building opportunities for Bahamians, and they support the economy.

THREATS

Many reef building species of corals are considered critically endangered by the IUCN. They have landed on the critically endangered list due to the many threats that they face.

Anthropogenic threats

- Habitat destruction from coastal development

As The Bahamas becomes an increasingly popular vacation destination globally, the demand for more infrastructure such as hotels, restaurants, and docks also increases. Sediment runoff from construction sites as well as dredging leads to siltation, which affects the clarity of the water, in turn affecting photosynthesis in coral polyps. Chemicals used in these construction sites and waste from these developments also pose future threats.

- Unsustainable fishing practices such as overfishing and illegal fishing

Overfishing can disrupt the delicate balance of a healthy food chain causing a loss in productivity. Trophic cascades are common results of overfishing, where the higher level predators are consumed and the herbivores or producers overwhelm the ecosystem.

Some illegal fishing methods that can disrupt a coral reef ecosystem include fishing while using SCUBA, using spear guns, using air compressors without a permit, and spearfishing within 200 yards of any shoreline in the "family islands" or within 1 mile of the shoreline in New Providence and Grand Bahama. In addition, using chemicals such as bleach, explosives, or firearms is illegal and can cause damage to the reef itself, as well as to other flora and fauna found on the reef.

• Climate Change > Coral Bleaching
Earth is undoubtedly experiencing the effects of climate change through mainly **anthropogenic** causes. Burning fossil fuels by energy consumption is emitting greenhouse gases into our atmosphere. This traps heat energy from the sun into the lower atmospheric layers of Earth, and in turn, is contributing to the warming of our oceans. Although coral reefs thrive in warm water, they must have optimal conditions between 23°-29° C, and too warm or too cold of water is harmful for corals. If the water temperature is outside of this optimal range, corals become stressed and expel their symbiotic algae living inside their tissues, zooxanthellae. Due to the colour pigments that zooxanthellae provide for coral giving them their beautiful colour, the coral skeleton loses its colour and becomes white. This is known as **coral bleaching**, and can lead to coral death. It is possible for the coral to gain new zooxanthellae after a bleaching event and recover, although it is very rare.

Figure 10. Coral bleaching occurs when coral polyps expel their zooxanthellae in response to extreme stressors like drastic changes in ocean temperatures. Credit: Perry Institute for Marine Science.

• Pollution
Coral reefs face threats of pollution from many different sources. In The Bahamas especially, resorts, golf courses and the like prove a huge issue of pollution in our waters. Fertiliser runoff from these developments are especially harmful to reefs because they create a nutrient-rich environment which can cause coral disease, prevent coral growth and development, or disrupt ecological functions. Failed septic systems, stormwater runoff, and runoff from farm sites and poorly managed dump sites also contribute to nutrient-rich environments on coral reefs.

Bahamian waters are very attractive to tourists, who visit our islands frequently Coral reefs are frequently visited by hundreds of tourists daily, most of whom will wear sunscreen that commonly contains oxybenzone, a chemical that can cause coral deformities and damage coral DNA if present in high concentrations (Smithsonian, 2022).. Many skin care companies now produce “reef-safe” sunscreen with ingredients that are not known to harm corals.

Plastic pollution also affects coral reefs; not only can items such as plastic bags or bottles smother the reef, but it has been discovered that some corals mistakenly ingest microplastics in place of food (Hall et al., 2015).

• Recreational Damage
Many tourists visiting The Bahamas for the first time are new to snorkelling and other water sports.Common mistakes when snorkelling and diving include holding your body vertical in the water column, which can result in a sharp kick to the reef, which can break off pieces of coral, or standing on the reef for a snorkel break, both of which are extremely damaging to the coral. It is important to practise keeping a safe distance from corals when snorkelling, and in no circumstance ever touch or stand on coral.

Boaters seeking to snorkel on a reef may sometimes throw their anchors too close to or on top of the coral reef, breaking off pieces of the coral which can take hundreds of years to grow. Finding a sandy patch near the reef or using moorings when available are the safest ways to explore a coral reef.

• Invasive species
Lionfish is an extremely invasive species in the Atlantic Ocean, especially in coral reef ecosystems. Native to the Indo-Pacific oceans, lionfish are thought to have made their way to our waters either by aquarium releases in Florida or hurricanes. As an invasive species, they eat a large percentage of their body weight, have no natural predators, and reproduce frequently and abundantly.

Figure 11. A lionfish observed on a Bahamian coral reef. Credit: Tim Higgs.

Natural threats
• Storms and hurricanes
Although coral reefs protect us from storm surges caused by common storms and hurricanes, their fragile skeletons can also be damaged by them. Corals near the surface in shallow waters can experience wave damage from big waves crashing over them during intense storms. In particularly intense hurricanes, debris from land such as wood, metal, or vegetation can be blown into the ocean and damage reefs in close proximity to the shoreline.
Hurricanes are becoming more intense due to climate change and coral reefs of today are exposed to greater stress from these larger storms. This is compounded by the additional stress from nutrient pollution and warming seas such that their combined influence can be particularly devastating for coral.

- Disease
  - White band disease

White band disease is a coral pathogen that has killed up to 90% of staghorn, elkhorn, and fused staghorn coral in the Caribbean region. It was first described in 1977 and scientists are still unsure of the cause of the disease. The pathogen causes coral tissue to peel from colonies of elkhorn and staghorn corals, leaving behind exposed white skeleton, which is quickly colonised by algae (Florida Museum of Natural History, 2018). This disease has led scientists to build coral reef nurseries to grow these coral species for outplanting back on the reef.

- Stony coral tissue loss disease

Stony Coral Tissue Loss Disease (SCTLD) is an unknown pathogen that spreads quickly between coral colonies, killing half of the reef building species of corals in the Caribbean region. Like white band disease the corals die, the tissue comes off, and algae begins to grow on the skeleton. Once a coral colony is infected with SCTLD it is likely to die. On some reefs, where the disease has existed for over 5 years, the coral reef ecosystem is failing to function as an ecosystem. SCTLD was first discovered in 2014. It reached The Bahamas in 2019 and has presently spread to most of the family islands. Scientists have been treating the disease with an antibiotic paste applied directly to the coral.

Figure 12. Stony coral tissue loss disease is currently the largest threat to reef-building corals in the region. Scientists are working to slow the spread of the disease. Credit: Perry Institute for Marine Science.

Conservation and Management

- Coral Reef Restoration. Scientists are working hard to restore Bahamian coral reefs by implementing restoration projects across the country. This can be done by a few methods:
  - The first is by building coral nursery trees, which allow corals to be suspended in the water column and grow at a faster rate than they would naturally. This works best for stony, branching coral species, especially staghorn coral. These structures are built from PVC pipe and anchored near a reef. Pieces of broken staghorn coral are cut into 5 cm fragments and hung from the nursery structures and receive a large amount of nutrients from being suspended in the water column. After about 12 months of

  growing on these nurseries, they are out-planted back onto the reef, adding to the reef structure.
  - The second is by collecting the spawn of corals during the full moons of August and September. This is when coral reefs release their gametes into the water column to be fertilised. Instead, they are collected and brought back to a lab where they will fertilise, grow, and then be out-planted onto a reef.

- Marine Protected Areas Network.
  - The Bahamas is a signatory to The Caribbean Challenge which has committed countries to protecting 20 percent of nearshore waters by 2020. Marine areas across the country have been, and are being, added to the system of Bahamian national parks (managed by the Bahamas National Trust) and marine reserves (managed by the Department of Marine Resources). Having designated areas that are managed helps to ensure that ecosystems remain healthy. It is also important to select sites of the correct size and location to ensure that the species living there have all the resources they need to grow and survive. Designing this collection of sites as a network enables managers to make provisions for species that move around or have various life stages that use different habitats (e.g. larvae drift along currents).
  - National Parks that include coral reefs: Abaco (Walker's Cay National Park, Fowl Cays National Park, Pelican Cays Land & Sea Park), Andros (Andros North Marine Park, Andros South Marine Park), Exuma (Exuma Cays Land & Sea Park, Moriah Harbour Cay National Park), Conception Island (Conception Island National Park), Inagua (Little Inagua National Park)

- Fishery regulations.
  - Fishery regulations are designed so that species are able to grow to maturity and have a chance to reproduce before they reach a legal size to catch.

Individual Actions

How can we help? Though we may not see coral reefs every day, they are essential for our survival as Bahamians. We can take action to help protect our reefs in our everyday lives:

  - Reduce use of single-use plastics, styrofoam, etc. Pollution can block sunlight from the reef, trap reef animals and plants, and injure animals found on the reef through consumption. The less garbage we produce, the less likely it is to end up in our oceans. Choose alternatives such as reusable water bottles, reusable bags, and more.
  - Conserve energy. Conserving energy in our everyday lives means less fossil fuels being burned and entering into our atmosphere. The more fossil fuels that are burned which contributes to climate change, the more coral reefs are affected by rising ocean temperatures.
  - Do not touch coral. Touching corals can damage them, as they are very fragile. Touching coral can also remove some of the protective mucus layer that corals produce, which is not good for the coral's health. Be sure to take caution when visiting a reef by keeping fins and other gear clear from touching the reef.
  - Use moorings if available. Anchoring on or near a reef can physically damage coral by breaking pieces off if the anchor drags or is dropped immediately on the reef, or by your boat and engine coming into contact with the reef crest.

Figure 13. When visiting a reef using a mooring is the best option. If moorings aren't available, anchor in the sand away from the reef. Credit: Cha Boyce.

- Check the active ingredients list on your sunscreen for chemicals called oxybenzone and avobenzone, which have been found to be harmful to corals. Zinc oxide is a safe option to use instead.
- Follow all fishing rules and regulations, including closed seasons for certain species, size limits, and catch limits.
- Support local environmental organisations

classroom activities

Classroom Activity: Build your own fish

Level: Grades 7-12

Duration: 45 minutes

Setting: Classroom

Objectives: Students will learn how to identify fish using their visible characteristics. They will also better understand how fish have adapted in their appearance and structure to live on the coral reef.

Materials:
- Paper
- Pencil
- Colouring utensils
- Print out (Information about the different parts of a fish)

Background
When looking at a fish, its features tell you about where it lives and how it functions within its ecosystem. Fish vary in size and shape; they also have different tail shapes, mouths, mouth location and body shapes.

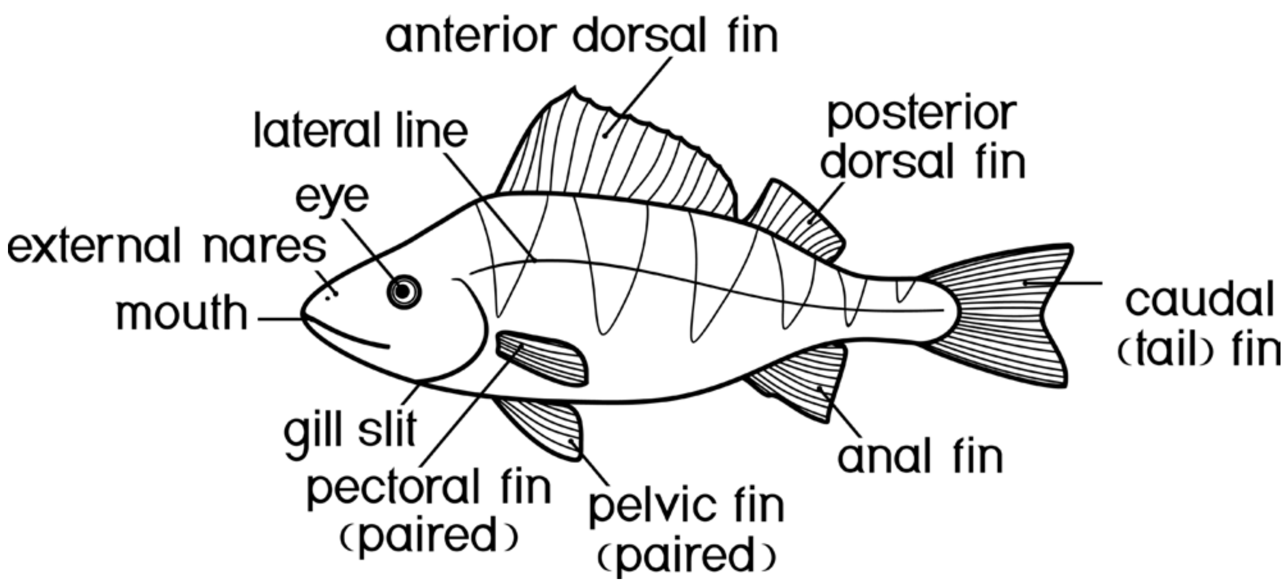
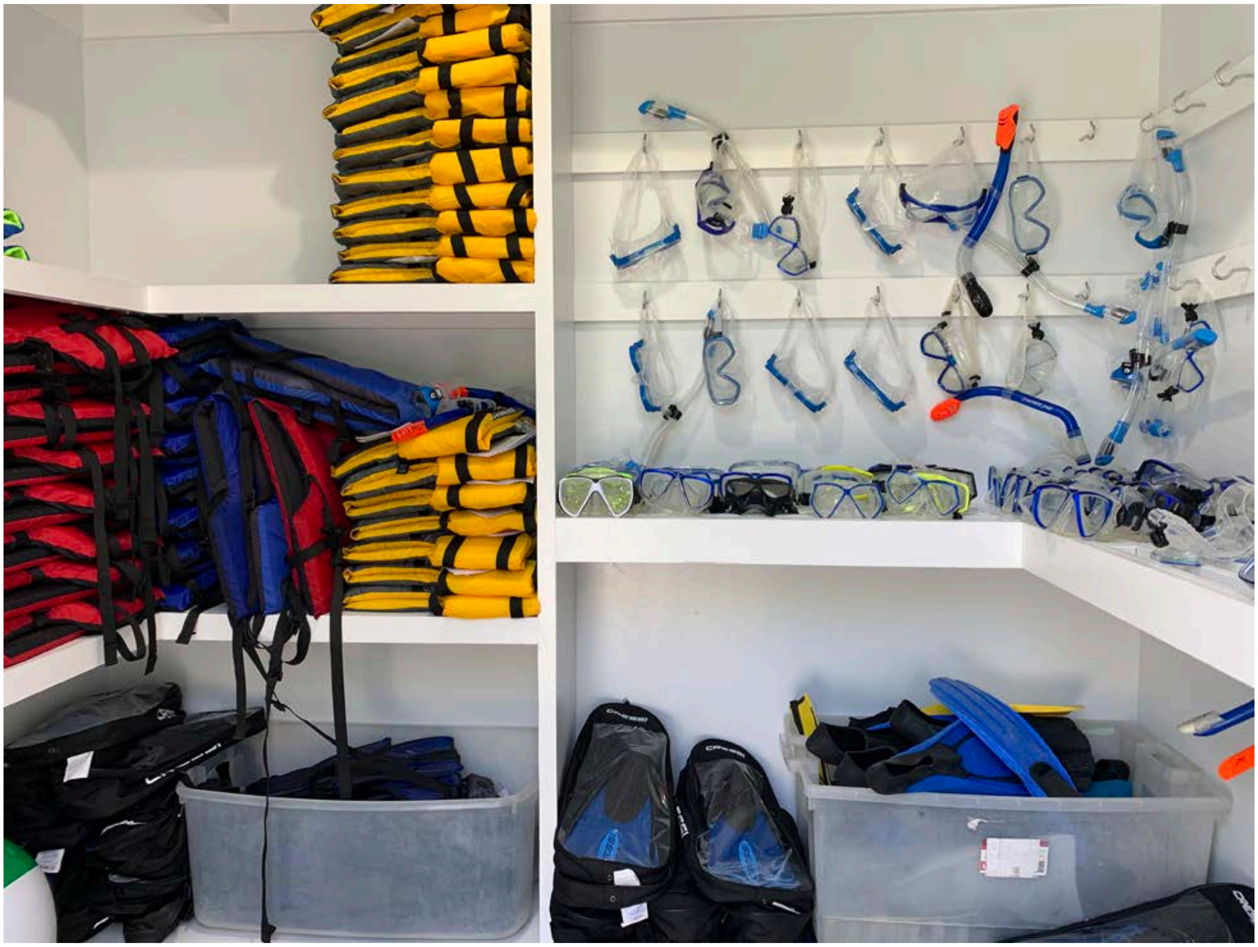


