Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Preface

Prepared by:
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A Learning Resource Prepared for the Organization of Eastern Caribbean States (OECS)

(Protecting the Eastern Caribbean Region's Biodiversity Project)

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PROJECT PARTNERS

The Organisation of Eastern Caribbean States (OECS) came into being on June 18th 1981, when seven Eastern Caribbean countries signed a treaty agreeing to cooperate with each other and promote unity and solidarity among the Members. The Treaty became known as the Treaty of Basseterre, so named in honour of the capital city of St. Kitts and Nevis where it was signed. It is the mission of OECS to be a major regional institution contributing to the sustainable development of the OECS Member States by assisting them to maximise the benefits from their collective space, by facilitating their intelligent integration with the global economy; by contributing to policy and program formulation and execution in respect of regional and international issues, and by facilitation of bilateral and multilateral co-operation. For more information visit **oecs.org.**

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An Outline of the Guide

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V) Appendix I: Teacher Tips and Strategies

This section of the guide contains some background information about the benefits and challenges of taking students outdoors. Teacher tip sheets cover planning logistics and help teachers develop a conservation ethic with their students. Several hands-on, sensory awareness activities help increase the ability to observe and be present in nature, emphasize getting to know local species and their habitats, and inspire local action and stewardship.

VI) Appendix II: Biodiversity Resources

This section lists additional resources, web links and further background information.

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I/ Welcome and Introduction to the Biodiversity Learning Resource

This resource has been developed for teachers and students to support and inspire them in teaching and learning about biodiversity at the CXC level. The content has been written to be accessible to secondary or high school students.

Many experienced educators have contributed to creating this guide, endorsing "tried-and-true" activities with practical, realistic teaching strategies. The background information has been written for students and teachers to review and use, and most of the activities are student-directed, with worksheets and learning strategies that support their learning. A section has been developed to support and inspire student action for biodiversity. The Appendices include teacher tip sheets to support teachers taking students on outdoor excursions and field trips, as well as simple sensory awareness activities to heighten students' observation skills while working outdoors. Relevant learning outcome links to the CXC syllabi are included, as well as assessment suggestions and a resource list.

The resource was developed as a component of the "Protecting the Eastern Caribbean Region's Biodiversity Project" of the Organization of Eastern Caribbean States (OECS) and was funded by USAID. While the resource is intended primarily for use in secondary or high schools throughout the OECS, the content has been developed to have relevance to the Caribbean as a whole.

The resource consists of two parts. The first introduces learners to the basic principles and concepts related to biodiversity and its conservation and protection. The second provides background, case studies and activities related to some of the Caribbean's ecosystems: open-ocean, coastal zone, coral reefs, mangroves, and tropical forests. Two other parts have been recommended for development should the necessary financial resources become available. These two additional resources would cover the linkages between biodiversity and culture and a focus on endangered species and spaces.

The two parts and their individual sections have been designed as "stand-alone" resources. Also, it is not necessary for the learner to work their way through the two sections sequentially, except to say that the material in Part 2 would be more readily understood and integrated after having studied Part 1 first.

It should be emphasized that the activities included with each section are meant as a guide only, rather than as directives to be followed. Teachers and students are encouraged to develop examples, case studies and activities localized to their particular country.

However you choose to use this guide, we wish you enjoyment and inspiration in your exploration of the amazing biodiversity of this region.

What the teaching professionals have to say about *Biodiversity of the Caribbean* as a learning resource...

"This Learning Resource is a great concept and in many ways the resource is guaranteed to enhance learning at both the teacher and student level."

"The emphasis on peer learning, self-teaching and life skills is the way forward by most new day educators and thus are most appropriate."

[Part 1] is well written and will a "life changing course" when applied. The outdoor activities are great and the synthesis is engaging and rewarding making science of biodiversity real and alive in the hands of the student. It will open the windows to the world around the students and areas such as wealth from trees and all species have values engage the practical aspects which cement the thought processes required for conservation of biodiversity."

"...the Actions for Biodiversity [section] is a challenging one for both teacher and student since it now challenges [them to] know more about their situation and commit to making a difference. The Interview in the community has so many winning points, it should be a core activity in this and other sections."

"Biodiversity in the Caribbean contains a wealth of information and offers a more holistic and real-world approach to Ecology than most of the textbook based material that teachers and students normally use."

"Both units will provide a very useful resource for teachers of the CSEC (and CAPE) CXC syllabus."

"One of the most useful features [of the activities in Part 1 are] the attempts to have students engaged in research and action, providing instructions for a range of activities such as debating, environmental management and so on. The questions and extensions should provoke thought and, if handled well by teachers, have a lasting effect beyond the passing of examinations."

II/ Suggested Learning Scope and Sequence

This learning sequence outline frames the development of the biodiversity sections. It combines learning styles and the main pedagogical learning theory of awareness leading to appreciation, understanding and action. The scope begins with the personal - what is relevant and understood by the individual – and expands outwards to one's natural community, then to the biodiversity of cultural and social communities. The scope next examines regional and global issues and finally, action learning: applying learning to effect change.

1) Environmental Awareness through Direct Experience

Start from where your participants are – focus on student experience. Begin with the personal: direct, sensory experiences with the natural world occurring in local surroundings. By starting with personal direct experiences, this allows participants to make meaning for themselves, and develop a felt context for understanding concepts, facts and information to follow.

2) Ecological and Natural History Connections

Next, study the natural environment. After participants have made some personal connections to the natural world, they are far more likely to assimilate ecological concepts, facts and information. Ecological concepts, including cycles and processes, relationships of organisms, and the diversity and importance of species and ecosystems are covered next.

3) Culture, Nature and Environments

Move outwards to discover local environments, communities and cultural connections. The environment is not just a natural biological entity, but includes social, cultural and spiritual meanings as well. By exploring their own cultures and traditions and those of others, students gain a deeper perspective on their relationships to the environment, and on environmental problems and solutions. Bioregionalism and place-based learning are important components.

4) Environmental Actions for Social Change

Expand the scope to include the political context of the environment and biodiversity, including global environmental issues and links between local, regional, international and global environments. Local and global issues around biodiversity can be examined. Emphasize the development of personal action skills that empower individuals to act responsibly. Action learning activities (skills-building, inventories, surveys, cleanups, etc.), simulations, debates, and projects are noted strategies.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

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Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Part 1 / Introduction

Biodiversity Basics: The Spice of Life

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

III/ Part 1: Biodiversity Basics: The Spice of Life

Epiphytes
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

"The diversity of life forms, so numerous that we have yet to identify most of them, is the greatest wonder of this planet."

~ Harvard biologist E.O. Wilson

Introduction

This section contains three units that emphasize biodiversity basics, ecological concepts and ecosystem exploration. Each unit's background information and corresponding activities support the learning outcomes of the CXC syllabi of biology, integrated science and geography. The three units are described further below. They are "stand-alone" resources – i.e. you don't need to have taught one to use another, but are presented in a sequenced order that highlights the key concepts and specific information on biodiversity and the Caribbean ecosystems.

Section A: The Basics of Biodiversity

This unit answers some basic questions about biodiversity, why it's important, and its relevance to the Caribbean region. Students explore local biodiversity to discover key concepts through hands-on activities around habitat, the uses of biodiversity, and endangered species of the Caribbean.

Key Concepts

• Biological diversity or biodiversity refers to the variety of life on the planet, reflected in the diversity of ecosystems and species, and the genetic variation within and among species and the ecosystems.

• Ecosystem diversity is the variety of species and ecological processes that occur in different physical settings.

• Species diversity is the number, different kinds, and relative abundance of species, which vary from habitat to habitat.

• Genetic diversity is the variation among and within species linked to differences in their genes.

• Richness and abundance of biodiversity depends on type of habitat – the area that provides plants or animals with adequate food, water, shelter and living space.

• Habitat varies with climate, soils, **vegetation**, geography and other factors.

• Biodiversity changes naturally over time.

• Biodiversity is threatened everywhere on the planet due to human activity.

• Habitat destruction and the extinction of species is much greater from human activity than it is from other causes.

• Competition between plants and animals native to a particular habitat with species that have been introduced disrupts biodiversity.

• Our survival depends on preserving biological diversity.

Section B: Ecology Processes, Cycles and Systems

This unit focuses on some ecology basics including food webs, **ecological niches**, cycles and interdependence. The water cycle, and chemical and physical properties of water are emphasized. The activities in this section engage students in exploring places that are meaningful to them and examines connections to place and community, as well as the key components of ecosystems and ecological cycles.

Key Concepts

• Plants and animals in ecological systems live in a web of interdependence in which each species contributes to the functioning of the overall system.

• Food webs and energy chains illustrate the interrelationships of all living things.

• Each species occupies a niche within the range of environments in which it is found.

• All life forms show **adaptations** to the **environments** in which they live.

• Diverse **plant communities** tend to support diverse **wildlife** communities.

• Ecological laws are ultimately as binding on human populations as on other species.

• All forms of life are affected by changes in their environments.

• Species differ in their ability to adapt to changes in their habitat.

Section C:
Ecosystems and Action for Biodiversity

These activities explore concepts of biodiversity with an emphasis on the effects of human activities on the environment. It also focuses on efforts to conserve biodiversity through monitoring, research, personal action and eco-tourism. Activities involve students in carrying out ecological studies, exploring natural and human systems, and researching sustainable tourism.

Key Concepts

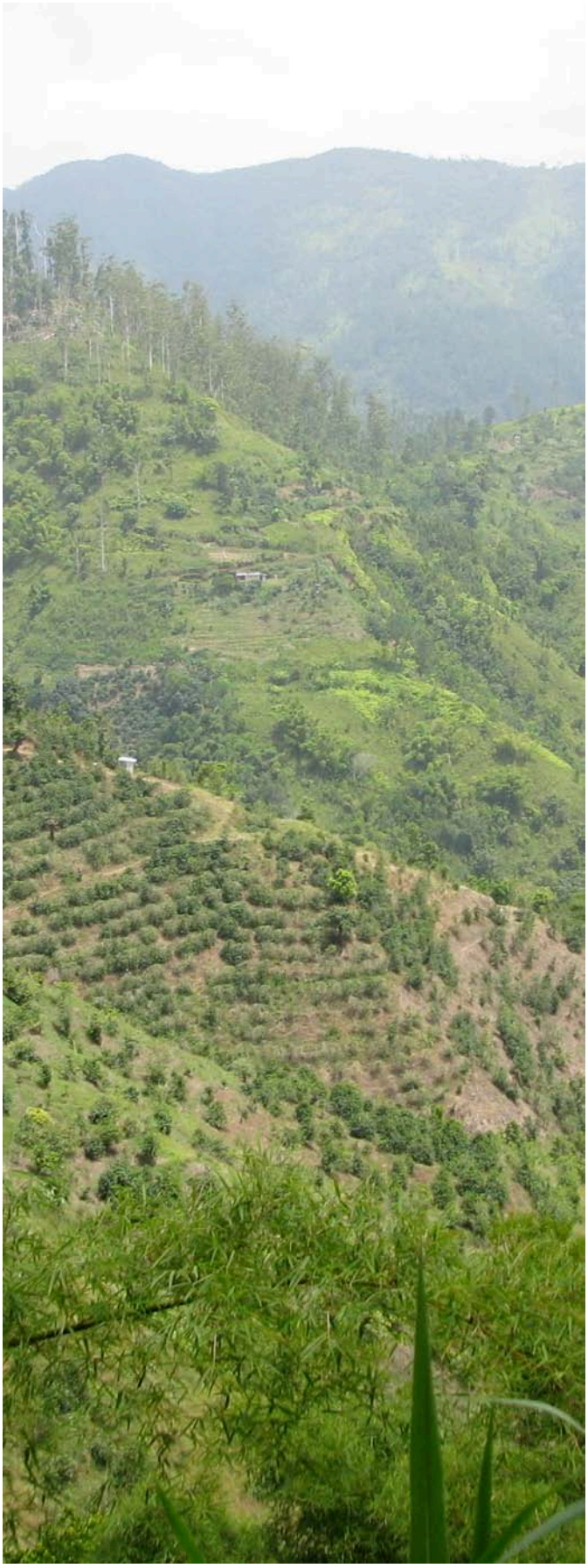
• Biodiversity is the basis for the region' history, cultures, foods, traditions, stories, legends, and art.

• Biodiversity of the Caribbean is a major tourism draw and a critical element of the region's economy.

• The biodiversity of the region is impacted by the human activities that result in: pollution, deforestation, over fishing, chemical use, development, and habitat fragmentation.

• Protection of biodiversity by government is not enough – this is a responsibility of everyone.

• Caring for biodiversity, sometimes called **stewardship**, by individuals and communities is an important tool in protecting and restoring the biodiversity of the Caribbean.



Small coffee plantation on the slope of Blue Mountains in Jamaica
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

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Part 1 / Section A

The Basics of Biodiversity

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

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CXC Learning Outcomes Matches

This section meets the learning outcomes of the CXC syllabi, as follows:

INTEGRATED SCIENCE

Section A – The Organism

General Objectives

Students should be able to demonstrate:

1. The interdependence of life processes
2. The relationship between an organism and its environment
3. The relationship between structure and function of an organism

GEOGRAPHY

General Objectives

Students should be able to demonstrate:

1. Interest in the nature of Natural and Human Systems and their interaction
2. An understanding of the processes at work in Natural & Human Systems
3. An understanding of the inter-relationships between the natural and human environment
4. An awareness of the need for the sustainable use of our resources
5. Knowledge and understanding of geography at the local, regional and global scales
6. An awareness and understanding of factors influencing patterns and changes in economic activity
7. Appreciation the relationship between the natural and human systems

BIOLOGY

Section A – Living Organisms in the Environment

General Objectives

Students should be able to demonstrate:

1. An understanding that there is both diversity and similarity of form in living organisms
2. An understanding that there is interdependence between living organism and their environment
3. An understanding that there is a flow of energy through living organisms within an eco-system
4. An understanding that materials are recycled in nature

Specific Objectives

Students should be able to:

1.1. Group living organisms according to observed similarities and differences
2.1. Identify the relative positions of producers and consumers in a food chain and relate the positions to the modes of feeling
2.2. Identify from a selected habitat, a food chain containing at least four organisms
2.3. Identify, from selected habitats, a herbivore, carnivore and omnivore
2.4. Identify from selected habitats, predator prey relationships
2.5. Construct a food web to include different trophic levels
2.6. Explain the role of decomposers
2.7. Discuss the advantages and disadvantages of special relationships to the organisms involved
2.8. Discuss the interdependence of organisms within a food web
3.1. Explain energy flow within a food chain or web
4.1. Explain, with examples, the continual re-use of materials in nature

Section C – Continuity and Variation

General objectives

Students should be able to:

2.6. Distinguish between continuous and discontinuous variation
4.1. Investigate the impact of environmental factors on genetically identical organisms

Section E –Environment and Human Activities

General Objectives

Students should be able to demonstrate:

1. An understanding of the importance of the physical environment to living organisms
2. Ability to undertake a simple ecological study
3. Understanding of the factors that affect the growth of populations
4. Appreciation of the finite nature of the world's resources
5. Understanding of the effects of human activities on the environment

Specific Objectives

Students should be able to:

1.1. Distinguish between environment and habitat
1.2. Discuss the importance of the physical environment to living organisms
2.1. Carry out a simple ecological study
3. 1. Identify factors that affect the growth of natural population
3.2. Illustrate using examples that human populations are subject to the same constraints as other natural populations
4.1. Describe various resources and their limits
4.2. Discuss the importance of, and difficulties encountered in recycling manufactured materials
5.1. Discuss the negative impact of human activity on the environment
5.2. Discuss the implications of pollution on marine and wetland environments
5.3. Discuss means by which environment could be conserved and restored

A.1. What is Biodiversity?

Biological diversity – or **biodiversity** – is a term used to describe the variety of life on the planet – the plants, animals, fungi and **micro-organisms**. Planet Earth is crawling, swimming, flying and teeming with life! From enormous whales cruising the oceans, to brilliantly coloured parrots, eagles, doves and other birds that fill the skies, to the millions of fish living in the seas and lakes, and the incredibly varied insects found almost everywhere, we share the land and sea with an amazing array of living things.

Our lives connect in thousands of ways with the plants and animals we share the Earth with. Everything we eat, our homes, our running water and our possessions are all formerly living things, or involve processes that connect with the lives and habitats of other species. Our health, cultural vitality and very survival are dependent on conserving the variety of life on Earth. All forms of life have value and play a role in the cycles of life on the planet. To care about them, we need to understand them. Biodiversity is the spice of life!

A.2. How Many Species are There?

We know approximately how many stars are in the Milky Way. We also know the number of atoms that make up the complex proteins in our bodies. But we do not know exactly how many species of organisms live on this planet. Estimates range anywhere from 2 million to 50 million!

In the face of such high uncertainty as to the numbers of species, biologists advocate applying the **precautionary principle** to decisions or actions that affect the **conservation** of biodiversity. This principle entails acting to avoid serious or irreversible ecological harm, despite the lack of scientific certainty as to the likelihood, magnitude or cause of harm.

We have a good idea of the number of larger species, like mammals and birds, but we are just beginning to discover how many invertebrates (animals without backbones) there are.
Scientists have described and named about 1.7 million species, or approximately 10 percent of the Earth's species, including:

- 950,000 species of insects
- 270,000 species of plants
- 19,000 species of fish
- 10,500 species of reptiles and **amphibians**
- 9,000 species of birds
- 4,000 species of mammals

Perhaps 90 percent – mostly plants and invertebrates – are still to be discovered! Though new species are being found worldwide, most are being discovered in the tropics – and their numbers are amazing. For example, as many as 160 species of beetles may depend on a single species of tropical tree.

A.3. The Basics of Biodiversity: Three Main Concepts

While we generally think only of the variety of species, biodiversity includes the billions of genes that species contain and the complex ecosystems that are their home, their habitat. These three levels of biodiversity are: species diversity, genetic diversity, and ecosystem diversity.

A.3.a. Species Diversity

One way of describing the biodiversity of a region is to count the number of species living there. This is called the region's species diversity. Climate, geography, history and other factors influence species diversity, e.g., a tropical rainforest has much higher species diversity that a desert region.

A **species** is a group of plants or animals that are more or less alike, and that are able to breed and produce fertile offspring under natural conditions. Each species is distinct from every other species. Horses are separate and different than donkeys, and chickens are distinct from parrots. From the 1700's when the famous scientist and taxonomist Linnaeus worked to classify all living things, scientists created a system that assigns all living things a species name. This is the most commonly referred to level of biodiversity.

A.3.b. Genetic Diversity

All forms of life on earth, whether microbes, plants, animals, or human beings, contain genes. Genes are the basic units of heredity, and carry the genetic code we inherit from our parents. Genes affect how different organisms look and behave. Genetic diversity refers to how each individual is different in some way from every other individual of its species. For example, you may have different colour hair or eyes from your friends, be shorter or taller or have smaller or larger feet. All breeds of domestic dogs belong to the same species, but there are many size, colour and shape variations.

Genetic diversity is the sum of genetic information contained in the genes of individual plants, animals, and micro-organisms. Each species is the storehouse of an immense amount of genetic information in the form of traits, characteristics, etc. The number of genes ranges from about 1000 in bacteria to more than 400,000 in many flowering plants and a few animals[1]. A house mouse has around 100,000 genes organized into four strings of DNA. If stretched out fully, each strand would measure about one metre, but would too thin to see if the naked eye! If the string were widened to that of a piece of wrapping string, the DNA strand would now be nearly a thousand kilometres long!

Genetic diversity is very important to the ongoing health of a species, for the more genetic diversity there is, the better a species can adapt to changing conditions in their environment. Genetic diversity also produces the raw material from which new species can evolve. Genetic information is used by humans to improve food crop production, develop stronger construction materials, and develop new varieties of ornamental and food plants. It is of-

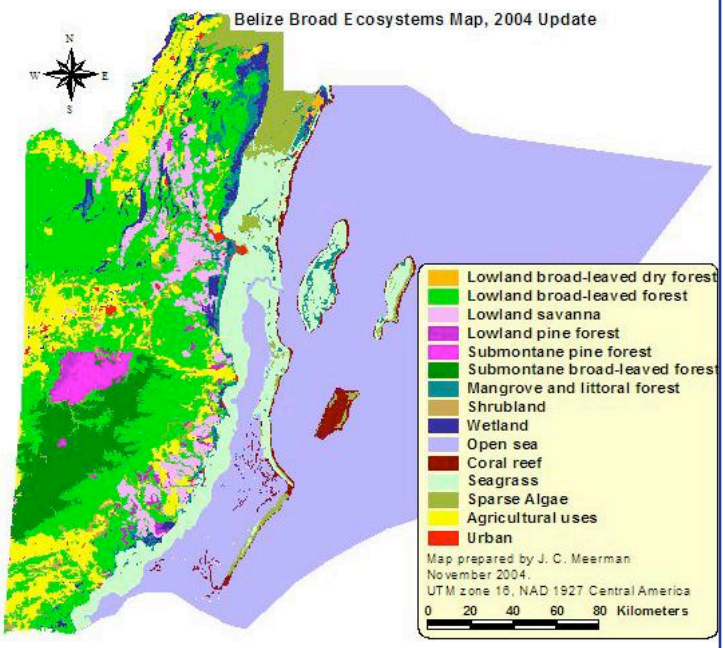
ten mentioned with reference to agriculture and maintaining food security. Unfortunately, **genetic erosion** of thousands of crops has already occurred, leading to the world's dependence for food on just a few species. Currently, a mere 12 species account for 75% of human nutrition, and just three crops – rice, maize, and wheat – account for 69% of the calories and 56% of the proteins that people derive from plants. The less genetic diversity within a species, the more vulnerable it becomes to further erosion and loss. This reduction of genetic diversity on food crops has a huge impact on food security for much of humanity.

A.3.c. Ecosystem Diversity

Ecosystem diversity is the variety of **habitats** or places where organisms live. When we look at the earth from space, we see a mostly blue sphere with irregular red, green, brown and white patches on its surface. As we zoom in closer, these patches become deserts, icepacks, mountains, forests, farmlands and cities. Each section is different, having it's own set of organisms, climate and physical environments. An **ecosystem** consists of all the living and non-living things in a given area that can interact with one another. An ecosystem can be as small as a puddle of water or a square meter of soil, or as large as a forest, a desert or an ocean. Different combinations of animals, plants, microorganisms, as well as the water, soil, rocks and air combine to make many types of ecosystems around the world. Two levels of ecosystem diversity are described: the diversity of species within an ecosystem, such as a coral reef, and the diversity of ecosystems on the planet.

The Caribbean can be broken down into geographically significant regions. Each sub-region contains a diverse range of species and ecosystems.
New York Botanical garden. (). Ethnobotany and floristics of Belize. Retrieved from: www.nybg.org/bsci/belize/belize.html

Biodiversity in Belize



Meerman and Sabido (2001). Belize ecosystem map. Retrieved from: biological-diversity.info/Ecosystems.htm

"Belize has some of the most extensive tracts of primeval rainforest in Central America. These forests are inhabited by healthy populations of some of Tropical America's rarest and most beautiful creatures including the puma, jaguar, ocelot, gray fox, Yucatn black howler monkey, Central American spider monkey, tapir, peccary, red brocket and white-tailed deer, agouti, paca, Mexican porcupine, scarlet macaw, jabiru stork, toucan, ocellated turkey, harpey eagle and many others.

Just off shore in the clear waters of the Caribbean is the world's second-longest barrier reef, supporting a rich assemblage of sea creatures including corals, manatees, sharks, rays, and others. Numerous habitats including rainforest, pine forest, savanna, marsh, and mangrove support 3,408 species of vascular plants in 209 families, with new species being discovered nearly every year." *(excerpt from New York Botanical garden. Ethnobotany and floristics of Belize. Retrieved from: nybg.org/bsci/belize/belize.html)*

For more information on biodiversity in Belize visit:
Reef Briefs *(ambergriscaye.com/reefbriefs/index.html)*

Biodiversity & Environmental Resource Data System of Belize *(biodiversity.bz/belize)*

Belize National Biodiversity Strategy (1998) *(cbd.int/doc/world/bz/bz-nbsap-01-p1-en.pdf)*

Belize Biodiversity Information System *(fwie.fw.vt.edu/WCS/index.htm)*

Threats and Challenges to Conservation in Belize *(tropicalconservationscience.mongabay.com/content/v1/08-03-03-Young.htm)*

A.4. Activity 1: Who Lives Here? Habitat Biodiversity

Banana tree growing on slope of the Blue Mountains in Jamaica
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

Objective:

Students participate in a hands-on exploration of a local natural area to gain an awareness of its species richness and variety, and understand what makes up an organisms' habitat.