Figure 14. Labelled diagram of a fish. Credit: Kazakova Maryia/Shutterstock.com.

Procedure:
1. Think about the types of fish you have seen before. Now imagine what kind of fish you would like to create.
2. Begin drawing your fish taking into consideration where you would want your fish to live, what they would eat and how they will move. Visualise the types of fins, mouth, tails etc. your fish would need.
3. Using your printout, justify the chosen body parts of your fish. For example tunas have terminal mouths so that they are able to chase and capture other fish.
4. Write a paragraph to accompany your drawing explaining where your fish lives, what it eats, how it gets its food and any adaptations it may have to survive in its habitat.

Suggested resources: Student worksheet: Fish Basics http://www.wpcouncil.org/wp-content/uploads/2019/05/Design-a-Fish.pdf

field trip activities



Typical gear used for a coral reef field trip. Credit: Friends of the Environment

field trip activities

Field Trip

Now that students have learned about the basics of coral reefs and what is present here in The Bahamas, it is time to take them in the field to experience it for themselves.

Objectives

- Students will be able to identify common species of fish and invertebrates found on coral reef ecosystems.
- Students will be able to experience and practice snorkelling skills

Materials needed

- Fish ID laminated cards
- Mask/snorkels
- Fins
- Lifejackets
- Pool Noodles
- Whistle (for chaperones)
- Camera (Optional)

Field Trip Activity: Coral Symbiosis "Minute to win it" relay

Level: Grades 7-12

Duration: 45 minutes

Setting: Outdoors (in the field or at school)

Objectives: Students will act out the different types of symbiosis on a coral reef and within the ocean in teams to compete in a relay. Based on the type of symbiosis portrayed, some teams may work together better than others to complete the race.

Materials:

- Starting point marker
- Ending point marker
- Measuring tape
- Zip ties
- String
- Timer (can be on teacher's phone)
- 40 items to be picked up (could be pieces of paper, paper clips, pencils, etc.)
- Printed sheet of background information

Background

Symbiosis is defined as any interactive association between two or more species living together (King et al., 2013). There are four main types of symbiotic relationships, mutualism, commensalism, parasitism and competition, which can all be observed in the ocean.

field trip activities

1. Mutualism example: coral polyps and zooxanthellae. A mutualistic relationship is one where both species benefit from each other. In this example, the coral polyp provides shelter and carbon dioxide (through respiration) for the zooxanthellae. The zooxanthellae provides the coral polyp with oxygen (as a by-product of photosynthesis), carbohydrates (as a by-product of photosynthesis) and its colour.

2. Commensalism example: remoras on sharks. A commensalistic relationship is one where one species benefits from the other (the other is known as the host), but the host neither benefits or suffers from the relationship. Remoras, often called "suckerfish" are able to attach themselves to larger marine animals such as sharks or rays (which would be known as the host), via an organ that acts as a suction cup. In doing so, this does not damage the host's tissue and allows the remora to obtain food from particles distributed by the host.

3. Parasitism example: barnacles on swimming crabs. In this relationship, one species known as the parasite lives on or in another species known as the host at the expense of the host. In this example, the barnacle is the parasite and the swimming crab is the host. One attached to the crab, the barnacle can sometimes enter the reproductive system and cause damage over time.

4. Competition example: sponges and coral reefs. In competition, species are competing for the same resources, which could include space, food, or other resources. There are two types of competition: intraspecific (between the same species) and interspecific (between different species). Sponges and coral reefs would therefore be considered interspecific competition. In this case, sponges are generally successful on a coral reef, which could mean them taking food and space that the coral reef needs to grow. However, in outcompeting the coral, it may eventually lead to coral death, which is not good for the sponges. Therefore, in competition, both species may suffer.

Procedure: Symbiosis Relay
Goal: to pick up all of the items in your lane before the minute is over

1. Mark an area with a start and finish line, about 15 metres.
2. Make one lane for each symbiosis example - 4 lanes total (mutualism, commensalism, parasitism and competition).
3. Spread 10 of the 40 items (could be pieces of paper, paper clips, pencils, etc.) in each lane. These items represent things that these species compete for on a coral reef (space, food, sunlight etc.).
4. Split students up into groups of 2. Randomly assign the groups a symbiotic example listed in the background (mutualism, parasitism, commensalism or competition). It is okay if several groups have the same example. Based on the symbiotic relationship example they were given, students will either have an advantage or disadvantage to the race to portray the symbiotic relationship on the coral reef. If you have more

field trip activities

than 4 groups, each pair of students will take turns completing the "minute to win it" game. Follow the rules based on your group assignment:

e. Mutualism: both "species" are working together to pick up as many items as they can from their lane collectively.
f. Commensalism: both "species" compete in the race, but only one person is allowed to pick up items.
g. Parasitism: the "parasite" in the group is not allowed to move. The "host" will have to carry the parasite with them across the finish line (piggyback or lifting) while picking up the items in their lane.
h. Competition: both "species" are competing against each other to pick up as many items as possible individually.

5. Set the timer for 1 minute.
6. Allow the first group of students to begin the game! Be sure each pair stays in their lane and does not interfere with the others.

Field Activity Discussion

- Who was the winner? / Did you expect this team to be the winner?
- Which group worked best together during the relay?
- Which group had the most difficult time working together?

References for activity

bfm3. (n.d.). Remoras galore: Commensalism on coral reefs. Coral Reefs Blog. Retrieved April 14, 2023, from https://coralreefs.blogs.rice.edu/2017/03/23/remoras-galore-commensalism-on-coral-reefs/#:~:text=The%20most%20classic%20example%20of,we%20might%20consider%20their%20back.
Society, N. G. (2022, October 31). Symbiosis: The art of living together. Education. Retrieved April 11, 2023, from https://education.nationalgeographic.org/resource/symbiosis-art-living-together/

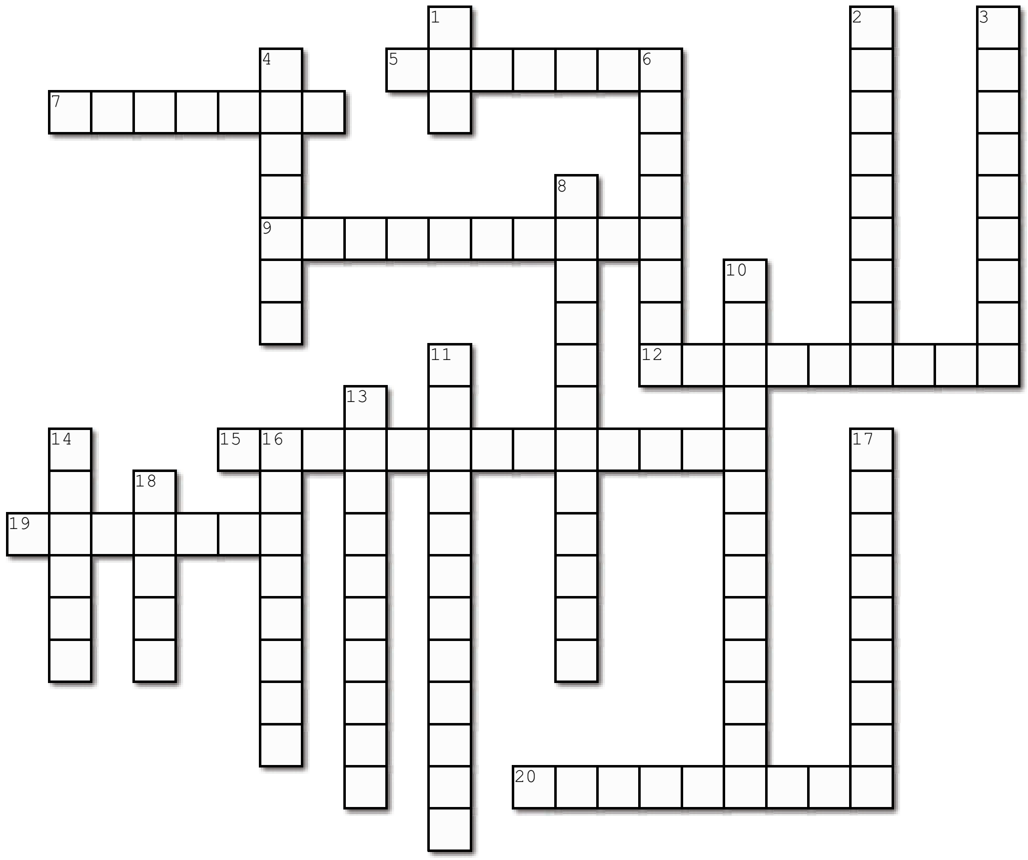
Additional Resources

Watch Friends of the Environment's "The Coral Reefs of Abaco: Our Future" on Youtube.
https://www.youtube.com/watch?v=nNbk_wH0RRw
Complete the accompanying crossword puzzle for the video (see next page)

Name:____________________

Coral Reefs

Complete the crossword puzzle below



Created using the Crossword Maker on TheTeachersCorner.net

Across

5. Green Sea ___________ primarily eat algae and seagrass, occasionally jellyfish and sponges.
7. This is what we call fish who eat algae off of the reef or rock.
9. Animal that consumes pieces of rock and coral and produces sand
12. Zooxanthellae provide coral with _______________ and their colour.
15. Microscopic algae that live inside coral tissue
19. Branching, hard coral with cylindrical branches
20. Coral _____________ is what happens when corals get too stressed

Down

1. Source of energy for coral reefs
2. Reefs protect the _________________ from big waves.
3. Teamwork between organisms
4. Predatory fish that live on coral reefs. Critically endangered.
6. A type of hard coral that scientists are using in coral reef restoration. One of the fastest growing corals.
8. Coral reefs have a high __________________, meaning there are many different species found on them
10. Usually found in pairs. They eat algae off the rock and even feed each other!
11. Scientists call the floating, inflatable bathtub for baby corals that they're growing 'coral _______________'
13. Chemical in sunscreen harmful to coral reefs
14. An entire colony of coral is made up of many tiny ____________
16. A filefish is an __________________, meaning they eat plants and animals
17. The scientist in the film, Craig Dahlgren, says corals are ______________ at an alarming rate
18. Apex predator of the ocean

FRIENDS of the ENVIRONMENT

BEP FOUNDATION
Bahamian Environment Protection

Solution on page 223

Open Ocean

The ocean covers 71% of Earth's surface and 65% is open, or deep ocean. The deepest part of the ocean is almost 11km deep, that's deep enough to fit Mt. Alvernia nearly 175 times. Mt. Alvernia on Cat Island is the highest point in The Bahamas at 63m above sea level.

Despite our extensive shallow sea, The Bahama islands are found surprisingly close to the deep ocean due to the layout of the ocean floor. This means that the deep ocean may be more vulnerable to land-based threats in The Bahamas than expected. The Bahamas is home to the world's largest submarine canyon, the Great Bahama Canyon which encompasses the Tongue of the Ocean and Northwest Providence Channel that leads to Northeast Providence Channel and drops off to the deep ocean. This canyon is prime habitat for deep-diving marine mammals. It is also a highly trafficked shipping lane. The Atlantic Undersea Test and Evaluation Center (AUTEC) is located on Andros, and is a base of operations for the United States Navy who coordinates practice naval exercises in the Tongue of the Ocean, which has been selected for the specific acoustic characteristics of the canyon.

Chapter Objectives

- Identify the zones of the ocean
- Demonstrate an awareness of major threats to ocean health
- Be able to identify flora and fauna characteristic of the open ocean
- Understand the value of ocean resources to The Bahamas

Ocean Zones

The open ocean can be split up into different zones classified by depth and the amount of light that penetrates to those depths. The photic zone (also called sunlight zone and epipelagic zone) is the layer of water where sunlight can penetrate, while the aphotic zone encompasses the depths below where light does not penetrate, and photosynthesis is impossible. The aphotic zone is divided into the mesopelagic zone, bathypelagic zone, abyssopelagic zone and the hadopelagic zone. Each zone hosts its own unique community of organisms.