Materials:

Clipboards (make your own from cardboard or old binder covers and big butterfly clips), pencils, Habitat Data Sheets for student teams, tools for exploring: trowels, buckets, plastic containers, hand lenses, small collecting nets, bug jars, binoculars, various field guides, art supplies.

Time:

1 or 2 periods outdoors, plus in-class time to create posters and/or a habitat mural.

Background:

Habitat

Whether you live in a large or small house, or townhouse, you need air to breathe, a source of water nearby, food, safe **shelter,** and enough space in which to live and grow. The other living things in our neighbourhoods share these same basic needs. A plant or animal's home is its **habitat** - this is where it finds its food, water, shelter and enough space to live and move, in a suitable arrangement. For example, there might be adequate food and shelter in an area, but no water close by. Within any area there may be many habitats – all slightly different from one another. The size of a habitat varies widely, from an entire forest to a pond, a rock or a patch of grass. Habitats, like our homes, are always changing. For example, a stream is affected by what happens within its watershed. For example, if a water source dries up, a tree is cut down, or a field is sprayed with pesticide, these changes will have serious impacts on the animals living there. Humans have choices in how we impact or influence the planet's habitats.

Protecting species of plants and animals is one of the reasons for creating parks: knowing where different plants and animals live, and the special habitats they need informs the decision-making process. In this activity, students explore a natural area to discover and document its biodiversity and range of habitats.

Procedure:

Part One: Biodiversity Explorers

1. Pair students up into teams, and give each team a clipboard, pencil and a Habitat Data Sheet. Define and discuss the terms Biodiversity and Habitat with the class. Discuss the things you expect students to look for, and explain that they will be collecting as much information as possible to develop a mural on the biodiversity they discover. Explain that they will be working to hone their observation skills through looking for biodiversity and habitat examples.

A.4. Activity 1: Who Lives Here? Habitat Biodiversity

2. Head outside to a local green space that has a few trees and plants – your school grounds or a local park (you don't need a large natural area). Do one or two sensory wakeup activities such as Sensory Wakeup Circle and Rainbow Chips, to tune in and focus everyone to their surroundings.

3. Have teams work to find examples of all the biodiversity clues on the student data sheet, taking turns locating and drawing their discoveries. Give them about 20 – 30 minutes.

4. Have some field guides available to look up any insects, birds or plants that students might find.

Part Two: Habitat Hunting

5. Next, have the teams choose a specific habitat: tell them to focus on a specific animal or plant and describe where it lives, some of its neighbours, and where gets its food and water. They should choose a name for their habitat, make a sketch of the components and record their findings on the data sheet. Tell students that they'll be making a poster or habitat mural with the information and drawings that they make outside, so it is important to capture as many details about colours, shapes and sizes as they can.

Back in Class: Habitat Diversity Mural

6. Give students art supplies and paper, and have the teams create a colour representation of the species and habitat they studied, with its name and specific components illustrated.. Have teams present their habitats to the class, and then create a Habitat Biodiversity Mural in a hallway with the completed posters.

Discussion might include:
- How many different types and numbers of habitats were found?
- What are some of the significant differences?
- Why is the diversity of habitats important?
- What are some ways they can be damaged by careless people?
- Are any of these habitats in danger of disappearing? Why?
- How could they be protected or enhanced?
- If you had to choose one of these to protect, which one would you chose and why?

Assessment Suggestions:

Data sheets are completed with sketches and adequate descriptive detail.

Habitat posters include references to an organism's food source (photosynthesis for a plant!), water (rain, a puddle, a nearby creek), shelter or home (e.g. an ant hill, hole in a tree, patch of earth to grow in), and space to live and move (e.g. is there enough space for a tree to grow? Enough area close by for caterpillars or pill bugs to collect food?)

Discussion Questions:

1) Most humans use resources far beyond the boundaries of their "habitats". Where does your food and water come from? Research what you had for lunch today, and refer to an atlas to explore what habitats some of the things come from that you and your family buy.

2) Protecting habitat for wildlife is one reason why parks are created. What are some other reasons?

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

A.4. Activity 1: Who Lives Here? Habitat Biodiversity

HABITAT DATA SHEET

Date: _____

Name(s): _____

Biodiversity: or biological diversity, the term used to describe the variety of life on Earth – plants, animals, fungi and micro-organisms.

Habitat: the place where an organism lives and can find food, water, shelter and living space in a suitable arrangement, varying in size from an ocean to a rotten log.

I. Biodiversity Evidence

Find all these clues, then draw one of each.

Find three different sized leaves from the same plant.	Find at least three different kinds of seeds.
Find at least three different kinds of leaves.	Find at least three leaves with different textures.
Find at least three different kinds of plant "skins" or surfaces.	Find at least 5 different kinds of plants.
Find a plant which has three different colours.	Find at least three different kinds of plants growing under a tree.

A.4. Activity 1: Who Lives Here? Habitat Biodiversity

Find at least three different holes made by animals.	Find at least three plants with different odours.
Find three different signs of an animal having eaten something.	Find at least three different kinds of leaf stalks.
Find three different consumers (animals) or evidence of them.	Find at least three different insects.
Find three different kinds of decomposers.	

A.4. Activity 1: Who Lives Here? Habitat Biodiversity

II. Habitat Hunting!

Now that you have explored the area's biodiversity, choose one habitat and describe it below, in words and drawings.

1. Habitat name (make up your own!) and description:

2. Plants you find here:

3. Birds or mammals, or their signs, that you see here:

4. Insects you see:

5. What else might live in this habitat?

6. Why would an animal or plant live here?

7. What are the signs of human influence?

8. Would you choose to protect this habitat and why or why not?

9. Make a rough sketch of the habitat you are visiting: include the food sources, water, shelter and living space for a chosen animal or plant.

A.5. Activity 2: Genetic Diversity and DNA[2]

Background:

All humans belong to the same species, but no two people are genetically the same, except for identical twins. DNA is an abbreviation for deoxyribonucleic acid. DNA is the building block of genes, and carries codes for what our body needs to make to survive, such as proteins, enzymes and hormones. Our DNA is organized into chromosomes. We have 46 chromosomes in total – 23 from each parent. Nearly 2 metres of DNA is located in the nucleus of every cell in our body! The millions of different combinations of DNA code give us the wonderful variety of differences among us. This activity explores seven of our genetic traits to see some similarities and differences in our genetic diversity.

Procedure:

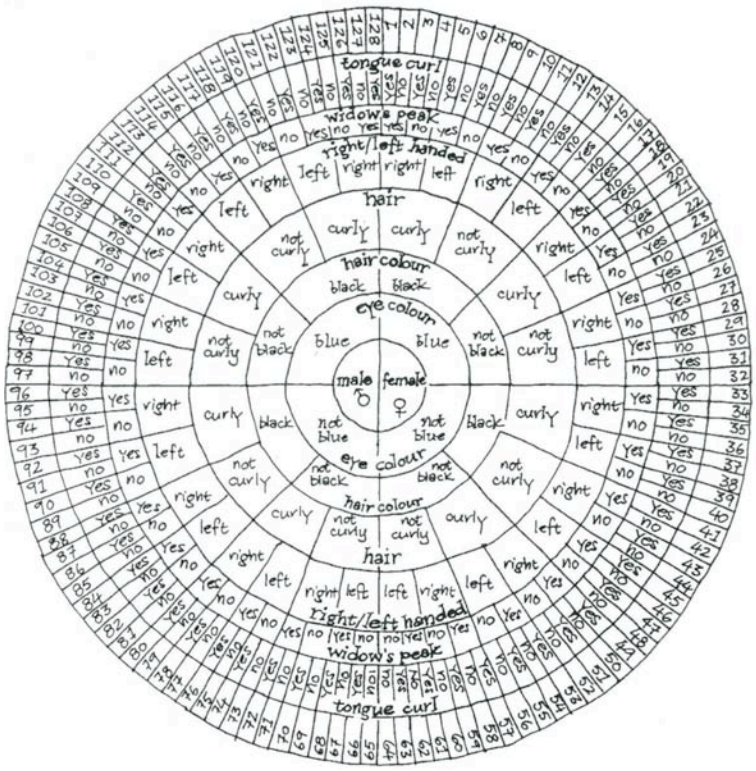
1. Starting from the inside of the wheel, colour in each characteristic as it applies to you. Move circle by circle to the outside of the wheel.

2. Record the number you get when you reach the edge of the circle.

3. Compare your number to others in the class. How many of you had the same number? Find out where your numbers branched off.

4. Use this activity with other family members to explore genetic similarities and differences.

The Genetic Wheel



Binder, D., Guy, S. and Penn, B. (1995).
Backyard biodiversity & beyond: a handbook for students and teachers.
Victoria, B.C.: Ministry of Environment.

A.6. Activity 3: Keys to Biodiversity

Objective:

Students will develop simple identification keys to organize information about biodiversity and develop classification skills and processes.

Materials:

Tree, shrub and plant leaves of different kinds and sizes: about 10 - 20 leaves per groups of four students. Please collect mostly dead leaves or needles for this activity. Some tree identification guides (optional).

Background:

Keys are useful tools for identifying species of any type. A dichotomous key is an identification tool which is based on a series of two (hence dichotomous) choices. A dichotomous key may be compared to a series of forks in the road that allows the user to make a choice, and therefore categorize organisms or things according to specific characteristics.

The importance of using dichotomous keys or other tools for classification is not just to learn the names of species or other objects. It is to sharpen your observation skills so you can differentiate between two similar objects or organisms. This skill or knowledge is then applied to problem-solving. For example, geologists classify rocks and landforms in order to determine the most likely place to find precious metals and oil and gas.

Procedure:

1) As a class, list a series of opposite characteristics that may be used to identify the students in the class. Write the series of opposite characteristics up on the board. For example:

Male	Female
Taller than 5 feet	Shorter than 5 feet
Large feet (bigger than size _)	Small feet (smaller than size _)
Curly hair	Straight hair

2) Now have students work to categorize their classmates into specific groups, i.e., students take turns to "sort" the class according to a specific characteristic. For example, the first division might be males and females. The class is now divided into two groups. The second choice might be height within each of the two groups – dividing each into two smaller groups. The third student may choose to split the four groups around hair colour or hair texture, and so on.

3) **The Object Key**

Once the class has had a chance to explore the concept of building dichotomous keys, develop a list of opposites that may be used to identify some object familiar to the students, for example, cell phones.

4) On the board, construct a dichotomous key to identify differences in the object.

5) Have students place their cell phones in a pile so everyone can see them. Test the key by choosing cell phones at random and having students key them. Do all students cell phones fit into one of the categories? If not, the trouble is usually caused by not using opposite traits.

6) **Leaf Keys**

Divide students into small groups and give each group a pile of leaves – at least 10 leaves per group and more if possible. Have each group develop a dichotomous key to sort and categorize the leaves, using characteristics of their choice.

Once a group has developed their leaf key, have two groups trade keys to test if the other groups' key works with their pile of leaves. Use the tree and plant field guides to identify species.

In summary, have students create a master list on the board of all the characteristics they used to develop their key.

Discussion / Journal Questions:

1) Why are identification keys an important tool in the study and conservation of biodiversity?

2) How do dichotomous keys measure the amount of biodiversity in a population?

A.7. Why is Biodiversity Important?

Should it matter to humans that other life forms are disappearing? Humans depend directly on the planet's biodiversity for survival, yet we often don't understand how our lives connect with the lives of plants and animals. Look around your home or school: everything is connected to the biodiversity of the planet.

Everything we eat is the combination of earth's processes that involve millions of living things – large and small. The paint on the walls comes from oil, a fossil fuel. The cotton clothing we wear is grown in tropical **wetlands**. Hardwood tables and desks come from tropical rainforest trees. The chalk we use on the blackboard at school is mined from underground deposits. Our health, survival and values are dependent on conserving the variety of life on Earth. Without worms and insects, most soil would grow nothing. Without bacteria, waste would never decay and break down to provide food for plants. Without **predators** such as crocodiles or sharks, sick animals would survive to infect the healthy ones.

Perhaps even more important, intact ecosystems perform many vital functions, such as purifying the air, filtering harmful substances out of water, turning decayed matter into nutrients, preventing erosion and flooding, and moderating climate. These functions are also called **ecological services**. Let's look at some specific values of biodiversity.

Plant Power!