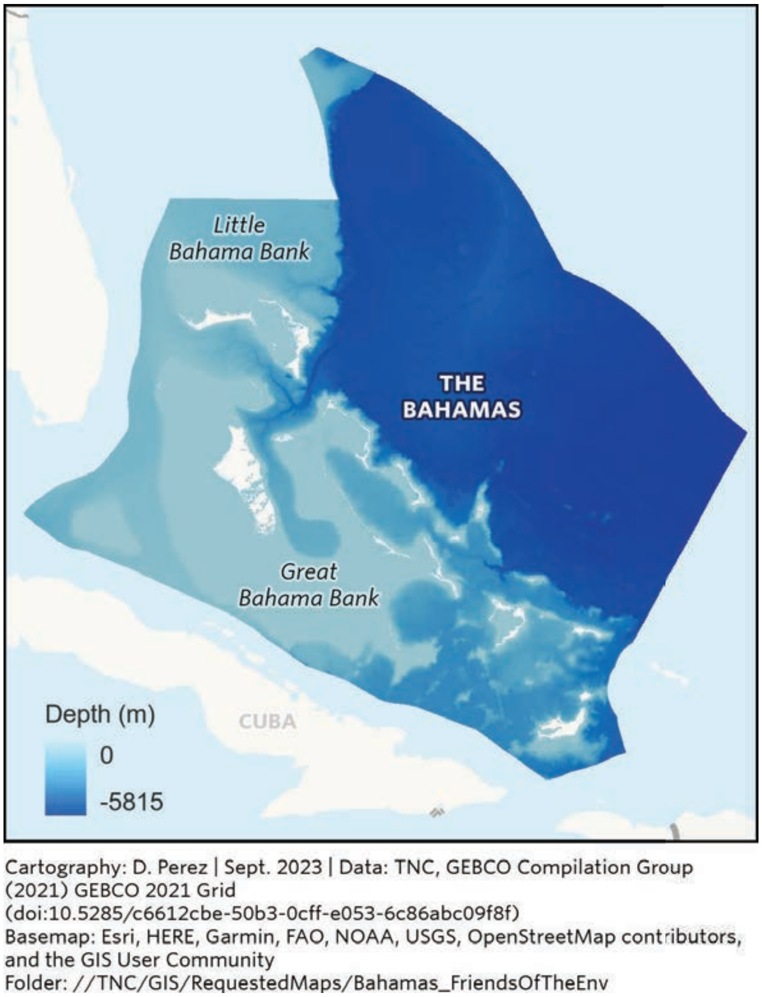


Figure 1. Map of Bahamian ocean territory. The highlighted area reflects the exclusive economic zone, while the shades of blue mark the depth contours of the ocean floor. Data: TNC, GEBCO Compilation Group (2021) GEBCO 2021 Grid (doi:10.5285/c6612cbe-50b3-0cff-e053-6c86ab-c09f8f)

Basemap: Esri, HERE, Garmin, FAO, NOAA, USGS, OpenStreetMap contributors, and the GIS User Community.

Epipelagic Zone (0-200m)

The first and shallowest category is the epipelagic zone that encompasses the surface of the ocean, from 0 to 200 metres. Sunlight provides these shallow waters with heat, creating a huge temperature range in these waters across the world, with tropical and subtropical waters being the warmest and having the best access to sunlight, allowing for the formation of important, productive ecosystems such as coral reefs and seagrass beds which rely on photosynthesis. Despite it being the smallest of the ocean zones, epipelagic waters host a huge diversity of life, ranging from tiny microscopic algae to huge whales weighing over 30 tonnes.

The epipelagic zone is the most productive zone of the ocean. It has an abundance of **dissolved oxygen** and sunlight which provides energy to huge numbers of microscopic phytoplankton via photosynthesis, causing high levels of primary production. Phytoplankton are microscopic, photosynthesising organisms and they are the foundation of most oceanic food chains. The epipelagic zone also provides energy for the deeper ocean zones, through dead organisms sinking down the water column.

Mesopelagic Zone (200m – 1,000m)

Also known as the twilight zone, little to no sunlight penetrates into the mesopelagic

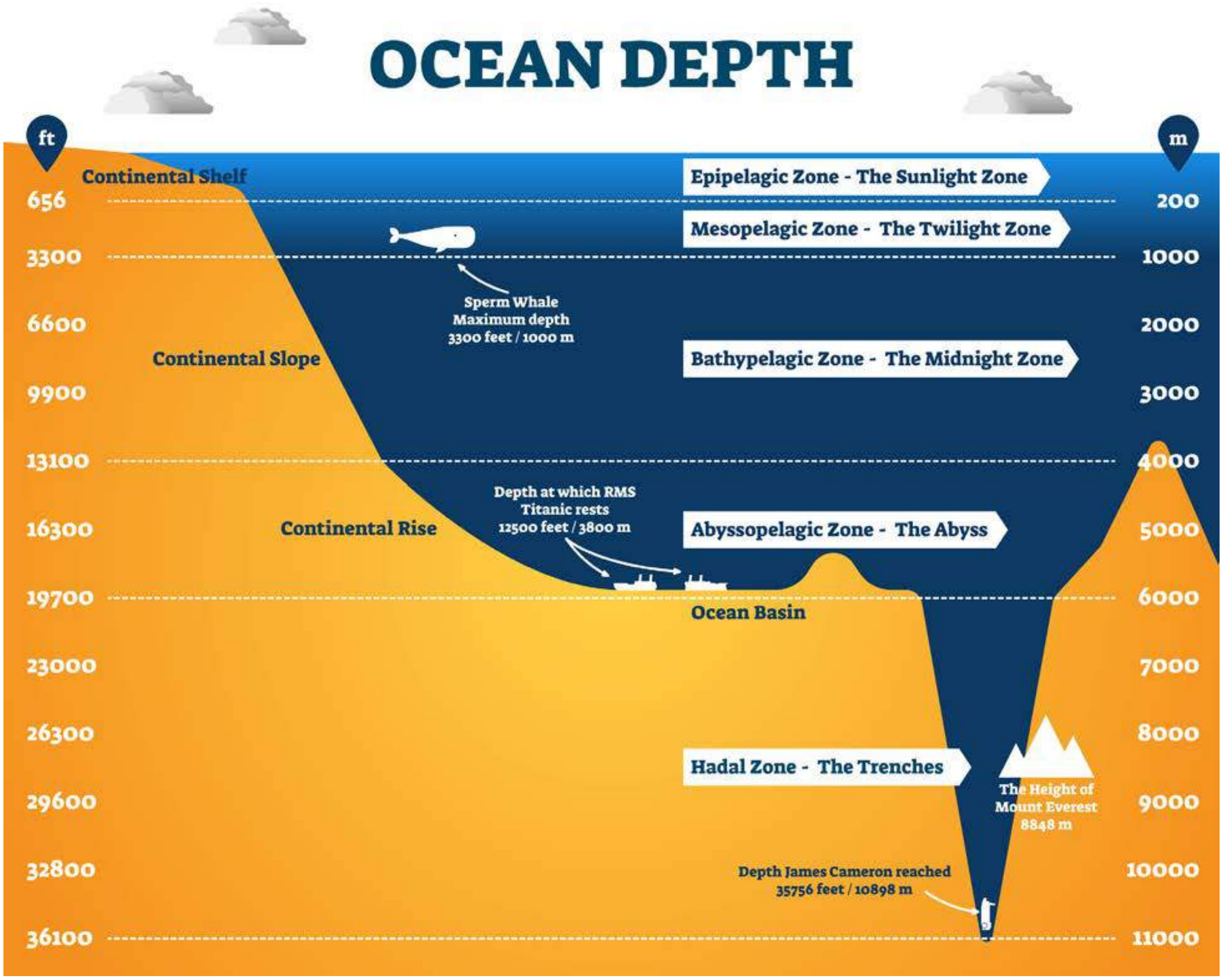


Figure 2. An illustration of the five depth categories of the ocean. Credit: VectorMine/Shutterstock.com.

zone, however, some dim light may be available in very clear waters. The mesopelagic zone also marks the start of dramatic changes in water temperature, salinity, and density with increasing depth. This zone is home to a range of strange organisms, all adapted for living in a low-light, low-food environment, for example, deep-sea hatchetfish, blobfish, jumbo squid, and **bioluminescent** jellyfish. These organisms are all very energy efficient and often rely on food sinking down from the epipelagic zone. Many animals travel up to the epipelagic zone at night to feed while also avoiding predators in mass vertical migrations. However, some top predators like melon-headed whales take advantage of nightly vertical migration. Satellite tagging studies in The Bahamas have shown that, instead of diving deeper during the daytime to access prey, melon-headed whales cleverly wait until nightfall to feed when the prey come closer to the surface in abundance (Joyce et al., 2017).

Many of the adaptations of mesopelagic organisms are focused on feeding and avoiding being fed upon. Fish are often small to minimise energy consumption and avoid predators, they are often dark coloured to avoid detection, or have specialised body shapes designed to reflect the low light and remain hidden.

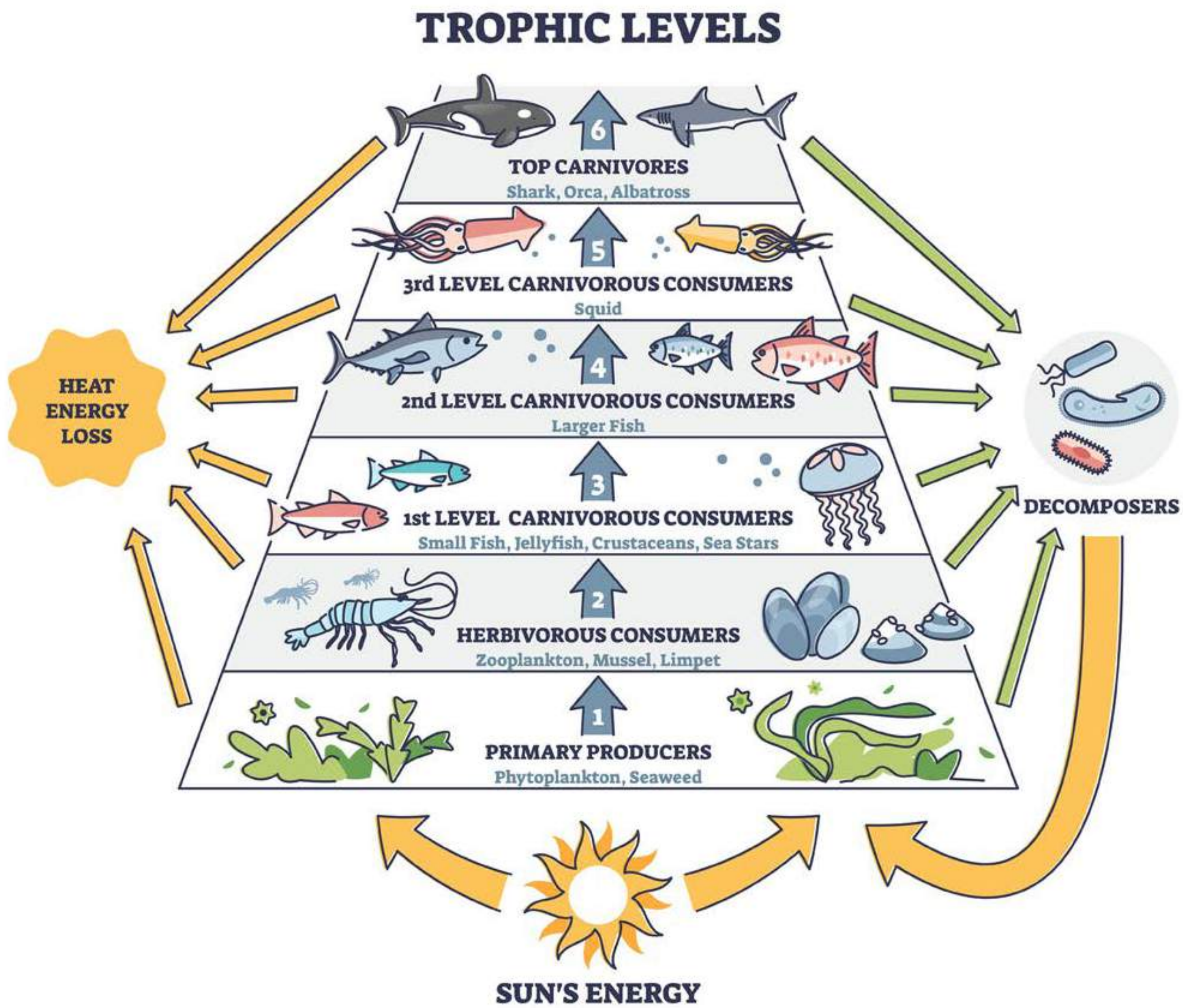


Figure 3. The Ocean's Food Chain. Credit: VectorMine/Shutterstock.com.

Bathypelagic Zone (1,000m – 6,000m)

Nicknamed the midnight zone due to the lack of available sunlight, the bathypelagic zone is almost void of primary productivity. This zone is much less densely populated than the two zones above it, however it is far from empty. Deep-diving whales, squid, and octopus can be found here as well as specialised fish and benthic organisms. All life living permanently in this zone has adapted to live in extreme cold temperatures, crushing atmospheric pressures, and constant darkness. Many of the organisms here grow to immense sizes like the giant squid but they grow very slowly, take a long time to reach sexual maturity, and live a long time. Scientists think this may be due to the lower temperatures these animals live in or they have evolved this way because larger animals tend to have more efficient metabolisms.

Predators often have specialised mouths to allow for easier prey capture and some species, such as anglerfish have evolved to use bioluminescent lures to attract their prey. Many of the whale species found in The Bahamas are specialised deep divers like

Figure 4. This squid has many characteristics common to animals living in the deep ocean, helping it adapt to its surroundings and avoid predators. Credit: Konstantin Novikov/Shutterstock.com.

the Blainville's beaked whale and sperm whales. Studies in The Bahamas have found that these whales dive over 1800m to feed on squid and fish (e.g., cutlassfish) in the bathypelagic zone and can hold their breath for more than an hour!