When plant communities are damaged or destroyed, so too are important ecological services that people and other living things depend on. Plants perform each of the following services, just to name a few:

• Maintain a breathable atmosphere by giving off oxygen

• Keep us cooler by providing shade and releasing moisture through their leaves

• Prevent mud slides and flooding

• Remove the main "greenhouse gas," carbon dioxide, from the atmosphere. Plants, particularly trees, are a major "carbon sink" – they absorb carbon dioxide from the atmosphere and store it in their tissues, making them important in combating climate change.

• Provide the major food source for human populations around the world.

Tropical Feast

Many of our most useful species have come from tropical rainforests. Coffee, tea, cashews, rice, cassava, cacao, bananas, citrus fruits, pineapples, avocados, vanilla, mangoes, cardamom, cloves, peanuts, pepper, ginger, cinnamon and rubber originated in tropical rainforests. Representing only 7% of the planet's land surface, tropical forests are home to more than half the species on Earth. We have only begun to explore the variety of species in tropical forests, yet we have already destroyed many of them.

A Diversity of Prescriptions

Open your medicine cabinet and you'll probably see a number of products derived from **wild** plants and animals. In fact, more than 25% of the medicines we rely on contain compounds derived from or modeled on substances extracted from the natural world. Aspirin, or salicylic acid, the best known pharmaceutical in the world, is derived from the bark and leaves of willow trees, and its name comes from "Salix", the Latin word for willow. The drug quinine, used to fight the deadly disease malaria, comes from the forests of Peru. Calcitonin, a hormone used for the treatment of osteoporosis, and protamine sulphate, an important medicine used in open-heart surgery, both come from salmon. Micro-organisms may well be the best-represented species in medicine cabinets: more than 3,000 antibiotics, including penicillin and tetracycline, were originally derived from these tiny life forms.

Biodiversity and the Bottom Line

A huge number of products derived from wild species support all levels of the global economy, and many businesses are based on biodiversity. For example:

• Bees, butterflies, birds, bats, and other animals pollinate 75% of the world's staple crops and 90% of all flowering plants.

• Sales of prescription drugs that contain ingredients extracted or derived from wild plants are worth tens of billions of dollars in the United States alone.

• Each year, more than 10 million people visit the Caribbean islands to enjoy the beauty of our island ecosystems, beaches, weather and wildlife[3]. These visitors generates more than two and a half million jobs (or 1 for every 56)[4] and more than $20million US of economic activity[5]. Of this, the nine Organization of Eastern Caribbean States benefit from about $1.5 million US in revenues[6].

• Certain types of bacteria make nitrogen available for use by crops, pastures, forests, and other vegetation. Economists estimate that the value of this activity is $33 billion annually.

• The dollar value of services provided by ecosystems throughout the world is estimated to be US$33 trillion per year. (The value of all human-produced goods and services per year is about US$18 trillion.)

"At least 40 per cent of the world's economy and 80 per cent of the needs of the poor are derived from biological resources. In addition, the richer the diversity of life, the greater the opportunity for medical discoveries, economic development, and adaptive responses to such new challenges as climate change."

~ The Convention about Life on Earth, (cbd.int)

All Species Have Value

Many people believe that biodiversity should be preserved simply because it exists. Each species has value in itself, independent of human use. We as humans have no right to deprive future generations of the biodiversity we enjoy. Humans have a moral obligation to be careful stewards of the Earth. Future generations also deserve a natural world that is rich and varied. Our children will inherit the planet with whatever biodiversity we pass on to them. The decisions we make as individuals and as a society today will determine the diversity of genes, species, and ecosystems that remain in the future.

Another Useful Online Resource

The Convention on Biological Diversity is a treaty to sustain the rich biodiversity on earth. Visit ***cbd.int/countries*** for more information on the National Biodiversity Strategy and Action Plans of countries in the Caribbean.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Making Biodiversity Profitable: Biodiversity Prospecting for Conservation

In 1991, INBio, the National Biodiversity Institute of Costa Rica, and the U.S.-based pharmaceutical company Merck and Co. announced an agreement with the country of Costa Rica. INBio **(inbio.ac.cr/en/)** is a non-governmental, non-profit, public interest organization whose mandate is to conserve and promote biodiversity. Under this agreement, INBio would provide Merck with chemical extracts from wild plants, insects and micro-organisms from Costa Rica's national parks. These chemicals would be used in Mercks' drug development programs. In return, INBio was given a two-year research budget of $1.5 million dollars, technical support and training, as well as royalties on any resulting commercial products. As part of its agreement with Merck, INBio contributes 10 percent of its budget and 50% of all royalties to Costa Rica's National Parks fund. This contract, renewed several times, was the first of is kind. It is serving as a model for biodiversity prospecting between conservation organizations and companies around the world. Biodiversity is becoming an important national asset, and Costa Rica is the first developing nation to use this asset towards funds, conservation and technology.

A.8. Activity 4: A Wealth from Trees

Background:

Explore the connections between products we use from trees, and biodiversity in the rest of the world. Do you enjoy eating bananas, mangos, and oranges, sipping hot chocolate, riding your bike, travelling in cars, reading the newspaper, playing cricket? All these items involve products gathered from trees. We use the fruits, bark, wood, leaves and sap of trees for many purposes and products. Lets look at some of the trees growing here in the Caribbean and in different parts of the world, and how they are used.

Procedure:

1) Brainstorm with the class a list of as many uses for trees as you can.

2) Working with a partner, you will need:
- A copy of the Tree Products Chart
- A copy of Trees and Their Uses
- A list of common Caribbean Trees

3) Fill out the Tree Products chart by using information from the Trees and their Uses.

4) Next, choose a Caribbean tree from the list which interests you.

Find out more about this tree and develop a short report or presentation to make to the class.

Your report should include:
- Name and Scientific name of the tree
- Place of Origin
- Where it is found (Habitat requirements: rainforest/ dry rocky sites, etc)
- Short Description of the tree: Height, colour of bark, description of leaves, flowers, fruit.
- Picture or drawing of the tree, its leaves and fruit
- Local and Export Uses
- Any interesting facts or local stories about the tree

5) With the class, make a Tree Collage or Chart using your tree report, to display in the school, with pictures and facts about each tree. If possible, bring in items made from wood or tree products to display as well.

Tree fern in the cloud forest of the Blue Mountains in Jamaica
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

Some "Not-So-Famous" wood products include:

Paper: Paper insulation for electric cables, paper fabrics used in hospital masks and gowns, and the outer layer of gypsum wallboard

Cellulose products: Are you wearing any rayon? This fabric is made from wood pulp or cellulose, and is used to make shirts and women's clothing.
Melamine is also made from cellulose, and is a type of plastic used to make everything from eye glass frames to dishes.

Chemical products: Paint thinner, tar, alcohol, paint products

A.8. Activity 4: A Wealth From Trees

Trees and Their Uses

Here is a list of some important trees and the services and products we derive from them.

Cinnamon *(Cinnamomum verum)*
A small evergreen tree 10–15 metres (32.8–49.2 feet) tall, belonging to the family Lauraceae, and is native to India, Sri Lanka, Bangladesh, and Nepal. The bark is widely used as a spice due to its distinct odour and taste.

Coconut *(Cocos nucifera)*
This well known palm tree grows to a height of 100 feet (30 m) and is best known for its fruit, which provides coconut milk, cream, coconut meat and jelly. The wood is used for furniture and walking sticks and the leaves for thatching roofs.

Cork Oak *(Quercus suber)*
An evergreen tree native to the Mediterranean and Atlantic coast of Africa. The thick, deeply textured bark is stripped every 9 – 10 years to produce the traditional cork, widely used for bottle stoppers, insulation, table mats, etc.

Nutmeg *(Myristica fragrans)*
An evergreen tree originally from southeast Asia, also grown in the West Indies. The fruit of this tree is the source of two different spices, mace and nutmeg. The outer fleshy fruit is also used to make jam and candy.

Olive *(Olea europaea)*
An evergreen tree from the Mediterranean region. The fleshy fruits of this tree are eaten and also pressed to produce olive oil for cooking.

Rubber Tree *(Hevea Brasiliensis)*
The rubber tree is native to the Amazon Basin in Brazil and adjoining countries. It grows best at temperatures 10 - 28°C with a well-distributed annual rainfall of 1,800 – 2,000 mm. It grows satisfactorily up to 600 metres above sea level (but is capable of growing much higher – to at least 1000 metres near the Equator), and will perform on most soils provided drainage is adequate. They are tapped for their latex which is processed to form Para Rubber. Seeds are also processed to make soap, paints and varnishes.

Teak *(Tectona grandis)*
An evergreen tree native to India and Indonesia. The wood of this tree is known for its durability, density and hardness. It is widely used in making furniture and veneers.

West Indian or Jamaican Mahogany *(Swietenia mahagoni)*
Found throughout the Caribbean, this deciduous tree has long been prized for its beautiful deep-red wood. It is very hard, resistant to termites and is considered one of the world's premier furniture woods. Its bitter bark is also used to treat fevers and malaria.

Willow, She-Oak *(Casuarina equisetifolia)*
A fast-growing evergreen tree, native to south-east Asia and Australia. It has been extensively planted in many countries for fuelwood and charcoal production, and also as erosion control, as it is salt tolerant and can grow in sand.

White Spruce *(Picea glauca)*
An evergreen tree native to North America. This fast-growing tree is harvested to supply pulp wood for the paper industry.

Yew *(Taxis brevifolia)*
A small evergreen tree native to northwest America. The bark of this species is the source of the drug taxol, used to treat ovarian and breast cancers.

A.8. Activity 4: A Wealth From Trees

Tree Products Chart (to make)

Name of Tree										
Place of Origin										
Local Use										
Export										
Medicinal Use										
Construction										
Paper										
Furniture										
Gums & Resins										
Fruit Used										
Seeds Used										
Bark Used										
Leaves Used										
Wood Used										
Other Uses										

A.8. Activity 4: A Wealth From Trees

A List of Some Caribbean Trees

Black Mangrove (*Avicennia germinans*)

Broadleaf (*Cordia sebestena)*

Bull Hoof (*Bauhinia divaricata*)

Bull Thatch (*Thrinax radiatus*)

Buttonwood (*Caocarpus erectus*)

Candlewood (*Amyris elemifera)*

Casuarina (*Casuarina equisetifolia)*

Cedar (*Cedrela odorata*)

Coconut Palm (*Cocos nucifera*)

Cotton Tree (*Ceiba pentandra)*

Fustic (*Maclura tinctoria*)

Ginep (*Meliococcus bijugatus)*

Headache Bush (*Capparis cynophallophora*)

Lignum vitae (*Guaiacum officinale*)

Logwood (*Haematoxylum campechianum*)

Mahogany (*Swietenia mahongani*)

Manchineel (*Hippomane mancinella*)

Mango (*Mangifera indica*)

Pepper Cinnamon (*Canella winterana*)

Pompero (*Hypelate trifoliata*)

Sea Grape (*Coccoloba uvifera*)

Tamarind (*Tamarindus indica)*

Wild Fig (*Ficus aurea*)

Wild Sapodilla (*Sideroxylon salicifolium*)

Yellow Ironwood (*Exosterna caribaeum*)

Yellow Mastic (*Sideroxylon foetidissimum*)

A.9. Biodiversity and Climate Change

Climate change is causing major shifts in the "average weather" that a given region experiences. This is measured by changes in all the features we associate with weather, such as temperature, wind patterns, precipitation, and storms. The rich variety of life on Earth has always had to deal with a changing climate. Adapting to new patterns of temperature and rainfall has been a major influence on the evolutionary changes that produced the plant and animal species we see today. Yet, according to the 2007 United Nations' Millennium Ecosystem Assessment[7], climate change now poses one of the principal threats to the biological diversity of the planet, and is projected to become increasingly important.

Climate change
(also sometimes called global warming) ... results from the build up of greenhouse gases such as carbon dioxide and methane in the atmosphere.

They are called greenhouse gases because they trap heat from the sun and hold it in Earth's atmosphere. Some heat also escapes, thus maintaining the Earth's average temperature conducive to support life.

However, as greenhouse gases increase in concentration, less heat escapes, and global warming occurs.

There are several reasons why plants and animals are less able to adapt to the current global warming. One is the very rapid pace of change: it is anticipated that over the next century, the rise in average global temperatures will be faster than anything experienced by the planet for at least 10,000 years. Many species won't be able to adapt quickly enough to the new conditions, or move to regions more suited to their survival.