Some species of coral can be found as deep as 2,000m in some parts of the world. These deep-sea reefs form refuge for hundreds of species of fish and benthic organisms and act as important nursery and spawning grounds for many animals.

Figure 5. Deep sea hatchetfish collected in a net trawl in the Tongue of the Ocean, Bahamas. Hatchetfish use bioluminescence to help evade predators. Credit: Bahamas Marine Mammal Research Organisation.

Another key ecosystem found in the bathypelagic zone is hydrothermal vents. These are cracks in the seafloor in volcanically active areas through which mineral rich, super-heated acidic water flows. This fluid emerges at 300-400°C, warming the surrounding seawater to 8-23°C. The water here is low in oxygen but high in chemicals that bacteria can turn into food through a process called chemosynthesis. The vents also deposit ores from the dissolved minerals they discharge. These conditions create small ecosystems with huge numbers of mussels, crabs, worms and other animals crammed into the tiny vicinity of the vents. There are no known hydrothermal vents in The Bahamas, however much of our seafloor is unexplored.

Hadopelagic Zone (6,000m – 11,000m)
The space below the bathypelagic zone is almost exclusively made up of deep trenches such as The Mariana Trench. These areas are known as the hadal realm or the hadopelagic zone. Despite being so far from the surface, the hadopelagic zone is home to a range of different organisms. Because these deep-sea trenches are so isolated, they have led to the development of many new species that are adapted to these extreme conditions. Only a small number of fish are known to live this deep, but there is a wide range of other benthic life such as sea anemones, bivalves, crabs and bristle worms.

Ocean Features: Seamounts
Seamounts are underwater mountains, rising up more than 1,000m from the seafloor. Scientists estimate there are over 100,000 of these across the world. These rising structures disrupt ocean currents, causing upwelling of nutrients which supports life. Although much of the open and deep ocean is highly unproductive, seamounts act as production hotspots, supporting entire ecosystems, e.g. many deep-water coral reefs are found on seamounts. Seamounts can also act as important waypoints for migratory species travelling through long stretches of open ocean. The Bahamas has several seamounts in the open ocean, particularly to the southeast of San Salvador.

Ecosystem flora and fauna

Because the open sea covers such a huge area and variety of depths, the range of diversity found there is staggering. The epipelagic zone contains the majority of marine life due to its access to sunlight. The main plants found in this ocean zone are species of seaweed that drift in the water, they can be categorised into groups of red, green and brown algae. Also found in the open ocean, microscopic photosynthesizing phytoplankton drift freely in ocean currents which dictate their distribution. Phytoplankton are not the only type of plankton found in the ocean, larger mobile plankton called zooplankton also occupy the open ocean and feed on phytoplankton. The open ocean is also home to thousands of species of fish, some travelling individually, for example, many species of shark, and others swimming in large groups known as schools, like blue fin tuna and herring. Crustaceans and smaller species of fish like herring and sardines feed on zooplankton and then in turn become food for larger predatory fish. These larger predators can be in the form of sharks, marine mammals, tuna, marlin, mahi mahi, squid, octopus and even birds.

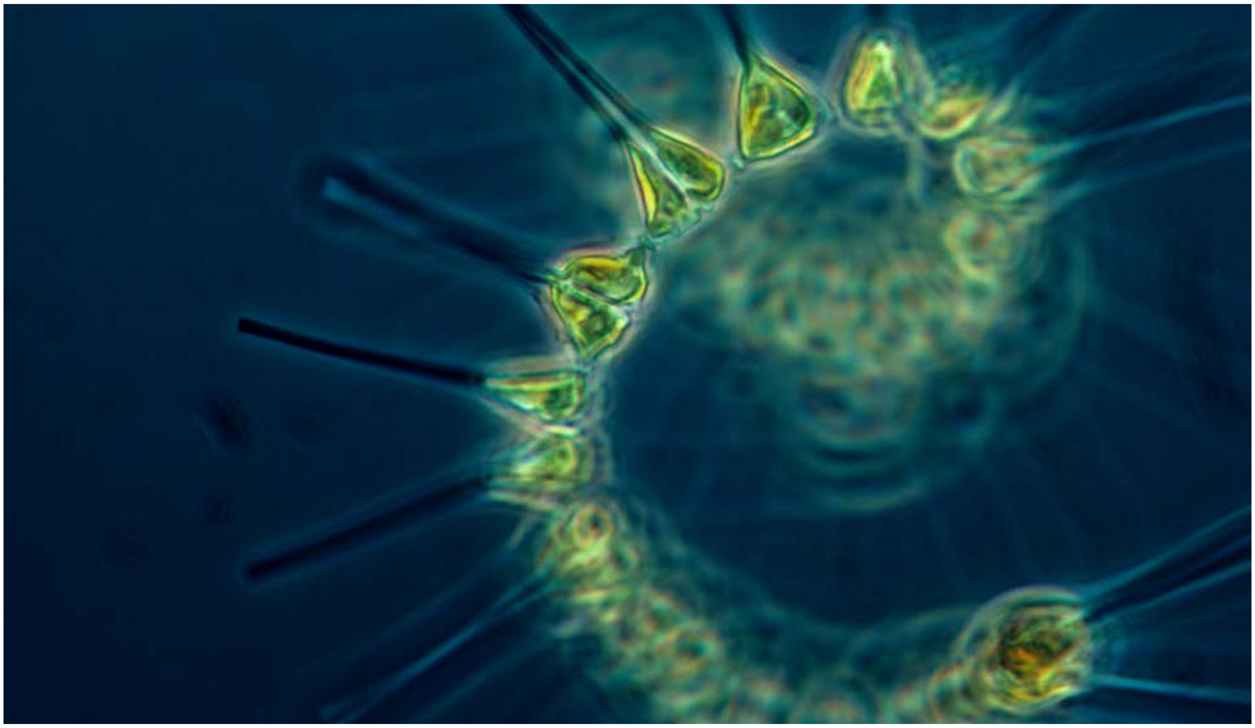


Figure 6. Phytoplankton. Credit: lego 19861111/Shutterstock.com.

Due to the lack of sunlight, plants are not found in the deeper ocean zones, except in the form of sinking detritus. Many animals live in the deeper ocean zones including wolf fish, eels, swordfish, squid, crustaceans and many other invertebrates. The deeper zones are also heavily used by marine mammals diving to feed. Due to the lack of primary productivity, many of these deeper-dwelling organisms are carnivores, they rise to the epipelagic zone at night to feed, rely on the sinking of dead organisms from shallower waters, or feed upon each other. There are only a few animals that can survive in the very deepest parts of the ocean. They include some species of squid and octopus, sea stars, sea spiders, sea worms and deep-sea crustaceans.

spotlight species

Blue Marlin

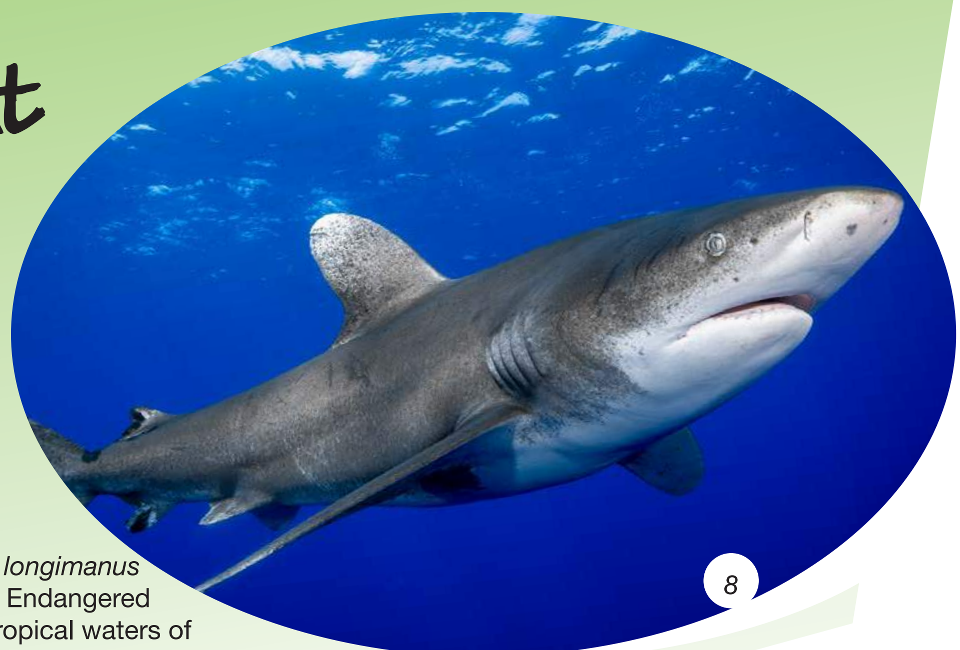
Scientific Name: *Makaira nigricans*
Conservation Status: Vulnerable
Distribution: Tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans

Figure 7. Blue marlin. Credit: kelldallfall/Shutterstock.com

The national fish of The Bahamas, the blue marlin belongs to a category of fish called "bill fish", which includes marlin, sailfish and swordfish. It feeds on a variety of animals close to the surface, using its sword-like bill to cut through a school of fish, bashing and stunning its prey before consuming it. Females can grow up to five metres in length, four times that of males. The blue marlin spends the majority of their lives far from land in the open ocean, where their only predators are killer whales, large sharks and humans. Due to their impressive size and distinct colouring, blue marlin are highly sought-after by game fishermen. In The Bahamas, blue marlin are catch and release only. Unless you are fishing in an approved tournament, all billfish caught must be returned to the sea unharmed.

spotlight species

Oceanic Whitetip Shark



8

Scientific Name: *Carcharhinus longimanus*
Conservation Status: Critically Endangered
Distribution: Tropical and subtropical waters of the Atlantic, Indian, and Pacific Oceans

Figure 8. Oceanic whitetip shark. Credit: Sail Far Dive Deep/Shutterstock.com.

The Bahamas is home to over 40 shark species, including bull sharks, lemon sharks, great hammerheads, tiger sharks, and oceanic whitetip sharks. Sharks have been threatened by humans for decades as a result of fishing bycatch and the shark finning trade. However, in 2011 The Bahamas became The Atlantic Ocean's first shark sanctuary, making it illegal to hunt sharks in Bahamian waters as well as to sell, import or export any shark products. Sharks are key indicators of ecosystem health and contribute significantly to The Bahamas GDP through wildlife tourism. Oceanic whitetip sharks may be found in deep ocean habitat throughout The Bahamas, but are well known to inhabit areas near seamounts off Cat Island and San Salvador, which has become part of local dive tourism.

spotlight species

Cuvier's Beaked Whale

Scientific Name: *Ziphius cavirostris*
Conservation Status: Least Concern
Distribution: In all oceans and across a range of latitudes from tropics to polar regions. Typically found near submarine canyons with steep slope habitat, such as that in the Great Bahama Canyon.

Figure 9. An adult male Cuvier's beaked whale, easily identified by its white head, erupted teeth at the tip of its lower jaw, and the linear scars marking its body. This linear scarring is a result of fighting with other males for dominance in their "harem-like" society. The circular scars are a result of parasitism from cookiecutter sharks. (Bahamas Marine Mammal Research Organisation).

There are 23 known beaked whale species, three of which inhabit the mesopelagic and bathypelagic zones in The Bahamas. These whales are extreme divers, for example, Cuvier's beaked whale can dive for over an hour at depths of over 1,000m. The longest and deepest foraging dive of any air breathing animal was a Cuvier's beaked whale diving for 137 minutes reaching a depth of 2,992m! They are toothed whales and use an acoustic ability called **echolocation** to map the environment around them, helping them hunt and navigate. Beaked whales are especially prone to injury as a result of noise pollution and vessel collisions.

Habitat Adaptations

Like all organisms, the animals living in the open ocean have evolved unique characteristics and adaptations to allow them to thrive there. Many of the adaptations of animals living in the shallower waters revolve around movement within the water. For example, bluefin tuna have streamlined bodies and specialised fins to allow them to swim faster and hunt with more agility. The fins of flying fish have evolved to make them strong swimmers but also enable them to actually glide through the air out of the water. Marine mammals are able to hold their breath for incredibly long periods of time, which allows them to take long hunting trips below the surface. Some species such as sperm and Cuvier's beaked whales (despite their small size) have evolved to dive to depths within the bathypelagic zone (usually 1,000-2,000m, but as far as 2,900m) dealing with severe changes in pressure.

Figure 10. A sperm whale diving in South Abaco. Credit: Bahamas Marine Mammal Research Organisation.

Deeper dwelling animals out of the reach of sunlight have had to evolve to catch their prey while avoiding predators in almost complete darkness. They do this in a variety of ways, some organisms produce their own **bioluminescence**. This can be used to lure in prey, to hide the silhouette of the organism's body from predators below, communicate, attract a mate and even as a light source to use while hunting. The lack of natural light at these depths has caused some animals to evolve without eyes. The bodies of many deep-sea organisms are completely transparent, e.g. many jellyfish and squid, making them even harder for predators to detect in low light. Many of the non-transparent animals are coloured black or red, this acts as **camouflage** as red light does not penetrate to these depths. Other fish have evolved silvery sides that reflect any light making them difficult to see. Because of the lack of easily accessible food, many deeper ocean animals can feed upon animals larger than themselves using large sharp, extended teeth and expandable jaws and stomachs.

Figure 11. Bioluminescent comb jelly. Credit: SaskiaAcht/Shutterstock.com.

The darkness makes finding a mate incredibly difficult for many animals. Some species such as the deep-sea anglerfish use light patterns and scent in order to find mates. In addition to this, male anglerfish are tiny and actually attach themselves to their mate using their hooked teeth. The flesh and blood vessels of the two fish then merge so that they share nourishment and don't have to locate other mates in their lifetime. In dark environments, marine mammals rely entirely on echolocation for communication and foraging, therefore it is critical that the ocean remain quiet.

One of the less understood adaptations of some deep-sea creatures is gigantism. This is when certain types of animals become enormous in size, a well-known example being the giant squid. Some creatures such as giant tube worms living on hydrothermal vents grow to their huge size due to abundant energy sources. However, for the majority of deep-sea gigantism cases, the animals live in habitats with a lack of food, it is not fully known how they achieve such severe growth. Many deep-sea creatures, including the gigantic ones, have been recorded to live for decades and even centuries . For example the Greenland shark (*Somniosus microcephalus*), are the longest-living vertebrates on Earth and are believed to be able to live for up to six centuries. These species tend to reproduce and grow to maturity very slowly, meaning recovering from large population drops is very difficult and can take decades.

In the ocean depths there is a lack of **dissolved oxygen** and sunlight, meaning organisms living in these conditions need an alternative to photosynthesis. Bacteria living on deep sea hydrothermal vents and near methane seeps produce their energy through a process known as chemosynthesis, where glucose is created using seawater and various chemicals outputted from the vents and seeps.

Ecological Role

The open ocean holds incredible ecological importance for the organisms living within the sea, as well as many outside it. A lot of the open ocean's importance comes from its sheer size, the abundance of life found within it and the important relationships between ocean organisms and ecosystems. One of the most important groups of organisms found in the open ocean is phytoplankton. These tiny marine plants are not just an important foundation for marine food webs, they are also responsible for producing roughly half of the oxygen that humans and other land animals breathe. If any serious long-term changes to the chemistry or processes of the open ocean were to occur, i.e. as a result of global warming, it could mean severe consequences for all the organisms (marine and terrestrial) that rely on phytoplankton.

The open ocean also absorbs huge amounts of atmospheric carbon dioxide, slowing the effects of greenhouse gas emission and climate change. It is estimated that nearly half of the carbon dioxide produced by humans during the last 200 years has been absorbed into the ocean. Ocean plants, including phytoplankton, also absorb carbon dioxide when photosynthesising and use it for growth. This carbon dioxide then sinks to the bottom of the ocean when the plants die, preventing it from being reintroduced to the atmosphere. The surface of the ocean absorbs over 50% of the sun's heat that reaches Earth. Important ocean currents then distribute this heat around the world, flowing for thousands of miles dictating our climates. The open ocean is also an essential part of the water cycle, giving life to many terrestrial organisms thousands of miles away. Huge amounts of water evaporate from the surface of the ocean, rising into the atmosphere as water vapour. When this vapour comes into contact with colder air, it condenses, forming clouds and rain, travelling huge distances during this process.

As previously mentioned, many of the organisms found in deeper waters migrate up to the shallows to feed and vice versa. This linking of different vertical regions of the ocean means that the ecological health of ecosystems throughout the water column depend on one another. For instance, fishermen have found deep sea pelagic organisms in the guts of commercially important fish caught near the surface. If the populations of these deep-sea fish were to drop, the surface fisheries would be negatively affected through loss of food. There is also evidence showing that deep regions such as seamounts and underwater canyons have been affected by overfishing, which will in turn affect the organisms depending on these areas.

Economic Value

With so little known about the open ocean, particularly the deeper regions, it is extremely difficult to put an economic value on the entire ecosystem. Much of the potential economic value of the open ocean is related to extraction: fishing, mining, bioprospecting. While not all of these opportunities have been realised, it is possible to isolate the value of some existing uses. For example, many of the high-value commercial fish targets such as swordfish and tuna are found in open waters, meaning the open ocean represents billions of dollars per year in fish stocks alone (globally). Traditionally, many fisheries were located in coastal waters, however, the depletion of these stocks has led to expansion to open and deeper waters. It is estimated that over 40% of all fishing grounds are now deeper than 200m.

In The Bahamas, Shark-related tourism brings in an estimated $100 million per year (Warwick, 2017), however not all of those activities are in the open ocean. Ocean sportfishing and fishing tournaments are popular activities across the country and also contribute to the tourism industry.

Figure 12. A dwarf sperm whale surfaces off Abaco. One of the smallest whale species found in The Bahamas, dwarf sperm whales often have to share their habitat with noisy vessel traffic. Credit: Bahamas Marine Mammal Research Organisation.

The ocean is also a sort of highway, hosting shipping lanes for commercial and recreational vessels. One of the busiest shipping lanes in The Atlantic passes through the Northwest Providence Channel in the northern Bahamas. Freeport, Grand Bahama is a hub for large vessels, as various services are provided such as fuelling and repairs. While The Bahamas does not currently benefit from shipping vessels that transit our waters, those that use the area for recreational purposes are required to purchase permits for cruising, sportfishing, and flats-fishing.

Threats and Conservation

Much like the rest of the ocean, the open and deep regions are under heavy threat from human disturbances.

Pollution: Chemicals

The epipelagic zone in particular, is heavily threatened and easily damaged by many forms of pollution. Fertiliser runoff from golf courses in The Bahamas can lead to poisoning of marine life as well as potential algal blooms, creating 'dead zones' along coasts with no oxygen dissolved in the water. Oil spills can also be devastating to the epipelagic zone as most oil floats on the water's surface, blocking sunlight and smothering and injuring animals. Damage from fertiliser runoff can be prevented through consistent use of phosphorus-free fertilisers, at the right time of year and in the right amounts, thus minimising the amount of potential overspill into oceans and rivers. Trees, shrubs, and grasses can be planted along the edges of fertilised areas to filter out excess nutrients, especially when bordering a water body. Other chemicals such as heavy metals and pharmaceuticals may be present in wastewater, and it is possible for them to enter the food chain.

Pollution: Plastics and Microplastics

Plastic is reaching all parts of the ocean! While plastic will linger in the epipelagic zone, it has also been found on the seafloor at a depth of nearly 7 miles in the Mariana Trench. Entanglement can result in drowning of air-breathing marine mammals and sea turtles and is often caused by lost or discarded fishing gear and ropes, which is known as ghost fishing. Ingestion of plastics occurs at many levels in the food chain, starting with animals as small as plankton. Plankton and small fish are common prey items so plastic tends to **bioaccumulate** in larger ocean predators - meaning that many human food sources are at risk of containing plastic and other chemicals that attach to those plastics. Research in Exuma Sound indicated that 21-30% of pelagic fish (dolphinfish, wahoo, yellowfin and blackfin tunas) captured for a study had plastics in their stomach (Zuckerman et al., 2017). This is a big concern for us, however ingestion of many small pieces of plastic can also lead to death of the fish themselves. Ingestion of microplastics by mesopelagic fish rising to shallower waters at night is a growing concern. The consumption of these microplastics increases buoyancy and can affect a fish's ability to return to the depths. It is even more difficult for these fish to differentiate between prey and plastic than most fish as they exclusively hunt at night. Ocean plastics can also negatively impact birds which forage in the sea. The main ways that individuals can help combat the plastic crisis are to cut down on single-use plastics and recycle wherever possible, for example, supporting The Bahamas' 2020 ban on single-use plastics. However, to have the greatest impact, manufacturers must be pressured into changing their ways and massively reducing the amount of plastic made.

Figure 13. Common types of debris found in our oceans include helium balloons and derelict fishing nets. Balloon releases are now illegal in The Bahamas. Credit: Bahamas Marine Mammal Research Organisation.

Pollution: Noise

Sound travels much faster and further in water compared to air and many forms of marine life tend to be very sensitive to sound. Marine organisms use sound for a variety of tasks such as finding food, finding a mate, feeding, and communication. Noise pollution can originate from many different sources, such as boat engines, navy sonar, oil and gas drilling, fish finders, and even coastal activities such as jet skiing.

Noise pollution can cause a decrease in affected populations of whales and dolphins and can even be fatal. Stranding events are known to occur shortly after military exercises. There was a well documented stranding event in the Northern Bahamas in 2000 which was linked to military activity. Many of the animals experienced severe ear damage and haemorrhaging as a result of the huge levels of noise they were exposed to. Marine mammals are not the only animals to have been documented in stranding events due to noise pollution, squid and octopus (including giant squid) have been observed to strand as a result of ships using seismic air guns in the area.

Ship Traffic

Aside from noise pollution, ship traffic can also impact marine life through vessel collisions. This threat is especially relevant to sea turtles and marine mammals. Size and speed of the vessels involved will affect the impact, but injuries may range from superficial to maiming to fatal. The Northwest Providence Channel is a major shipping pathway for vessels transiting The Bahamas and Nassau and Freeport are important ports-of-call for both passenger and merchant vessels. In The Bahamas there are numerous records of turtles being killed and dolphins and manatees receiving scars from boat propellers. The effects of noise pollution and vessel strikes can be effectively managed together. Studies have found that ship speed is a major factor contributing to a vessel's noise output.

Figure 14. Marine mammals strand for a number of reasons including illness and injury. The Bahamas Marine Mammal Stranding Network responds and collects data where appropriate to learn more about the cause and how we can help marine mammals in The Bahamas. Credit: Bahamas Marine Mammal Research Organisation.

Using designated shipping lanes with speed limits can reduce the noise output from ships, while simultaneously directing them away from areas with high collision risk and lowering the likelihood that any collisions that do occur will be fatal.

Overfishing

Overfishing occurs when fishery resources are taken from the sea faster than their reproductive rates allow their numbers to replenish, causing drops in populations. The longer a fish takes to grow to maturity the more vulnerable it is to overfishing. Advances in fishing technology since the 1980's have led to more and more fish being taken from the ocean, at increasing depths. Seamounts are also extremely vulnerable to overfishing. Because they tend to be so isolated, many of the species found on a particular sea mount will not be found on others, meaning if one seamount is affected by overfishing or habitat destruction, some species may be lost forever. The best way to combat overfishing is to protect important and vulnerable areas by implementing marine protected areas (MPAs). These are set up by the government and prohibit fishing and other harmful practices in areas of importance. Responsible management of fisheries is also another key method in avoiding overfishing. Strict regulations, scientific-based decision-making regarding catch quotas, and fishermen engagement are essential to ensure fish populations don't drop to dangerous levels.

Destructive Fishing Practices

Many marine animals which are caught by fisherman are not part of the target fishery, this is known as bycatch. Most bycatch is discarded, or killed in the process, including millions of turtles, sharks and marine mammals around the world each year. Long-line fishing is a particularly concerning fishing practice responsible for a lot of bycatch. Very long lines with multiple hooks hanging down are cast out into the ocean and left to catch whatever is attracted to the bait and lights that are set on the lines. Long line fishing has been banned in The Bahamas since the 1990's, however this practice is still used in international waters and common debris from the fishery often washes up on Bahamian shores. Ghost Fishing occurs when fishing gear is left unattended and animals become trapped or caught on the gear.

Figure 15. Ghost Fishing: these Nassau grouper were caught in a trap that was lost or left behind. Often, fish that are caught in ghost traps die. Credit: Krista Sherman

Organisms that are introduced into new areas that are not naturally found there are known as invasive alien species. Invasive species can often be devastating to local wildlife: introducing new diseases, predating on local species, or outcompeting local wildlife and causing extinctions. In the epipelagic zone, invasive species are regularly transported to new areas by attaching to the hulls of boats or by 'stowing away' in the water tanks of ships. By travelling this way, invasive species have spread all over the world, thousands of miles from their native habitats. Species do not only invade new ecosystems in shallow waters, the same deep-sea exploration submarine that explored The Titanic wreck was recorded accidentally transporting invertebrate species between different sets of hydrothermal vents during its travels. Lionfish are one of the most well known marine invasive species in The Bahamas. Based on research investigating the spread of lionfish in The Atlantic it is thought that they originated off the coast of Florida in several locations, possibly the result of poor aquarium management.

Climate Change

Climate change can, and is, affecting the open ocean in many physical ways that can have biological ramifications. An increase in the ocean's temperature can affect the position of currents, impacting weather patterns and the movement of organisms around the oceans. Absorption of carbon into seawater increases the acidity of the ocean, which is a concern especially for invertebrates that form their skeleton out of calcium carbonate.

Lack of Data

The open ocean is the world's largest biome, the deeper waters past 200m cover 87% of the seas bottom and include a huge variety of important ecosystems, e.g. hydrothermal vents, seamounts, cold seeps, canyons, etc. The benthic ecosystems at these depths remain poorly documented and are thought to contain the oceans highest amount of biomass and undiscovered species. Studies have suggested that effective conservation of this deep-sea biodiversity is essential for maintaining important functions across the ocean.

Did you know?

The Bahamas Marine Mammal Research Organisation has studied whale and dolphin populations in The Bahamas since 1991! They are based in Sandy Point, Abaco. Each summer they offer a "Whale Camp" for teens and young adults wishing to learn more about marine mammal research and conservation. www.bahamaswhales.org

Injured and/or stranded marine mammals should be reported to The Bahamas Marine Mammal Stranding Network (242) 366-4155.

classroom activities

How do whales talk?

Credit: Bahamas Marine Mammal Research Organisation

Objective: Students will learn that the noise interferes with whales ability to find each other in their families.

Summary: This game is about how sperm whales use sounds to communicate and recognise their family members. Each sperm whale family uses a different pattern of clicks, known as "codas". In this game, you assign each student a coda by whispering it in their ear, so no one knows what each other has.

Level: Grades 7-12

Duration: 15-30 minutes

Setting: Classroom

Procedure

1. Split the class into 3 groups.
2. Assign each student a coda for their relevant group by whispering it in their ear, so no one knows what each other has.
   Group 1: click, click (known as 1+1)
   Group 2: click, click, pause, click-click-click (known as 1+1+3)
   Group 3: click-click-click-click, pause, then click (known as 4+1)
3. Have students walk around the room without speaking, but making their codas. They can use their tongue to "click".
4. Once they find others in their family with the same coda, students must sort themselves out into the groups that represent their common whale family.
5. For more of a challenge, play the game again, but play ship noise in the background (can be found on YouTube). If you do not have access to sound, make noise of your own to represent ship noise.

Supplemental Classroom Discussion

- What is the role of a top predator in an ecosystem?
- What can we do to help protect open ocean ecosystems in The Bahamas?

field trip activities

Field Trip Ideas

If possible, go on a class boat trip to go dolphin/whale watching. Liaise with environmental agencies in your communities. If this is not available in your community, consider visiting local ports or docks and interviewing fishers and mariners to learn more about how they utilise ocean habitats. Consider developing a short survey or interview to gather information about the types of fishery resources they target and the marine habitats they visit most often. Other topics of discussion could include fisheries regulations, marine debris, any concerns fishers have about their industry. As with any field trip, ensure students are properly chaperoned.