As well, the massive changes humans have made globally to landscapes, watersheds and the ocean have reduced the resilience of these ecosystems, and the likelihood that they will adapt to climate change. Other human-induced factors include pollution, the introduction of invasive species and the over-harvesting of wild animals through hunting or fishing. This loss of biodiversity has major implications not just for the variety of life on our planet, but also for the livelihoods of people around the world.

Some Impacts of Climate Change on the Caribbean

Computer models predict an average global temperature increase of 1.4 to 5.8 degrees C by the year 2100. Island ecosystems are especially vulnerable to climate change because island species **populations** tend to be small, localized, and highly specialized, and thus can easily be driven to extinction. Predicted impacts associated with such a temperature increase include:

- a further rise in global mean sea level of 9 to 88 cm
- more frequent and powerful extreme climatic events, such as heat waves, storms, and hurricanes
- an expanded range of some dangerous "vector-borne diseases," such as malaria
- further warming of the Arctic and Antarctic, leading to more sea-ice disappearance, and a further rise in sea levels
- increased coastal erosion
- more extensive coastal flooding
- higher storm surge flooding
- landward intrusion of seawater in estuaries and aquifers
- higher sea-surface temperatures
- the destruction of coral reefs, which are highly sensitive to temperature and chemical changes in seawater

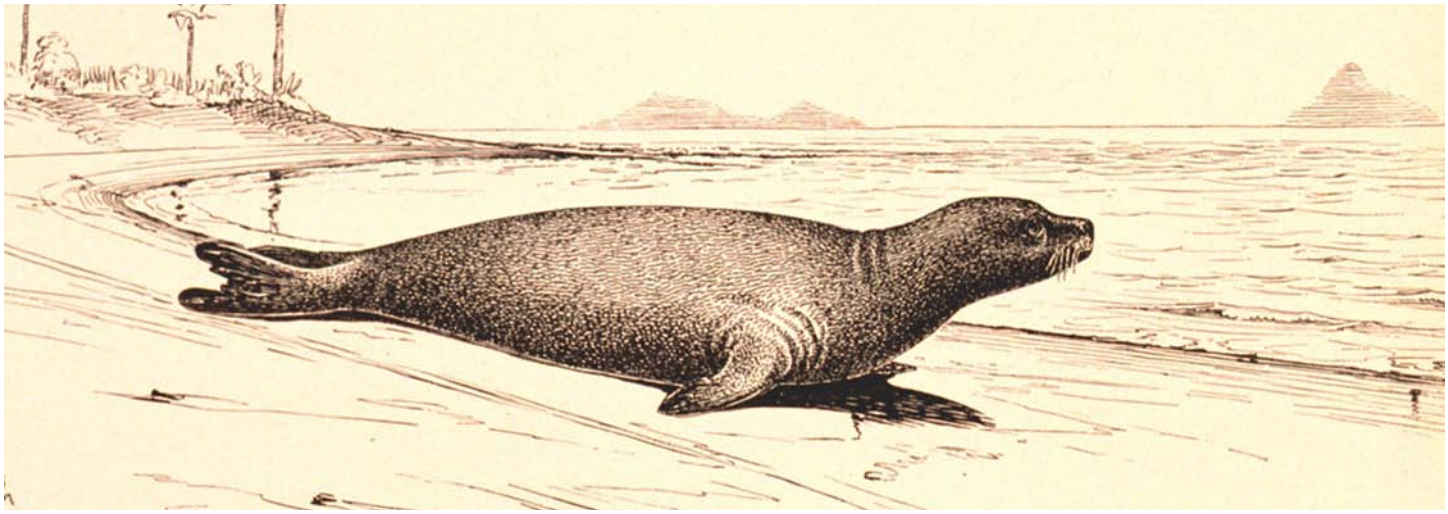
Many of these changes are already taking place in the Caribbean. In Part 2 of this Learning Resource you will find more details on how climate change is affecting some Caribbean ecosystems.

A.10. Extinction: What Causes the Loss of Species?

Extinction is a natural biological process. Over the lifetime of the Earth, millions of species have lived and then disappeared. Throughout geological history, the loss of species has been relatively slow – perhaps a few species per million years. Sometimes this rate has increased dramatically. Around 65 million years ago, 75 percent of the species known from fossil records, including dinosaurs, disappeared. The cause of this mass extinction is uncertain, although it may have been the result of a collision with an asteroid or comet.

Since 1600, about 40 species of mammals and 90 species of birds have been confirmed as extinct. Now the extinction rate is as high as several species per day. The loss of **habitats**—the places where organisms live and get the nutrients, water, and living space they need to survive—is the primary reason biodiversity is in decline.

When people cut down a forest, fill in a wetland, trawl a seabed, or plough up grassland, they change the natural habitat of the species that live there. Tropical and temperate forests are being cut down to make way for agriculture and grassland. Cities are growing rapidly around the globe, and natural areas are being broken up. Not only can such changes kill or force out many



Scientific Sketch of a Caribbean Monk Seal from the U.S. National Museum
National Oceanic and Atmospheric Administration (NOAA). (2008). NOAA confirms Caribbean monk seal extinct. Retrieved from: noaanews.noaa.gov/stories2008/20080606_monkseal.html.

Gone Forever: Caribbean Monk Seals

In the Caribbean, monk seals (Monachus tropicalis) were widely found throughout the islands. They had beautiful brownish-grey fur and measured nearly 3 m in length. The Monk Seal got its name from the numerous folds of fur that fell around its neck when resting, resembling the folds of a monk's hood. During the 1700's, they were heavily hunted for their hides and oil by European fishermen. Their reproductive rate was slow, as the females bore pups only once every two or three years. The last of these seals was seen in 1952 on the Serranilla Bank, west of Jamaica.

animals, micro-organisms, and plants; they also can disrupt complex interactions among species. Countries set aside parks and protected areas, but most of them are relatively small in size. Small protected areas cannot support the diversity of species that large areas can, and small areas are very vulnerable, as there is less habitat available.

Campaigns to save endangered animals used to focus just on saving the species, but scientists now realize that in order to save a species, its habitat must also be protected and be of sufficient size.

Species that are most threatened by human activity include:

• Large animals that need lots of space as part of their habitat.

• Slow reproducers, like whales, that take a long time to reproduce.

• Island species that can lose their genetic diversity or are vulnerable to introduced species; For example, the mongoose was imported from India and Burma during the late 1800's, to many of the Caribbean islands to control the rat infestation of sugar cane fields. Unfortunately the mongoose also eats eggs, reptiles, amphibians and farmyard chickens, and has no natural predators. They have become a predator of many local bird and lizard species.

• Species that live in the same lowland, coastal or river valley habitats that are popular places for humans to live.

How Many are Enough?

" For reasons of disease, genetics and simple accident, no population of wild animals can be considered secure unless it contains at least 500 individuals."

~ Colin Tudge, Last Animals at the Zoo

Some species are more at risk than others as a result of human activity. Large animals usually need more space than smaller animals. When a habitat is reduced, the larger animals usually feel the impact first. Once a species is gone, it is lost forever – it cannot be brought back. Each lost species means a piece of our heritage is gone. The loss of a species from an ecosystem may also indicate larger problems within that system.

Endangered species refers to those species with populations so low that they could become extirpated or extinct. Extirpated refers to a species that no longer exists in a country or region but does exist elsewhere. An extinct species no longer exists anywhere – it is lost forever.

Discussion Questions:

1) List as many reasons for the extinction of species as you can.
2) Why should we value maintaining biodiversity?
3) Do you see the effects of climate change around you? If so, what are the ways?

A.11. How Do We Know What is Endangered? IUCN Red List of Threatened Species

The International Union for Conservation of Nature (IUCN) has been working to assess the conservation status of species around the world for more than forty years. Scientists work to identify species of plants and animals threatened with extinction to highlight and promote their conservation. The IUCN Red List of Threatened Species is the most comprehensive listing of the global conservation status of the world's known plant and animal species. It provides information on plants and animals that have been globally evaluated using the Red List Categories and Criteria.

There are 9 categories in the IUCN Red List system:

Extinct
Extinct in the Wild
Critically Endangered
Endangered
Vulnerable
Near Threatened
Least Concern
Data Deficient
Not Evaluated

For more information on taxonomic, conservation status and distribution information on plants and animals that have been globally evaluated, go to the IUCN website **iucn.org.**

The Plight Of Endangered Species

As of 2008, there were 44,838 species on the International Union for Conservation of Nature (IUCN) Red List and 16,928 of them were threatened with extinction, up from 16,308 last year. This includes both endangered animals and endangered plants.

One in five mammals, one in nine birds, nearly one third of all amphibians and 70% of the world's assessed plants on the 2008 IUCN Red List were in jeopardy.

The total number of extinct species has reached 869; however, the number of extinctions could exceed 1,100 if the 257 Critically Endangered species tagged as "Possibly Extinct" were added in.

International Action: The Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) is an international agreement established by the United Nations (UN). Its aim is to preserve biological diversity around the world. It was presented at the June 1992 UN Conference on Environment and Development - the Earth Summit - in Rio de Janeiro. It contains plans for economic, environmental and social changes that support biodiversity across the globe. As of October 1998, more than 170 countries had signed the convention, including all the Caribbean nations.

The CBD has three main objectives:

- to conserve biodiversity,
- to enhance its sustainable use and
- to ensure an equitable sharing of benefits linked to the exploitation of genetic resources.

The CBD Secretariat is located in Montréal, Canada.

Check out the website for annual reports, individual country biodiversity strategies and actions and information on programmes at **cbd.int.**

For the Caribbean Islands alone (excluding Mesoamerica countries such as Belize), there are 2114 species of animals and plants on the IUCN's Red List. A few examples are given below.

CARIBBEAN ANIMALS	CARIBBEAN PLANTS
Gundlach's Hawk (Accipter gundlachi)	Pokemeboy (Acacia anegadensis)
Sharp-Shinned Hawk (Accipter straitus)	Vahl's Boxwood (Buxus vahlii)
Rainbow Parrotfish (Scarus guacamaia)	Holywood Lignum Vitae (Guaiacum sanctum)
West Indian Manatee (Trichechus manatus)	Commoner Lignum Vitae (Guaiacum officinale)
Jamaican Ground Iguana (Cyclura cornuta)	Corossie (Attalea crassispatha)
Staghorn Coral (Acropora cervicornis)	West Indian Almond (Terminalia intermedia)
Hawksbill Turtle (Eretmochelys imbricata)	Small-leaved Mahognay (Swietena mahagoni)
Grenada Dove (Leptotila wellsi)	Southern Red Cedar (Juniperus bermudiana)
Saint Lucia Parrot (Amazona versicolor)	West Indian Walnut (Juglans jamaicensis)
Spotted Eagle Ray (Aetobatus narinari)	
Spotted Sandpiper (Actitis macularius)	
Redmouth Grouper (Aethaloperca rosa)	
Elkhorn Coral (Acropora palmate)	
Loggerhead Turtle (Caretta caretta)	
Leatherback Turtle (Dermochelys coriacea)	

A.12. Activity 5: Species and Spaces Exploration

Background:

The Caribbean is located on a part of the Earth where there is an amazing variety of geology, climate and therefore – biological diversity. The beaches, forests, mountains and coral reefs support a huge number of plant and animal species well adapted to their environment. However, the Caribbean is also a popular place for humans to live and visit as tourists. Pressure on the small land base of the islands has caused some species to become extinct, and others to be threatened with habitat loss.

Objective:

In this activity students will research some of the interesting animals found in the region, and describe their habitat and the factors which threaten their survival.

Procedure:

Choose an endangered or threatened species of animal that is found in the Caribbean that you would like to know more about. Check the list of Caribbean plants and animals for some suggestions.

Write a report on your chosen species, including the following information:

- Common name and scientific name
- Current IUCN status (Endangered, threatened, vulnerable, etc)
- Countries where it is found: (countries)
- Type of environment in which it lives.
- What does it eat / how does it get its food?
- What are its predators?
- Make a food web showing the ways the species connects with other living things in its habitat.
- Why is it threatened?
- Suggest some strategies or ideas for its protection.
- Include some unique characteristics and interesting facts about your animal.
- Are there any stories or poems that have been written about your animal?
- Include some photos or drawings of your animal.

Saint Lucian Whiptail Lizard
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Use the class reports to build a Biodiversity Exhibit at your school, community centre or local mall, and highlight the special and threatened species of the region, along with suggestions for their conservation. Have an open house to display the exhibits.

Check out the conservation laws in your country that apply to protecting endangered species (review the St. Georges' Declaration Of Principles for Environmental Sustainability)

Call the ministry with responsibility for the environment for information on any biodiversity-related projects being conducted in your country.