Utilise virtual programs to explore the open ocean from your classrooms.

Anthropogenic Threats

Chapter Objectives

- Understand human-caused threats to Bahamian ecosystems
- Discuss and identify solutions to those threats

Every ecosystem in the world shares a mutual threat; humans. Anthropogenic threats are those that are human-induced and negatively affect natural ecosystems; these can be direct or indirect. The main types of anthropogenic threats include pollution, introduction of invasive species, habitat changes (such as fragmentation, modification or conversion) and overexploitation of natural resources (Sponsel, 2013). Anthropogenic threats can lead to biodiversity loss, species extinction, global warming, a collapse of ecosystems and more.

Some anthropogenic threats discussed in the chapters include ocean acidification, sea level rise, coastal erosion and climate change.

Climate Change

Climate change refers to changes in the state of the global weather patterns accredited to the increased level of carbon dioxide produced by the use of fossil fuels such as coal, oil, and natural gas. Fossil fuels are non-renewable resources of energy that contain high percentages of carbon dioxide that is emitted when the fuels are combusted. The excess carbon dioxide in the atmosphere absorbs radiant energy causing the temperature of the earth to rise thus resulting in changes in the weather. This has and can have implications for natural and human systems all over the globe (IPCC 2013, 2014). The major sectors contributing to greenhouse gas (carbon dioxide) emission in The Bahamas are electricity and transportation, although in comparison to the rest of the world our emissions are low. While climate change in itself is a threat, there are many secondary aspects of climate change, for example ocean acidification, sea level rise and coastal erosion.

Ocean Acidification

25-30% of the carbon dioxide (CO_2) that is released into the atmosphere every year is absorbed by the ocean, therefore as atmospheric CO_2 levels increase so do the levels in the ocean (NOAA, 2023.). Ocean acidification is the decrease in pH of the ocean, which is caused by the uptake of CO_2 from the atmosphere. "As CO_2 reacts with seawater it forms carbonic acid, causing a reduction in seawater pH. Seawater is naturally 'buffered' against these pH changes, but the buffering process consumes carbonate ions" (NOAA, 2023). Therefore, the more carbon dioxide absorbed by the ocean, the more carbonate ions are consumed.

As the ocean's acidity increases, its ability to absorb atmospheric CO_2 decreases. Unfortunately, this means without somewhere for future CO_2 emissions to go the impacts of climate change may be accelerated. Aside from the impacts of climate change like global warming, ocean acidification causes direct impacts to marine ecosystems by disrupting physical and biological processes. Organisms that form parts of their anatomy using calcium carbonate ($CaCO_3$) are especially at risk (European Science Foundation, 2009). For example, increasing ocean acidification has been shown to significantly reduce the ability of reef-building corals to produce their skeletons (Marubini et al., 2008). Coral biologists reported that ocean acidification could compromise the successful fertilisation, larval settlement and survivorship of Elkhorn coral, an endangered species. These research results suggest that ocean acidification could severely impact the ability of coral reefs to recover from disturbance.

There are many "side effects" or negative impacts from ocean acidification including slowing/reversing of calcification, poor growth and development of organisms and negative impacts to food resources. When shelled organisms are at risk, the entire food web may also be at risk (Feely et al., 2004).

These resources are used in human societies largely as a source of energy, water, and for fisheries, and overall they are an important part of the marine ecosystem, and contributor of sand. As such, ocean acidification is a threat to key Bahamian industries such as fishing and tourism. Ocean acidification is an emerging global problem; it's important to understand the risks and consequences and recognize that the underlying cause is **anthropogenic** CO_2 emissions. This understanding by governments and industries could help set forth critical decisions needed to reduce emissions and reinvigorate actions to reduce environmental stressors such as overfishing and pollution.

Sea Level Rise

The results of climate change include sea level rise. According to the Intergovernmental Panel on Climate Change, the global mean sea levels are currently rising and are expected to continue to rise far into the future (Church et al., 2013). The burning of fossil fuels and other human and natural activities over the years has allowed huge amounts of heat-trapping gases to escape into the atmosphere. It is these gases which have caused an increase in the Earth's surface temperature. The majority of this thermal energy (about 80%) is absorbed by the ocean. Sea level rise can be linked back to a specific set of factors, most of which are caused by climate change. These factors are: the melting of glaciers and polar ice caps, Greenland and Antarctic ice sheets, ice loss from Greenland and West Africa, contributions from water storages on land and thermal expansion (Church et al., 2013). These factors have been affecting the sea level in small increments over the past century. However, these small increments over time can have adverse effects on coastal habitats such as flooding, erosion, contamination of aquifers and agricultural soils.

This is crucial when it comes to The Bahamas because it is generally one big coastal region. For The Bahamas, sea level rise means decreased natural protection from natural disasters (i.e. increased flooding of communities), powerful storm surges (causing residents to evacuate their homes) as well as destruction of terrestrial and coastal infrastructure. It can also have adverse effects on the agriculture of The Bahamas by causing an increase in the salinity of the soil, damaging the crops and making it more difficult to farm on the land. Sea level rise is especially severe for The Bahamas because it is composed of low lying islands and this increase in sea level can eventually result in relocation of the residents as was similarly done with The Carteret Islanders of Papua New Guinea.

Figure 1: Coastal erosion on ocean facing beach. Photo credit: Olivia Patterson-Maura

Coastal Erosion

Climate change will affect the erosion of the coastal environment of The Bahamas through ocean acidification, sea level rise, and an increase in frequency and magnitude of storm events and wind speeds.

The islands of The Bahamas are founded on a variety of materials such as oolite, coral reefs, and shells that all have a calcium carbonate (limestone) base. Due to its porosity and chemical make-up calcium carbonate is susceptible to erosion when carbonic acid is present. Evidence of such erosion can be seen in the presence of blue holes around the islands of The Bahamas (Roach, 2008).

Coastal erosion can be facilitated through storm surge, which happens when extreme low pressures coinciding with storms cause a rise in sea level (Natural Environment Research Council, 2014). This can cause unusual flooding, which is often coupled with wave and wind action, as from a hurricane.

Increased wind speeds arise from the increased magnitude of land-ocean temperature differences. The increased wind speed may drive stronger upwelling, a process in which deep, cold water rises towards the surface, which will change the shoreline morphology. The changes in direction and strength of near-shore currents can also have intense impacts on coastal environments by altering the transport and retention of sediment (Woodson, 2010).

Pollution
Pollution is the presence in or introduction of a substance which is harmful or poisonous into the environment. There are five major types of pollution: air, water, noise, light and soil. Here in The Bahamas, there are some major concerns in regards to pollution.

Improper Solid Waste Management
Solid waste management is the safe and controlled disposal of garbage, refuse and sludge. The Bahamas in recent years have improved solid waste management practices; however pre-existing practices are still present creating adverse effects on both the environment and human health.
One method of waste disposal that can be observed throughout The Bahamas is open dumping. Many of the newer facilities that were initially landfills have become open dumping grounds. There are many adverse effects on the environment that are related to open dumps:

Figure 2. Sanctioned dump site in Snake Cay, Abaco. Photo Credit: Juliette Deal.

1. Ground water contamination- due to the seepage of toxic chemicals from the solid waste in the soil which will later be leached into the groundwater supply. These toxic chemicals are also carried by rainwater into ponds, lakes and oceans damaging aquatic habitats and posing a hazard to aquatic wildlife.
2. Fire and explosions- due to the presence of combustible materials fires are frequently releasing harmful gases and toxic emissions into the atmosphere.
3. Large vermin populations- around dumps there are large populations of rats, roaches, mosquitoes. This not only has a negative impact on the environment but presents itself as hazardous to human health.

Sewage and Waste Water Disposal
In The Bahamas there is a severe lack of infrastructure to manage sewage and wastewater. Many residential areas utilise septic systems and soakaways which can contaminate nearby wells and other water sources if not built or managed properly. Very few islands have sewage treatment plants, so this waste is often dumped in open fields. Liveaboard boats can also be a source of pollution in nearshore areas. Per marine pollution regulations, boats are either supposed to discharge their waste in the open ocean or at a suitable pump out facility. There is no management or oversight to understand what is happening with this waste in the absence of proper facilities. Waste can be transported through the movement of water, whether runoff or by natural tides and currents meaning that impacts can also spread. Waste disposal on land is also a concern as it can contaminate fresh water resources and enter the food chain. Improper waste disposal poses risks to marine and terrestrial life, as well as human health.

Unsustainable Development
Unsustainable development is when present progress is occurring at the expense of future generations. Unsustainable development persists because of the lack of land-use planning regulations, building regulations and enforcement of any existing regulations. Due to The Bahamas' dependence on the tourism industry and our status as a coastal destination hot spot, there are always proposals for large developments and these developments are often unsustainable due to their scale and the amount and types of resources required to construct and operate them. It should be noted that tourism is not the only industry that may create impacts due to development. Development impacts include: changes in landscape, loss of biodiversity; air, water, and land pollution; soil compaction and damage/destruction of native vegetation; disturbance of native fauna and local people; and high consumption of water and energy.

Unsustainable Use of Natural Resources
To use our natural resources sustainably, would be using them in such a way that they are able to replenish themselves or exist for generations to come. Unfortunately, many of The Bahamas' natural resources including fishery products, salt, aragonite, and freshwater, are being consumed at an unsustainable rate.

Figure 3. Conch midden at Coconut Tree Bay, Abaco. Photo Credit: Friends of the Environment

- **Overfishing**

Overfishing is the removal of a fishery resource from a body of water at a rate that exceeds the ability of the reproducers to replenish the population, resulting in the species either becoming depleted or very underpopulated in that given area. There are three major commercial species in The Bahamas: queen conch (*Aliger gigas*), Nassau grouper (*Epinephelus striatus*) and Caribbean spiny lobster (*Panulirus argus*). All of these species are being heavily fished; queen conch and Nassau grouper are both listed as endangered species. Globally, spiny lobster are listed as "data deficient", however The Bahamas has steadily been collecting data to support management of a sustainable fishery. Periodic stock assessments keep track of population health and the information is used to guide decision-making with the fishery. The Bahamas has the only marine stewardship council (MSC) certified spiny lobster fishery in The Caribbean. Certification enables the product to be sold to a wider audience, due to the desire of many markets wanting a sustainable product. The process of certification guides a number of policies and procedures that help improve and standardise the fishery; these policies could inform improvements in other fisheries. In general, efforts have been made to regulate Bahamian fisheries in the forms of policies, fishing regulations (size limits, maturity, fishing methods) and closed seasons. However, many of these policies are outdated or are simply not rigorous enough. It is also very hard for the relevant agencies to enforce regulations. Cross-sectoral cooperation and significant resources (e.g. money and man-power) are required to effect change.

- **Exploitation of natural resources**

The exploitation of natural resources is the use of natural resources (trees, salt, fish, aragonite etc.) for economic growth, which often leads to environmental degradation. Forms of environmental degradation include: pollution (air, water, land), habitat destruction and landscape degradation, destruction of natural flora and fauna, and desertification.

Figure 4. Clear cutting of vegetation. Photo credit: Jeff Gale

Table 1. Human uses for various natural resources and related concerns

Natural Resource	Use	Status	Concerns
Land **-Arable land**	-Development -Farming	Active	-Habitat loss -Soil erosion
Forests **Caribbean Pine** **Commercial hardwood species (ex. Mahogany)**	Timber for homes, furniture, etc.	Logging was an active industry from 1905-1970s	Exploitation of pine forests leads to habitat loss for endemic and endangered species, loss of native flora and fauna
Minerals including salt, bat guano, aragonite, petroleum and limestone	-Cooking purposes -Use in chemical industry -Fertiliser -Cement and steel production -Fuel Source -Building and road construction -Exploration	19th century active industry	-Water Pollution -Loss of biodiversity -Habitat destruction -Pollution -Soil erosion
Freshwater	Potable water for daily functions	Active	-Depletion of freshwater resource -Contamination
Coastal Zone (Mangroves, Sandy Beaches, Rocky Shores)	Development- particularly for tourism	Active	-Habitat destruction -Soil erosion -Loss of biodiversity -Pollution
Marine Resources (Fisheries)	Export and Local distribution as food source	Active	-Biodiversity loss -Overfishing commercial species to extinction -Pollution

Mitigation measures against Anthropogenic threats

After reviewing this chapter, the need for mitigation measures for anthropogenic threats are understood. Humans are disrupting a balance that allows life on Planet Earth to be possible.

Everyone must do their part to conserve our environment; as well as ensure that our governments are implementing policies to ensure the protection of our ecosystems on a larger scale. Some mitigation measures include:

1. Implementation and enforcement of regulations on commercial species to ensure sustainable fisheries.
2. Regulations should coincide with scientific evidence to ensure effectiveness
3. Use alternative energy sources to reduce the use of non-renewable resources that magnify greenhouse gas emissions
4. Proper disposal of all waste: solid, sewage, etc.
5. Implementation of land and marine parks

The Bahamas Protected Areas System

One of the main conservation approaches for ecosystems in The Bahamas is through establishment and management of protected areas. Our country has shown a commitment to ensuring the representation of key habitats in protected areas, for example through our participation in the Caribbean Challenge which resulted in the designation of many areas encompassing nearshore marine habitats.

This group of protected areas is also referred to as a "network" which alludes to its collective value in protecting ecosystems that are critical for organisms throughout their various life cycles. While there are still some gaps in our protected areas system such as the need for inclusion of certain habitats or greater coverage of some habitats, we should still be proud of what our country has achieved. The table below includes a list of Bahamian protected areas compiled by The Bahamas Protected Areas Fund (BPAF).