A.13. References

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3. Caribbean Tourism Organization. (2008) *Latest Statistics 2008*. Retrieved from: onecaribbean.org/content/files/Dec9Lattab08.pdf

4. World Travel and Tourism Council. (2004) *Progress and Priorities Report: 2004-2005*. Retrieved from: wttc.org/eng/Download_Centre

5. Caribbean Tourism Organization. (2004) *Tourist Expenditures in the Caribbean*. Retrieved from: onecaribbean.org/statistics/expenditure

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Jennifer Goad

Part 1 / Section B

Ecologocial Processes, Cycles & Systems

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

Table of Contents

Introduction

This unit focuses on some ecology basics, including food webs, ecological niches, nutrient cycles and interdependence. The Water cycle, the Carbon and Nitrogen cycle and ecosystem components are highlighted. Activities engage students in exploring places that are meaningful to them, and examines connections to place and community, as well as the key components of ecosystems and ecological cycles.

"Try to imagine the Earth without ecosystems… Each ecosystem represents a solution to a particular challenge to life, worked out over millennia… stripped of its ecosystems, Earth would resemble the stark, lifeless images beamed back from Mars…"

~World Resources 2000 – 2001

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

CXC Learning Outcomes Matches

This section will meet the learning outcomes of the CXC syllabi, as follows:

INTEGRATED SCIENCE

Section A – The Organism

General Objectives

Students should be able to demonstrate:

1. The interdependence of life processes
2. The relationship between an organism and its environment
3. The relationship between structure and function of an organism

Unit XI – The Terrestrial Environment

Specific Objectives

Students should be able to:

7. Discuss food chains and food webs found in an environment
8. Describe the oxygen, carbon, nitrogen and water cycles

Section B – The Home/Workplace

UNIT II – Water and the Aquatic Environment

Specific Objectives

Students should be able to:

3. Explain how the water cycle provides man with a continuous fresh supply of water
4. Discuss the chemical and physical properties of water
6. Describe the relationship between living organisms in the aquatic environment
7. Discuss the effects of water pollution on aquatic life

BIOLOGY

SECTION A – Living Organisms in the Environment

General Objectives

Students should be able to demonstrate:

1. An understanding that there is both diversity and similarity of form in living organisms
2. An understanding that there is interdependence between living organism and their environment
3. An understanding that there is a flow of energy through living organisms within an eco-system
4. An understanding that materials are recycled in nature

Specific Objectives

Students should be able to:

1.1. Group living organisms according to observed similarities and differences
2.1. Identify the relative positions of producers and consumers in a food chain and relate the positions to the modes of feeling
2.2. Identify from a selected habitat, a food chain containing at least four organisms
2.3. Identify, from selected habitats, a herbivore, carnivore and omnivore
2.4. Identify from selected habitats, predator prey relationships
2.5. Construct a food web to include different trophic levels
2.6. Explain the role of decomposers
2.7. Discuss the advantages and disadvantages of special relationships to the organisms involved
2.8. Discuss the interdependence of organisms within a food web
3.1. Explain energy flow within a food chain or web
4.1. Explain, with examples, the continual re-use of materials in nature

BIOLOGY

Section E –Environment and Human Activities

General Objectives

Students should be able to demonstrate:

1. An understanding of the importance of the physical environment to living organisms
2. An ability to undertake a simple ecological study
3. An understanding of the factors that affect the growth of populations
4. An appreciation of the finite nature of the world's resources
5. An understanding of the effects of human activities on the environment

Specific Objectives

Student should be able to:

1.1. Distinguish between environment and habitat
1.2. Discuss the importance of the physical environment to living organisms
2.1. Carry out a simple ecological study
3.1. Discuss the factors that affect the growth of natural population
3.2. Illustrate using examples that human populations are subject to the same constraints as other natural populations
4.1. Describe various resources and their limits
4.2. Discuss the importance of, and difficulties encountered in recycling manufactured materials
5.1. Discuss the negative impact of human activity on the environment
5.2. Discuss the implications of pollution on marine and wetland environments
5.3. Discuss means by which environment could be conserved and restored

GEOGRAPHY

General Objectives

Students should be able to demonstrate:

1. Interest in the nature of Natural and Human Systems and their interaction
2. An understanding of the processes at work in Natural & Human Systems
3. An understanding of the inter-relationships between the natural and human environment
4. An awareness of the need for the sustainable use of our resources
5. Knowledge and understanding of geography at the local, regional and global scales
6. An awareness and understanding of factors influencing patterns and changes in economic activity
7. An appreciation for the relationship between the natural and human systems

Section II – Natural Systems

Specific Objectives

Students should be able to:

9. Describe the water cycle

B.1. Ecology: The Study of Living Things in their Homes

We often use the word "ecology," but what does the word actually mean?

The word ecology comes from the two Greek words: "oikos," meaning "house or place to live," and "logos," meaning "study of." **Ecology** therefore, is the study of **organisms** in their home, a study of the relationships and interactions among living things and their surroundings. These include both the **abiotic** (non-living things, like rocks and water) and **biotic** (living things, such as plants, fungi, animals, etc.) The interactions between and among living and non-living things, such as the water cycle, photosynthesis and prey-predator relationships, are also important elements of ecology.

B.2. Levels of organization

Looking at Earth from space, we see a mostly blue sphere with green, brown and white patches on its surface. As we zoom closer, these patches become deserts, oceans, mountains, forests and cities. If we zoom in even closer, we can pick out a wide variety of living organisms. If we could magnify these plants and animals we could see that they are made up of cells which are in turn made up of molecules atoms and subatomic particles. All matter can be viewed as different levels of organizations – from sub-atomic particles to the universe. **Ecologists** focus on five levels of organization: organisms, populations, communities, ecosystems, and the biosphere.

Reef fish swims through a vibrant coral reef
Climate Change Matters Trust. (n.d.). Understanding climate change. Retrieved from: climatechangematters.net.au/understand.htm

ECOLOGICAL EXPLORATION

Expand your studies with these helpful online resources!

National Geographic Wild World

nationalgeographic.com/wildworld/terrestrial.html

Scientists have mapped 867 land-based ecoregions (Terrestrial Ecoregions) across the globe. Instead of being defined by political boundaries, each is distinguished by its shared ecological features, climate and plant and animal communities.

World Wildlife Fund Ecoregions of the World

worldwildlife.org/wildworld/profiles/terrestrial_nt.html

WWF provides a detailed synopsis of terrestrial NeoTropical ecoregions of the world. For some Caribbean Specific examples visit:

Belizean pine forests (NT0302)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0302_full.html

Greater Antilles mangroves (NT1410)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt1410_full.html

Jamaican dry forests (NT0218)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0218_full.html

Jamaican moist forests (NT0131)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0131_full.html

Northern Honduras mangroves (NT1426)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt1426_full.html

Trinidad and Tobago dry forests (NT0231)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0231_full.html

Trinidad and Tobago moist forests (NT0171)
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0171_full.html

B.2.a. The Biosphere

The **biosphere** is a word used to describe the area where life exists on the planet - the zone or sphere on earth in which all living things exist and interact. The biosphere contains all of the oxygen, water, carbon, minerals and other building blocks necessary for life. The biosphere consists of three life zones: the atmosphere, the hydrosphere and the lithosphere.

1. **Atmosphere**: Air - above us, a thin layer of useable atmosphere no more than 11 km high;

2. **Hydrosphere**: Water - around us, a limited supply of water in rivers, lakes, oceans, and underground deposits as well as in the atmosphere;

3. **Lithosphere:** Earth - below us, a thin crust of soil, minerals, and rocks extending only a few thousand meters into the earth's interior.

The intersection of these three zones is the biosphere – the area on Earth that supports life as we know it. To put the biosphere in perspective, if the earth were an mango, the biosphere would be no thicker than its skin. Everything in this "skin of life" is interdependent and limited, because essentially, no new matter enters or leaves the earth. All of the earth's supplies of oxygen, water, carbon, and other essential elements must be recycled again and again for life to continue.

Air helps purify the water and keeps plants and animals alive, plants help renew the air and soil and keep animals alive, and the soil keeps plants and many animals alive, and helps purify the water. This is an amazingly effective, complex and enduring system. The main law of ecology is " Everything is connected to everything else". We are beginning to understand that disrupting or stressing the biosphere in one place often causes unpredictable and sometimes undesirable effects elsewhere.

B.2.b. Biomes

Scientists study the biosphere by breaking it down into smaller divisions. The largest of these divisions is called a biome. A biome includes large regions that have similar biotic components, such as similar plants and animals, and similar abiotic components, such as similar temperature and amount of rainfall.

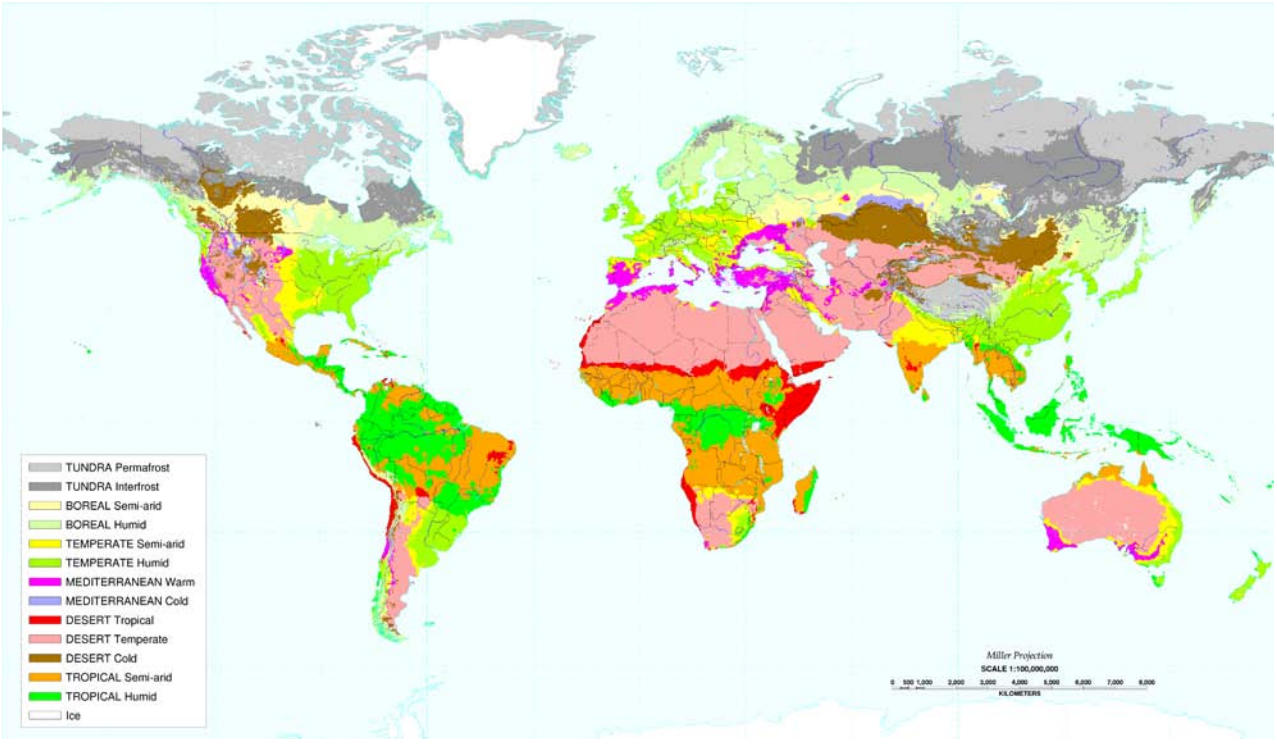
There are eight **terrestrial** or land-based biomes on the planet. Temperature and precipitation are the two main factors that influence the characteristics of a biome.

The eight main biomes are:
Permanent ice, Tundra, Grassland, Desert, Boreal Forest, Temperate Deciduous Forest, Temperate Rainforest, Tropical Rainforest.

Activity

Work with a partner and study the map using the key to familiarize yourself with the location of each biome. Describe two patterns you see in the distribution of the biomes. Provide an explanation for these patterns based on your general knowledge.

Major Biomes of the World



United States Department of Agriculture. (2003). Natural resources conservation services: major biomes map. Retrieved from: soils.usda.gov/use/worldsoils/mapindex/biomes.html.

B.2.c. Ecosystems

What is an Ecosystem?