Table 1. Current protected areas of The Bahamas as of 2020.
https://bahamasprotected.com/protected-areas/register/

Name	Island	Acres	Type	Managing Entity
Abaco National Park *	Abaco	22,500	Terrestrial	Bahamas National Trust
Acklins Bight	Acklins & Crooked Island	61,436	Marine	Not Assigned
Adelaide Creek	New Providence	370	Wild Bird Reserve	Min. of Env. & Housing
Andros North Marine Park	Andros	5,000	Marine & Terrestrial	Bahamas National Trust
Andros South Marine Park	Andros	3,500	Marine	Bahamas National Trust
Betty Cay	Exuma	3	Wild Bird Reserve	Min. of Env. & Housing
Big Darby Island	Exuma	499	Wild Bird Reserve	Min. of Env. & Housing
Big Galliot Cay	Exuma	20	Wild Bird Reserve	Min. of Env. & Housing
Big Green Cay	Andros	519	Wild Bird Reserve	Min. of Env. & Housing
Black Sound Cay National Park	Abaco	2	Marine and Terrestrial	Bahamas National Trust
Blue Holes National Park *	Andros	40,000	Terrestrial with freshwater	Bahamas National Trust

Name	Island	Acres	Type	Managing Entity
Bonefish Pond National Park *	New Providence	1,235	Marine & Terrestrial	Bahamas National Trust
Booby Cay	Mayaguana	121	Marine	Not Assigned
Bottle Cay	Eleuthera	10	Wild Bird Reserve	Min. of Env. & Housing
Cable Beach Golf Course	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Carmichael North	New Providence	1,932	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Carmichael South	New Providence	731	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Cat Cays	Bimini		Wild Bird Reserve	Min. of Env. & Housing
Cay Sal	Cay Sal	4,162,319	Marine	Not Assigned
Cedar Cay	Eleuthera	5	Wild Bird Reserve	Min. of Env. & Housing
Central Abaco	Abaco	1,323	Protected Forests	Forestry Unit, Min. of Env. & Housing
Central Andros	Andros	240,488	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Channel Cays & Flat Cay	Exuma	45	Wild Bird Reserve	Min. of Env. & Housing
Cistern Cay (Private)	Exuma		Wild Bird Reserve	Min. of Env. & Housing
Clifton Heritage Park	New Providence	208	Heritage	Clifton Park Authority
Conception Island National Park	Conception Island	30,000	Marine & Terrestrial	Bahamas National Trust
Coral Harbour West	New Providence	1,781	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Corry Sounds	New Providence	697	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Crab Cay Marine Reserve	Abaco	1,075	Marine Reserve	Department of Marine Resources
Crab Replenishment Reserve *	Andros	4,000	Marine & Terrestrial	Bahamas National Trust

Name	Island	Acres	Type	Managing Entity
Cross Harbour	Abaco	15,182	Marine	Not Assigned
Deals Creek	Abaco	6,899	Protected Forests	Forestry Unit, Min. of Env. & Housing
Dolly Cay	Andros		Wild Bird Reserve	Min. of Env. & Housing
East Abaco Creeks - Cherokee	Abaco	5,902	Marine	Not Assigned
East Abaco Creeks - Snake Cays	Abaco	3,281	Marine	Not Assigned
East Abaco Creeks - The Bight	Abaco	4,062	Marine	Not Assigned
East Grand Bahama	Grand Bahama	55,013	Forest Reserve	Forestry Unit, Min. of Env. & Housing
East Grand Bahama	Grand Bahama	120,448	Marine	Not Assigned
East grand Bahama Cays	Grand Bahama	15,272	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Eight Mile Bay	Abaco	32,774	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Exuma Cays Land & Sea Park	Exuma	174,194	Marine and Terrestrial	Bahamas National Trust
Finley Cay	Eleuthera	12	Wild Bird Reserve	Min. of Env. & Housing
Fowl Cays National Park	Abaco	3,200	Marine & Terrestrial	Bahamas National Trust
Goat Cay	Cat Island	30	Wild Bird Reserve	Min. of Env. & Housing
Goat Cay	Exuma	30	Wild Bird Reserve	Min. of Env. & Housing
Goulding Cay	New Providence	5	Wild Bird Reserve	Min. of Env. & Housing
Graham’s Harbour Iguana &				
Seabird National Park	San Salvador	5,723	Marine & Terrestrial	Bahamas National Trust
Grassy Creek Cays	Andros	425	Wild Bird Reserve	Min. of Env. & Housing
Green Cay	Andros/ Exuma	2,697	Marine	Not Assigned
Green’s Bay National Park	San Salvador	586	Marine	Bahamas National Trust

Name	Island	Acres	Type	Managing Entity
Guana Cay	Exuma	5	Wild Bird Reserve	Min. of Env. & Housing
Harrold & Wilson's Ponds National Park *	New Providence	250	Terrestrial with freshwater	Bahamas National Trust
Harvey Cay	Exuma	5	Wild Bird Reserve	Min. of Env. & Housing
High Cay	Abaco	20	Wild Bird Reserve	Min. of Env. & Housing
Hogsty Reef	Inagua/ Acklins	12,322	Marine	Not Assigned
Hope Great House	Crooked Island	4	Terrestrial	Bahamas National Trust
Inagua National Park	Inagua	220,000	Terrestrial, RAMSAR	Bahamas National Trust
Joulter Cays **	Andros	92,734	Marine	Not Assigned
Kemps Bay	Andros	31,551	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Lake Cunningham	New Providence	173	Wild Bird Reserve	Min. of Env. & Housing
Lakeview	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Leaf Cay	Exuma		Wild Bird Reserve	Min. of Env. & Housing
Leon Levy Native Plant Preserve	Eleuthera	25	Terrestrial, Plant Preserve	Bahamas National Trust
Little Abaco	Abaco	6,671	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Little Darby Island	Exuma	336	Wild Bird Reserve	Min. of Env. & Housing
Little Harbour	Abaco	5,399	Protected Forests	Forestry Unit, Min. of Env. & Housing
Little Inagua National Park	Inagua	62,800	Marine & Terrestrial	Bahamas National Trust
Little San Salvador	Cat Island	450	Wild Bird Reserve	Min. of Env. & Housing
Lucayan National Park	Grand Bahama	1,937	Marine & Terrestrial	Bahamas National Trust
Mamma Rhoda Cay	Berry Islands	3	Wild Bird Reserve	Min. of Env. & Housing

Name	Island	Acres	Type	Managing Entity
Mangrove Cay	Andros	14,277	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Marine Farm	Crooked Island	4	Terrestrial	Bahamas National Trust
Marls of Abaco	Abaco	214,097	Marine	Not Assigned
Mars Bay	Andros	5,077	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Marsh Harbour	Abaco	6,277	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Marshall	New Providence	112	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Millars Sounds	New Providence	360	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Moriah Harbour Cay National Park	Exuma	22,833	Marine and Terrestrial	Bahamas National Trust
No Name Cay Marine Reserve	Abaco	1,213	Marine Reserve	Department of Marine Resources
Normans Castle	Abaco	12,011	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Northshore/Gap-Marine	Grand Bahama	233,919	Marine	Not Assigned
Paradise Island	New Providence	699	Wild Bird Reserve	Min. of Env. & Housing
Pelican Cays Land And Sea Park	Abaco	2,100	Marine & Terrestrial	Bahamas National Trust
Perpall Tract *	New Providence	192	Marine	Not Assigned
Peterson Cay National Park	Grand Bahama	1,090	Marine & Terrestrial	Bahamas National Trust
Pigeon Cay	Andros		Wild Bird Reserve	Min. of Env. & Housing
Pigeon Cay (Private)	Exuma		Wild Bird Reserve	Min. of Env. & Housing
Pigeon Creek & Snow Bay National Park	San Salvador	5,060	Marine	Bahamas National Trust
Primeval Forest National Park	New Providence	8	Terrestrial	Bahamas National Trust

Name	Island	Acres	Type	Managing Entity
Prospect Ridge	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Prospect Water Works	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Rand Nature Centre *	Grand Bahama	100	Terrestrial	Bahamas National Trust
Red Bays	Andros	15,063	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Red Sound	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Rock off Hog Cay	Exuma	3	Wild Bird Reserve	Min. of Env. & Housing
San Andros	Andros	57,834	Forest Reserve	Forestry Unit, Min. of Env. & Housing
Sandy Point	Abaco	48,947	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Sea Breeze	New Providence	233	Conservation Forest	Forestry Unit, Min. of Env. & Housing
Sister Rocks	Andros		Wild Bird Reserve	Min. of Env. & Housing
Skyline Heights	New Providence		Wild Bird Reserve	Min. of Env. & Housing
South Abaco Blue Holes National Park	Abaco	31,833	Marine	Not Assigned
South Berry Islands Marine Reserve	Berry Islands	63,005	Marine Reserve	Department of Marine Resources
South Bight	Andros	4,670	Forest Reserve	Forestry Unit, Min. of Env. & Housing
South West Marine Managed Area	New Providence	18,222	Marine	Not Assigned
Southeastern Bahamas Marine Managed Area	Crooked Island/ Acklins/ Mayaguana	6,053,010	Marine	Not Assigned
Southern Great Lake National Park	San Salvador	4,068	Terrestrial with freshwater	Bahamas National Trust
Stafford Creek	Andros	57,909	Protected Forests	Forestry Unit, Min. of Env. & Housing

Name	Island	Acres	Type	Managing Entity
Sweet Bread	Abaco	7,006	Protected Forests	Forestry Unit, Min. of Env. & Housing
The Caves	New Providence		Wild Bird Reserve	Min. of Env. & Housing
The Exuma (Jewfish Cay) Marine Reserve	Exuma	37,165	Marine Reserve	Department of Marine Resources
The Retreat	New Providence	11	Terrestrial	Bahamas National Trust
Tilloo Cay Reserve	Abaco	11	Terrestrial	Bahamas National Trust
Twin Lakes	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Union Creek Reserve	Inagua	6,150	Marine	Bahamas National Trust
Walker's Cay National Park	Abaco	5,800	Marine	Bahamas National Trust
Washerwoman Cut Cays	Andros	195	Wild Bird Reserve	Min. of Env. & Housing
Water Cay	Eleuthera	7	Wild Bird Reserve	Min. of Env. & Housing
Waterloo	New Providence	494	Wild Bird Reserve	Min. of Env. & Housing
West Coast Marine Park	San Salvador	10,313	Marine	Bahamas National Trust
West Side National Park *	Andros	1,500,000	Marine & Terrestrial	Bahamas National Trust
Westward Villas	New Providence		Wild Bird Reserve	Min. of Env. & Housing
Wood Cay	Eleuthera	15	Wild Bird Reserve	Min. of Env. & Housing

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Glossary

Abiotic Non-living. Referring to the absence of living organisms.

Adaptation A change in the structure or habit of an organism that makes it better adjusted to its surroundings. Short-term change is physiological (for example, acclimation) or behavioural (phenotypic adaptation), and long-term change is genetic (genotypic adaptation).

Ahermatypic Non-reef-building, as applied to corals.

Algal Mat A sheet-like accumulation of cyanobacteria ('blue-green algae') that develops in shallow marine environments.

Anchialine Having an underground connection to a larger tidal body (such as the sea) but no surface connection.

Angiosperm Plants that produce flowers and bear their seeds in fruits.

Anthropocene An informal term identifying the current geological age - a time period that marks the influence of humans on climate and the environment.

Anthropogenic Environmental change caused by the presence or activities of humans.

Aquifer A body of porous rock or sediment saturated with groundwater.

Autotroph An organism capable of synthesising organic nutrients directly from simple inorganic substances, such as carbon dioxide and inorganic nitrogen.

Berm Terrace of a beach that has formed in the backshore, above the water level at high tide. Berms are commonly found on beaches that have fairly coarse sand and are the result of the deposition of material by low-energy waves.

Bioaccumulate The gradual build up over time of a chemical in a living organism. This occurs either because the chemical is taken up faster than it can be used, or because the chemical cannot be broken down for use by the organism (that is, the chemical cannot be metabolised).

Biodiversity Short for biological diversity, biodiversity refers to the variety of life on the planet, inclusive of plants, animals, microorganisms, and the genetic information they contain. Bioluminescence The emission of visible light by living organisms.

Biomass Matter originating from living plants, including tree stems, branches, leaves as well as residues from agricultural harvesting and processing of seeds or fruits.

Biotic Of or pertaining to life and living organisms.

Blade The broad, flat portion of a leaf. Also known as lamina.

Camouflage Concealing coloration, in animals, the use of biological coloration to mask location, identity, and movement, providing concealment from prey and protection from predators.

Carbon Sink A reservoir that absorbs or takes up atmospheric carbon; for example, a forest or an ocean. See sequestration (carbon).

Carnivore An animal that eats meat.

Calcification The process of deposition of sparingly soluble calcium salts within or adjacent to the cells of animals and plants.

Climax Community The natural vegetation that exists in an area at the end of a succession. This develops over a long enough period of time without major environmental change or human interference. Climax is indicated by a community of vegetation that is stable, self-maintaining, self-reproducing, and in equilibrium with its environment. (See Plant succession).

Conifer (-ous) Any member of the division Pinophyta, class Pinopsida, order Pinales, made up of living and fossil gymnospermous plants that usually have needle-shaped evergreen leaves and seeds attached to the scales of a woody bracted cone.

Conservation The planned protection, maintenance, management, sustainable use, and restoration of natural resources and the environment, in order to secure their long-term survival.

Constructive waves Low energy waves that result in the build-up of material on the shoreline.

Crustose Coralline Algae A red macroalgae that accumulates calcium carbonate and generally grows as encrusting, pink-coloured, veneers over the reef substrate.

Cyanobacteria One of the major bacteria phyla, distinguished by the presence of the green pigment chlorophyll and the blue pigment phycocyanin. They perform photosynthesis with the production of oxygen.

Deciduous Falling off or being shed at the end of the growing period or season.

Decomposer Heterotrophs (such as scavenging birds and mammals, insects, fungi, and bacteria) that break down dead organisms and organic wastes into smaller and smaller components, which can later be used by producers as nutrients.

Decomposition The process of breaking down organic material, such as dead plant or animal tissue, into smaller molecules that are available for use by the organisms of an ecosystem.

Desiccation The drying-out of an organism that is exposed to air.

Destructive waves Very high energy waves, most powerful in stormy conditions. These waves are responsible for coastal erosion.