Walk into the forest on a warm day and look, feel, smell and listen. A gentle breeze flows over your skin and the air feels cool and damp. The sounds of the town are left behind as big trees, vines and ferns surround you. Sunlight cascades through the canopy of leaves to shine on a variety of shrubs and herbs at your feet. A parrot squawks noisily overhead, and looking down, you see a large snail slide across a rotten log. Turning over the log you uncover a frenzy of activity as ants, beetles, worms and termites move in all directions to escape. You pick up a handful of soil to look for other signs of life, but you can only imagine that it teems with millions of bacteria and other **microorganisms**. Scientists call this forest – and other natural systems of organisms interacting with their environment – an ecosystem.

Ecosystem: a community of living things interacting with one another, and with their physical environment. An ecosystem can be a planet, a forest, a pond, a tide pool, or a fallen log. An ecosystem includes the living organisms in a community, the non-living components, and their interactions. The biosphere is the sum total of all the ecosystems on the planet.

There are two major parts of an ecosystem: "non-living" or abiotic, and "living", or biotic.

1) The **non-living** components include the sun, the source of energy for almost all life on earth. They also include air, water, soil, physical factors such as wind, rain, heat, and all the chemicals essential for life. There are essentially six basic measurable elements that make up all living things on this planet: carbon, oxygen, nitrogen, hydrogen, phosphorus and sulphur. We share these elements with all other life forms on Earth – from insects to elephants. These crucial life elements are limited - we can't "make more" water, more oxygen, or more carbon if we run out, nor can we "get rid of" our garbage and wastes. The recycling of these elements through the ecological processes such as the carbon and water cycles is what enables life to continue - your glass of water this morning might have been a drink for a dinosaur thousands of years ago!!

2) The **living parts** of an ecosystem can be divided into producers (plants), consumers (animals), and decomposers (fungi, bacteria, etc.).

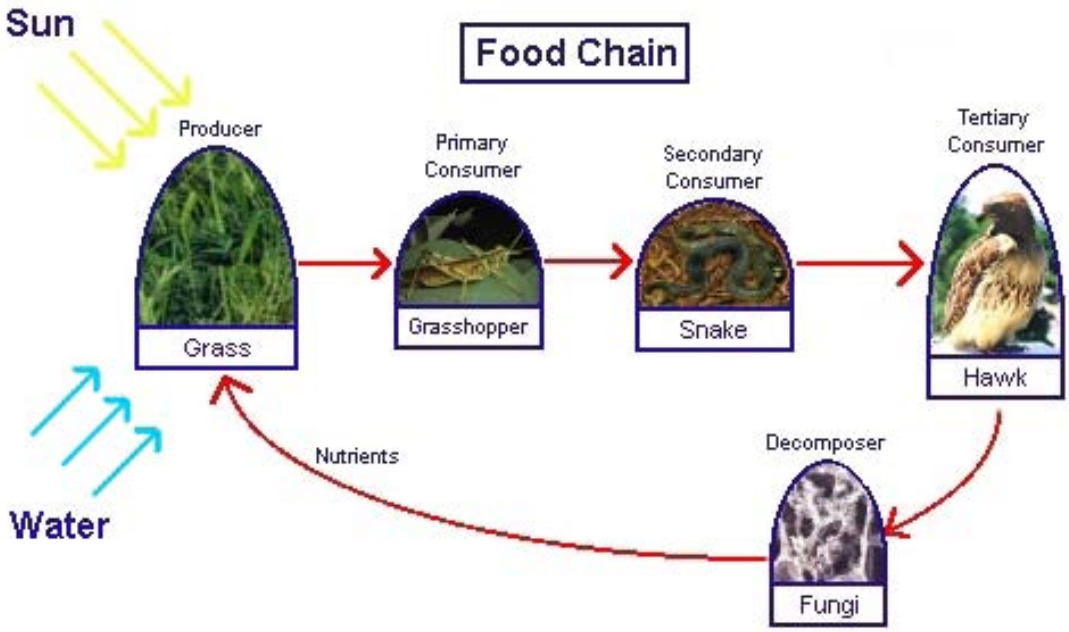
a) **Producers** are plants, and they range in size from tiny floating **algae** to huge trees. Plants are miraculous, as they are the only living thing able to manufacture their own food from the sun's energy. All organisms need food energy to move, grow, and reproduce, etc. This energy comes from the sun. Plants are able to modify solar energy, carbon dioxide and water through a process called **photosynthesis** into simple sugars. Plants are the earth's basic, primary food source.

b) **Consumers**

The rest of us living things on earth can't make our own food, and so must eat plants or other animals. There are three basic types of consumers:

Primary consumers: These are **herbivores** or plant eaters, such as grasshoppers, mice, cows, and **zooplankton**. They may, like caterpillars, feed on only one species of plant, or like goats, feed on a variety of plants.

Secondary consumers: These are the carnivores or meat eaters, such as frogs, hawks, mosquitoes, snakes, and barracudas that feed on herbivores and other carnivores.



Utah State Office of Education. (2000). Food chains.
Retrieved from: jenningsk12.net/WE/peimann/Science/FoodChains/Foodchains.html

Omnivores: These are generalist species such as opossums, raccoons, crabs, pigs, rats and humans that eat both plants and other animals.

c) **Decomposers or Micro-consumers:** The third component of all ecosystems are the decomposers, often overlooked, yet critical to the functioning of an ecosystem. Decomposers include micro-organisms such as bacteria, fungi and molds that break down dead animals and plants and waste products into simpler substances. Decomposers break down dead materials and release nutrients such as nitrogen, phosphorus and in a form useable to plants and algae. Decomposers complete the cycling of essential chemicals through the biosphere. Imagine what our world would look like if there were no decomposers… dead animals and plants, animal waste and garbage would be everywhere!

Simplifying Ecosystems Reduces Biodiversity

When humans modify ecosystems for our own use, we simplify them, that is, we reduce their biodiversity. Every farm field, highway, pipeline, and use of insecticides make ecosystems simpler. We bulldoze forests containing thousands of inter-related plants and animal species, and cover the land with buildings, roads or fields that contain single crops such as corn, rice or wheat.

Large-scale farming focuses on maintaining very simple ecosystems based on fast-growing, single-crop plant species. However, due to their simplicity, these systems are very vulnerable. A single disease or pest can wipe out an entire crop unless we protect the crop with chemicals such as **pesticides** (pest-killing chemicals) or **herbicides** (weed-killing chemicals) and support the crops' growth with chemicals such as water and fertilizers.

It is not known how many species can be eliminated from an ecosystem without damaging its ability to function. It is likely that an ecosystem with more species is more stable than one that has lost some species. For example, research has shown that grassland plots with a greater number of plant species are better able to withstand drought than those with less species diversity. This **resilience** or ability to return to initial state after a disturbance may well be important in the future, as changes in temperature and precipitation brought on by climate change impacts ecosystems.

Investigating Species Diversity

Explore the following online resources for specific information pertaining to species diversity in Belize, Honduras and Trinidad & Tobago.

Biological Diversity in Belize
(biological-diversity.info/species-list.htm)

Biodiversity of Honduras
(google.com search?client=safari&rls=en-us&q=Biodiversity+of+Honduras&ie=UTF-8&oe=UTF-8)

Birds of Trinidad and Tobago
(pages.interlog.com/~barrow)

B.3. Activity 6: My Special Place

Objective:

Students choose and explore a natural special place in the schoolyard, park or other natural area, and describe the environment around them with sensory descriptors, reflect on its importance and ecosystem components they experience, and discover their own connections.

Materials:

- Class set of "sit-upons" (large squares of cardboard wrapped in plastic bags)
- Student journals, pens, coloured pencils
- A natural area such as a park

Time required:

1 period outdoors

Background:

Local natural areas are critical for protecting biodiversity. By visiting a local natural area, students can spend some quiet time reflecting, observing and describing their surroundings, ecosystem components, and exploring any connections they might feel to the place itself. Direct, personal experience and involvement with natural areas in our communities helps develop one's sense of place, and helps to re-integrate the links between people and their communities. Through these personal links, the elements that make up an ecosystem and the importance of biodiversity can be better understood.

Procedure:

1) **Before departing:** Explain the purpose of the field trip and have students write the following words in their journals, as clues for what to look for in their special places:
Colours, shapes, smells, textures, sounds, temperatures, communities, "Belly-Back."

(Students can try checking out "Belly – Back" views of their chosen place: first have them lie face down on the ground and check out what they can see at this close-up level. After a few minutes, have them turn over on their backs, look up, and explore this expansive view of their special place.)

On another page, have them record these questions:

- What is special to you about this spot –what attracted you to it?

- Does this spot remind you of past moments, places you have been, or things you have read?

- What does it tell you about yourself?

- You are surrounded by an ecosystem: look for the different components, and describe organisms or evidence you see of:
Producers, Consumers, Decomposers / Decomposition

2) **Outside:** Take the class to a natural area: a park is ideal, although a non-paved portion of the schoolyard can also work. Have some high-energy activities planned beforehand to use up some of the students' excess energy. Then, calm things down by leading them in a Sensory Wake-up activity.

3) Tell students you will be asking them to look for a spot or an object that is particularly beautiful, meaningful or enticing to them. For example, they may feel drawn to an old tree, a brightly coloured flower, or a shady bench. Before seeking their spots, work together to establish some easy-to-see boundaries for the group. Insist that students give one another space (at least a few metres between students is preferable) and remain silent during the activity.

4) Have students bring their journals and pens, coloured pencils or paints with them as they find and move to their spots. Give students at least 10 - 15 minutes to think about and respond to the questions and clues they have written in their journals.

5) **Back in Class:** Have students write about their special places in their journals, using the details they captured while in their spots.

Assessment Suggestions:

Develop some criteria with the students around what makes a good story. Stories should contain descriptive references to all the senses, and to personal connections students felt to their place. Some ecosystem elements should be included. Bonus marks for reflections on other experiences and places, and on personal preferences.

B.4. Activity 7: Recipe for an Ecosystem

Objective:

Students design and draw their own special place - a local ecosystem - and share its characteristics and ecosystem functions. Students reflect on and describe the special characteristics of a local ecosystem of their choice, and describe specific members of the community and their inter-relationships, including the main producers, consumers and decomposers.

Background:

Developing connections to special places such as local ecosystems requires direct experiences and explorations as well as creative activities that foster personal connections and meaning. This activity allows students to use both their creativity as well as their knowledge about the ecological components of a local forest, ocean or mangrove ecosystem to reflect on the members of these unique community, and discover their own connections.

Procedure:

1) Give each student an imaginary deed to a Caribbean ecosystem of their choice. On this plot, they are free to create their own special ecosystem, complete with as many trees, rivers, oceans, animals, birds, insects, hills - whatever they desire. Humans don't necessarily have to make a living from this special place, although students can include this aspect if they like. Encourage creativity and imagination.

2) Review the key components of what defines a ecosystem with the class, and ensure that students include these elements in their "recipe". E.g. the source of energy (the sun), the abiotic elements, elements of the water cycle (rain falling from clouds, water underground/ in lakes, the ocean,) the biotic elements such as the producers, primary consumers, secondary consumers and decomposers (dead materials decomposing).

Suggestions might include:

• Imagine yourself sitting in your ecosystem, and try to sense all of what is around you: what do you feel, smell, hear, see, taste?

• What organisms live there? Plants? Animals? Insects? People?

• What are the characteristics of your ecosystem? How are these represented in your special place?

• Imagine the unique parts: what makes it especially enjoyable and meaningful to you?

• Describe your chosen ecosystem, and draw a picture of it.

3) Ask students to emphasize the concepts of connections and community. As a follow-up, have students discuss the components they have included in pairs: What are some similarities and differences in each individual's created environment? Did everyone include all or most ecosystem components, such as the sun, air, water, soil, climate, plants, plant eaters, carnivores, decomposers? What aesthetic components did they include and why they are important to each individual?

Assessment Suggestions:

Look for inclusion of all the main ecological elements in each student's project: are the main components included? I.e. Producers (trees, plants), Consumers - Herbivores or plant eaters such as caterpillars, mice, birds, fish, and Carnivores such as hawks, bats, sharks; Decomposers such as bacteria..

This activity can be used as an assessment tool after students study the components of an ecosystem and/or go on a field trip.

Extensions:

An interesting extension is to ask students to design a human community - what is the ideal place they would like to live in, what would be part of their neighbourhood: markets, gardens, farms, parks, schools, etc.? How can a human community and a natural ecosystem co-exist in harmony? Who would live there: people, plants, domestic and wild animals? How would people make a living there? Where would the food, energy, raw materials and water come from? What would the roads be like (would there be any?)