Detritivore An animal which feeds on fragments of dead and decaying plant and animal material.

Detritus Particles of organic material derived from dead and decomposing organisms, resulting from the activities of the decomposers. Detritus is the source of food for detritivores.

Diatom Microscopic single-celled organism found in naturally occurring water and moist soils. There are about 100,000 species. Distribution of different diatom species is affected by salinity, pH, and other environmental factors.

Dicotyledon Larger of the two subgroups of flowering plants or angiosperms, characterised by two seed leaves (cotyledons) in the seed embryo. Other general features include broad leaves with branching veins; flower parts in whorls of fours or fives; and a taproot.

Dissolution weathering This process occurs when water comes into contact with rocks and dissolves the minerals that make up that rock into individual elements.

Dissolved oxygen A measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms

Ecosystem A geographic area where plants, animals, and other organisms, as well as weather and landscapes, work together to form a bubble of life.

Echolocation An animal's use of sound reflections to localise objects and to orient in the environment.

Endangered (species) A species threatened with extinction. According to the IUCN, a taxon is endangered when the best available evidence indicates that it meets any of the following criteria: population reduction, restricted geographic range, small population size and decline, very small or restricted population and extinction probability analysis; it is therefore considered to be facing a high risk of extinction in the wild. (see extinct)

Endemic species Those that are restricted to a geographical area and do not occur naturally in any other part of the world.

Endolithic Growing within or between stones.

Epiphyte A plant or plant-like organism that grows on another plant, but is not a parasite.

Erosion The geological process in which earthen materials are worn away and transported by natural forces such as wind or water.

Eutrophication The process by which a body of water becomes, either by natural means or by pollution, excessively rich in dissolved nutrients, resulting in increased primary productivity that often leads to a seasonal deficiency in dissolved oxygen.

Evaporation The process by which a liquid turns into a gas; in the water cycle this substance is liquid water evaporating into water vapour.

Extinct (species) Having no living member remaining, either in the wild or in captivity.

Fauna Animals. The animal life characterising a specific geographic region, environment, or time period.

Fascicle A tuft or bunch of branches or leaves all arising from the same place.

Filter Feeder An organism that filters out food particles (such as plankton, bacteria, or detritus) from freshwater or seawater.

Fire climax community A climax community of vegetation that is maintained by periodic fires. (See Climax community).

Flora Plants. The plant life characterising a specific geographic region, environment, or time period.

Food Chain The transfer of energy from primary producers through a series of organisms that eat and are eaten, assuming that each organism feeds on only one other type of organism

Food Web A group of interconnecting food chains within an ecosystem, which often has numerous organisms at each level.

Foraminifera/forams Single-celled protozoan microorganisms that live near the surface of the ocean and have skeletons made of calcium carbonate.

Fossil The organic remains, traces, or imprint of an organism preserved in the earth's crust since some time in the geologic past.

Fragmentation (habitat) The breakup of large habitats into smaller, isolated fragments, which may or may not be connected by corridors.

Fragmentation (reproduction) A method of asexual reproduction, occurring in some invertebrate animals, in which parts of the organism break off and subsequently differentiate and develop into new individuals. It occurs especially in certain cnidarians and annelids. In some, regeneration may occur before separation, producing chains of individuals budding from the parent.

Grazer A herbivorous vertebrate animal that feeds on grass and herbs. An aquatic invertebrate that feeds by scraping or rasping material from organic mats (e.g. algal mats) coating the surface of a sediment or rock, or that eats larger plants.

Groyne A breakwater made from rock, concrete, wood, or metal, erected on a beach to inhibit the movement of sand and shingle and to protect against longshore drift.

Gymnosperm Any plant whose ovules and the seeds into which they develop are borne unprotected, rather than enclosed in ovaries, as are those of the flowering plants (the term gymnosperm means naked seed).

Halocline A well-defined vertical gradient of salinity in the oceans and seas.

Herbivore An animal that eats only vegetation.

Hermatype Reef-building coral characterised by the presence of symbiotic algae within their endodermal tissue. Also known as hermatype.

Heterogeneous Not originating within the organism in question; of foreign origin.

Heterotroph An organism that obtains nourishment from the ingestion and breakdown of organic matter.

Hydrology Hydrology is the study of the distribution and movement of water both on and below the Earth's surface, as well as the impact of human activity on water availability and conditions.

Interdependent Dependent upon one another : mutually dependent

Intertidal The zone of the shore that lies between the high and low water marks, which is submerged at high tide and exposed at low tide.

In situ On site or in its natural location.

Invasive species An aggressive introduced species which spreads and dominates its new location, competing with and often replacing native species and proving difficult to remove.

Invertebrate An animal without a backbone.

Irrigation To supply (land, crops, etc.) with water by artificial means.

Leaching To remove soluble components from a solid by infiltration of a solvent. For example, to leach salts from soil by dissolving them in water, which percolates through it.

Limestone A sedimentary rock composed dominantly (more than 95) of calcium carbonate, principally in the form of calcite.

Macrograzers A macroorganism that feeds primarily on plants (See macroorganism)

Macroorganism An organism large enough to be seen by the normal unaided human eye

Marine Of, or produced by the sea or ocean.

Medusa A jellyfish in the phylum "Cnidaria". The free-swimming body type, resembling an umbrella or bell, that floats convex side uppermost.

Micrograzers A microorganism that feeds primarily on plants. (See microorganism)

Microorganism An organism (such as a bacterium or protozoan) of microscopic or ultramicroscopic size.

Microplastic Small pieces of plastic, less than 5 mm (0.2 inch) in length, that occur in the environment as a consequence of plastic pollution.

Monoecious Describing plant species that have separate male and female flowers on the same plant.

Mutualism Interactions between two species that are beneficial to both species.

Monocotyledon Subclass of flowering plants (angiosperms) characterised by one seed leaf (cotyledon) in the seed embryo; the leaves are usually parallel-veined.

Native species A living organism that originated in their location naturally and without the involvement of human activity.

Near threatened (species) A species that is inclined to be threatened with extinction but not yet qualified as vulnerable.

Nematocyst A specialised cell in the tentacles of a jellyfish or other coelenterate, containing a barbed or venomous coiled thread that can be projected in self-defence or to capture prey.

Node A site on a plant stem at which leaves and axillary buds arise.

Omnivore An organism that eats both plants and animals.

Oolite A rock consisting of small round grains usually of calcium carbonate cemented together.

Oolith A small, round grain consisting of concentric layers of calcium carbonate, silica, or dolomite that have precipitated around a shell fragment, sand grain, pellet of alga, or other central object. Also called ooid.

Overexploitation The use or extraction of a resource to the point of depletion (for inorganic resources) or extinction (for organic resources).

Ovoviviparous Producing eggs that develop within the maternal body (as of various fishes or reptiles) and hatch within or immediately after release from the parent.

Pioneer zone The first line area to the shore, in which plants are adapted to the marine environment.

Plant succession The process by which the mix of species and habitat in an area changes over time

Quarry An area that is dug out from a piece of land or the side of a hill or mountain in order to get stone or minerals. Used also as a verb, "to quarry".

Queen's Commonwealth Canopy The Queen's Commonwealth Canopy (QCC) was launched at the Commonwealth Heads of Government Meeting in Malta in 2015, with the vision of creating a pan-Commonwealth network of forest conservation projects that marks Her Majesty The Queen's service to the Commonwealth and conserves indigenous forests for future generations. It is the first environmental initiative that The Queen gave her name to. Since its creation in 2015, when seven countries initially committed themselves to the initiative, a total of 54 Commonwealth countries are now committed to the QCC. Collectively, those countries have dedicated in excess of 115 sites and projects to the QCC, conserving almost 12 million hectares of indigenous forests around the Commonwealth.

Pellet A small mass of indigestible material that is regurgitated by predatory birds such as owls. Pellets may contain fur and bones and give clues to what the birds eat.

Population A group of individuals of the same species that live within a defined area and interact with each other.

Pteridophyte A vascular, non-flowering plant which comprises ferns and other vascular plants.

Resin A clear, yellow, sticky substance produced by some trees and plants and used to make varnish, medicine, or plastics, or a similar substance produced chemically for use in industry.

Rhizome A horizontal underground plant stem, possessing buds, nodes, and scalelike leaves, and capable of producing roots and shoots of a new plant.

Roost A roost is a place where birds or bats can sleep or rest safely.

Rosin A translucent material of varying colour resulting from the distillation of pine oleoresin. Rosin is used as an ingredient in printing inks, varnishes, and for rubbing on the bows of string instruments.

Salinity The amount of dissolved salts in seawater, measured by weight in parts per thousand (ppt).

Sand dune A mound of sand that is formed by the wind, usually along the beach or in a desert. Dunes form when wind blows sand into a sheltered area behind an obstacle.

Sclerite A hard plate or element of the exoskeleton of some arthropods.

Sedimentation Sedimentation occurs when eroded material that is being transported by water, settles out of the water column onto the surface, as the water flow slows.

Sequestration (carbon) The uptake and storage of atmospheric carbon in, for example, soil and vegetation.

Sessile Permanently attached to the substrate.

Sheath Of leaves, the base of a blade or stalk that encloses the stem.

Shoal An area of shallow water, or a submerged sandbank visible at low water.

Siltation The process of blocking something with sand or soil; the sand or soil that blocks something.

Skeletal sand Skeletal sands are made of the remains of animals and plants and generally have not travelled very far from their source. The size of skeletal sands depends on the skeleton they came from and the amount of exposure to wind and waves. Most skeletal sands come from tropical regions.

Soil Erosion The detachment and movement of topsoil by the action of wind and flowing water.

Storm berm A berm formed by the upper reach of storm wave surges or the highest tides. Storm berms generally include an accumulation of seaweed, driftwood, and other water-borne materials. See "berm".

Stygofauna Animals that live permanently underground in water. They live in a range of groundwater habitats—from tiny spaces between sand grains to pools and streams in caves.

Speleothem A secondary mineral deposited in a cave by the action of water. Also known as a cave formation.

Subsidence A process that occurs over millions of years where erosion causes a volcanic island to sink to the seafloor.

Symbiosis Any interactive association between two or more species living together.

Terrestrial Related to, or living or growing in or on, land.

Transect A straight line that cuts through a natural landscape so that standardised observations and measurements can be made.

Turbidity Deficiency in clarity or purity (e.g. of water).

Turpentine An essential oil produced by steam distillation of pine woods and from gum turpentine; used as a solvent and a thinner for paints and varnishes.

Understory A foliage layer occurring beneath and shaded by the main canopy of a forest.

Uninodal Having a single node.

Vertebrate Any one of a large group of animals comprising all chordates (phylum Chordata) that possess a backbone made of vertebrae. Vertebrates include the fishes, amphibians, reptiles (including birds), and mammals.

Vulnerable (species) A species likely to be classified endangered in the near future unless circumstances that threaten reproduction and survival improve.

Zooxanthellae Unicellular, golden-brown algae (dinoflagellates) that live either in the water column as plankton or symbiotically inside the tissue of other organisms.

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Coral Reefs

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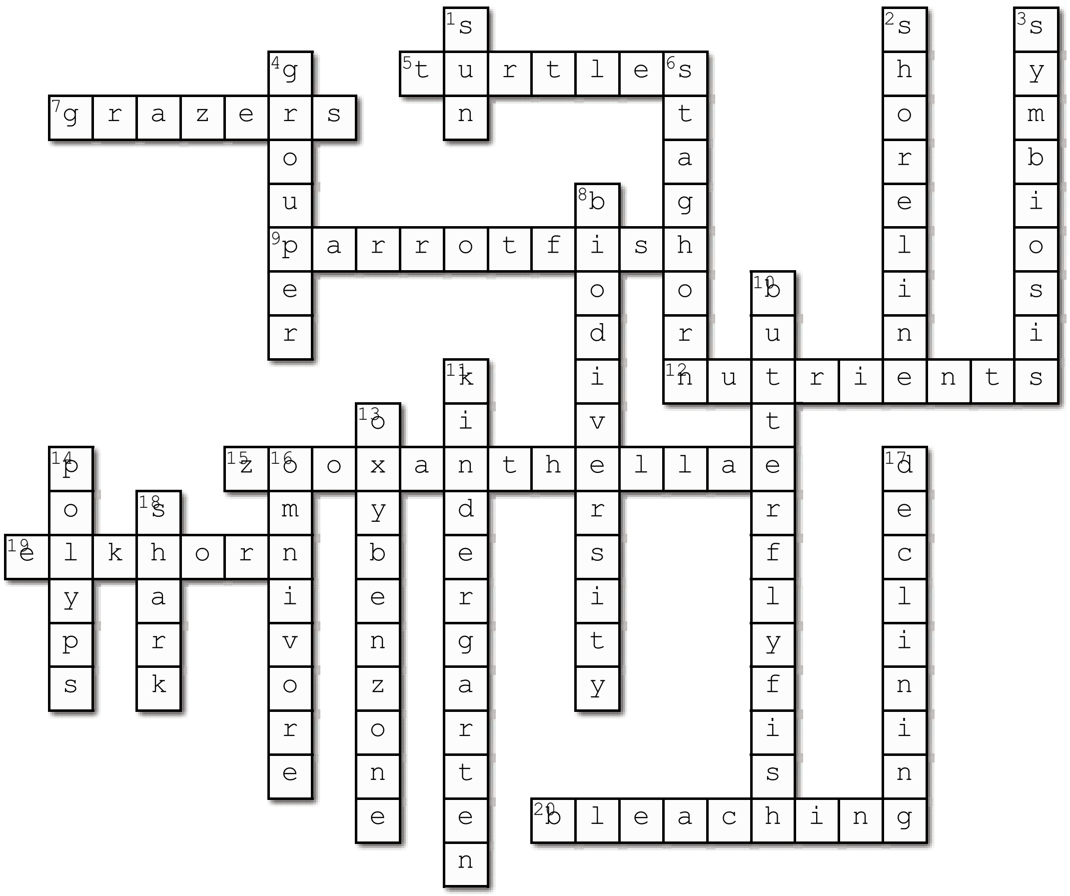

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