Discussion questions:

1) It is sometimes said that humans don't adapt to their environment; instead they make their environment adapt to them. Can you give some examples of this?

2) Cities are human-made ecosystems, but some animals have found a niche in urban areas. Can you describe some animals that have adapted to life in towns and cities?

3) Why are plants the basis for all life on Earth?

B.5. Ecosystem Functions: How Do Ecosystems Work?

B.5.a. Energy Flows and Chemical Cycles

What keeps you, a palm tree, a pigeon, a mosquito and other living organisms alive on this planet? To survive, you and every other living thing must have an input of both **energy** and **matter**. A tree gets its energy directly from the sun, while you and other animals get energy from certain nutrients in the food supply. You also have to get rid of waste matter and heat – a balance needs to be maintained. Life on earth depends on the cycling of critical chemicals and the flow of energy through the biosphere.

Students should have a basic grasp of these cycles, and the matter and energy laws to understand the way ecosystems work.

B.5.b. Know Your Matter and Energy Laws!

Law of Conservation of Matter

We often talk about consuming or using up matter or **resources**, but actually we don't consume any matter. We only borrow some of the earth's resources for awhile – through eating it, processing it, using it and then discarding or recycling it. We may change matter into another form, such as burning complex gasoline molecules and breaking them down into simpler molecules of water and carbon dioxide. But we never create or destroy any matter – hence the:

Law of Conservation of Matter: *In an ordinary physical or chemical change, matter is neither created or destroyed, but merely changed from one form to another.*

This means we can't throw anything away either – everything must go somewhere – and all we can do is to reuse or recycle some of the matter we think we have thrown away.

The **First Law of Energy: The Law of Conservation of Energy**, or the **First Law of Thermodynamics**: *in any ordinary physical or chemical change, energy can neither be created or destroyed, but merely changed from one form into another.*

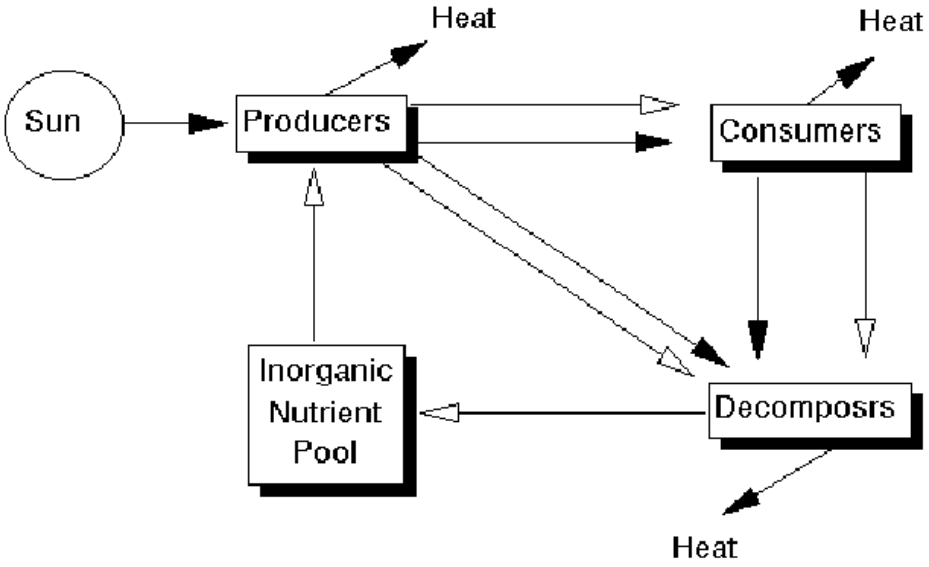
This energy law holds for all systems – both living and non-living. Green plants need the sun's energy to produce food energy, and animals must get their energy from eating plants or other animals; however, energy can never be recycled.

According to the **Second Law of Energy**, or the **Second Law of Thermodynamics**, *when energy is converted into work (i.e. when we burn coal or eat food), some of the energy is always degraded to a more dispersed and less useful form – usually heat energy given off to the environment.*

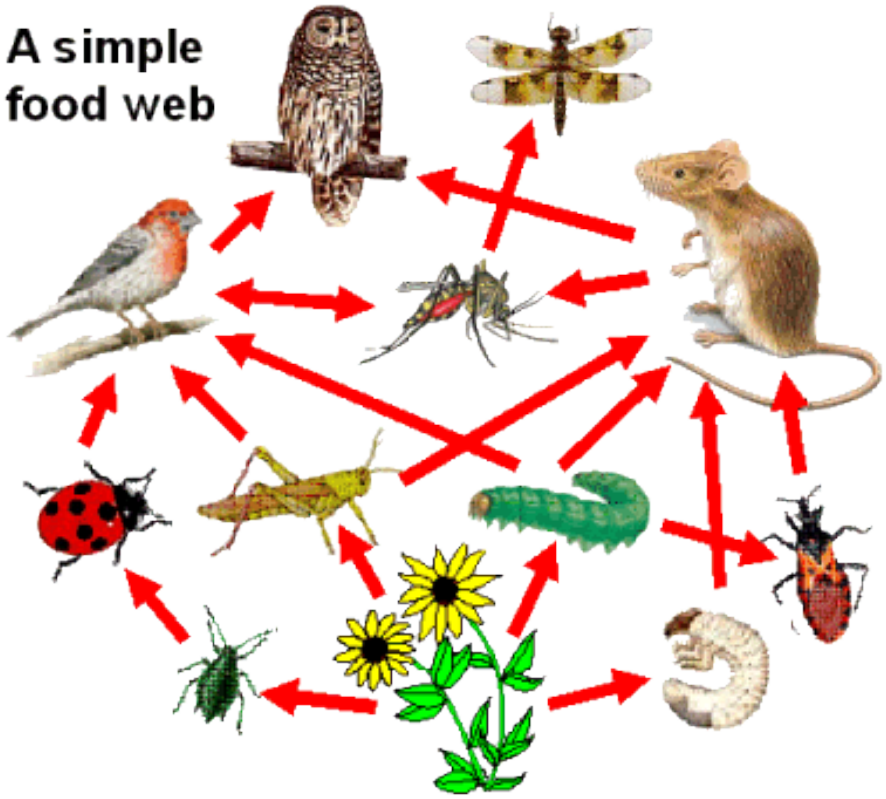
So – what does this look like at the ecosystem level?

Organisms don't live in isolation. To get the matter and energy they need, living things must interact with their physical environment and with other organisms – through breathing, eating, drinking and reproducing. Life at the ecosystem level depends on matter cycling and energy flow. Chemicals must cycle in the ecosphere because no significant amount of matter enters or leaves the earth, and because, according to the law of conservation of matter we cannot create any new matter or destroy what we have.

As energy flows through an ecosystem or an organism, it is always degraded to less useful heat energy. So – life at the ecosystem level depends on matter cycling – the one-way flow of energy through the ecosystem is used to cycle the essential chemicals – such as carbon, oxygen and nitrogen – back to a form that is useable by plants. This one-way flow of energy is the study of who eats or decomposes whom! These essential chemicals must be completely cycled - there is no such thing as waste matter. One organism's waste or death is another organism's food.



Drawing depcting the flow of energy
Rahman, M. (2008). Energy flow. Retrieved from: realku.blogspot.com/2008_07_01_archive.html.



NC State University. (2008). General etymology: trophic levels: food webs.
Retrieved from: cals.ncsu.edu/course/ent425/library/tutorials/ecology/trophic_levels.html.

B.5.c. Food Chains

All organisms, alive or dead, are potential sources of food for other organisms. A caterpillar eats a leaf, a bird eats the caterpillar, a hawk east the bird. When all of these animals die, the materials from which they are made are broken down into simpler substances by decomposers. This energy flow sequence is called a food chain. A **food chain** involves the transfer of energy from one organism to another – and the flow always moves in one direction – from producers to consumers. The different feeding levels of producers and consumers in a food chain are called **trophic levels** – from the Greek word "trophikos," for "food."

B.5.d. Food Webs

The food chain concept is a useful way to trace who eats whom in an ecosystem. In reality however, such simple food chains don't exist by themselves. Many animals feed on several different types of food at the same trophic level. Also, omnivores, such as humans and pigs, eat different kinds of plants and animals at different trophic levels. For example, birds that normally eat seeds may switch to insects in the rainy **season**. A rat might eat earthworms at certain times of the year, but go after fallen fruit when they are plentiful, and switch to grasshoppers during the fall season.

Natural ecosystems consist of many complex networks of food chains. When we draw all the connections and relationships we get a **food web** instead of a series of linear food chains. Food webs in ecosystems add a degree of stability for species. When one type of food becomes unavailable, animals may be able survive by switching to another type of food if it is available . Food webs also help us to understand the complexity in an ecosystem, and the interdependence of all species to one another.

B.6. Activity 8: Chains and Webs

Objective:

Students will understand the concept of an ecosystem, and recognize some of the ecological components and relationships that form food chains and webs. Students will be able to recognize the interconnectedness of living things within a natural system, describe organisms in terms of their roles as part of interconnected food webs, and understand the scale of impacts on Caribbean ecosystems and the challenges facing conservation and restoration efforts.

Background:

An ecosystem is a community of living things that interacts with each other and with their non-living environment (soil, rocks, etc). Caribbean ecosystems are amazingly diverse, beautiful and exciting places. They are home to hundreds of plant species, as well as amphibians, reptiles, birds, mammals and fish – indeed, they are one of the most biologically diverse ecosystems in the world! Over the past few hundred years, many of the ecosystems have been cleared and converted for agriculture, housing, tourism and industrial development. There has also been invasion by exotic species that out-compete native species for space, food and water. Some of the most serious invasive species are the mongoose, goats, rats, cats, and cane toads, also called bullfrogs.

By learning about some of the plant and animal species and how they interact, students will be able to understand the connections and dependencies within an ecosystem, and further appreciate Caribbean ecosystems and the challenges they face. This activity has students identifying different components in a chosen local ecosystem, creating paper chains that represent ecosystem relationships, and then participating in a food web game as different members of an ecosystem.

Procedure:

Paper Chains: Ecosystem Food Chains

1) With the class, discuss that all living things need energy and minerals to live and grow. Brainstorm the meaning of the following terms relating to how living things get their food energy: Producers, Primary Consumers and Secondary Consumers.

Producers produce their own food from inorganic compounds and a source of energy. They are mainly green plants, who use the sun's energy and compounds from the soil to make their own carbohydrates through photosynthesis.

Consumers can be further divided into:
• Herbivores (plant eaters, such as rabbits, cows, caterpillars),

• Carnivores (animal eaters, such as cats, owls, mosquitoes),

• Omnivores (consume both plants and animals, such as humans, dogs, pigs) and;

• Decomposers (feed on dead plant and animal material: such as bacteria, fungi, slugs, worms, Turkey Vultures).

2) Ask students to name some examples of each, and discuss which category humans belong to.

3) Have copies of the Caribbean Ecosystem case studies available (see Part 2). In small groups, have students work to identify and list the ecological components that are producers (mainly plants), and the different consumers, including herbivores, carnivores, omnivores and decomposers. Groups should also list as many non-living components of the ecosystem as possible (sun, water, rocks, soil, air, wind, etc.). Have groups pair up and share their lists.

4) Now pass out sheets of paper, tape and scissors to each group and have each student construct labelled food chains according to the following colours and codes (or whatever colours you have):

Green paper chains: producers
Yellow paper chains: herbivores
Pink paper chains: carnivores
Blue paper chains: omnivores
Brown paper chains: decomposers

5) Have students make up as many food chains as they can from their created lists. So, for example, a green circle of paper labelled Mango tree linked to a yellow circle of paper labelled parrot linked to a pink circle of paper labelled Yellow Snake. A (green) plant linked to a (yellow) insect linked to a (pink) Crab Spider linked to a (pink) Green Lizard.
A (green) Mahogany tree to a (yellow) wood-boring beetle to a (pink) woodpecker (dead) to a (brown) bacteria. Display the food chains across the classroom.

Ecosystem Webs

This adaptation of the Ecosystem Web game portrays the complexity, connections and interdependence of ecosystems in a fun, participatory activity.

1) Have students choose a Caribbean ecosystem to explore.

2) Now have students come up with lists of plants, consumers and decomposers in a chosen ecosystem.

3) Have students choose one organism, and make their own ID card that represents this organism, to wear on their chest (with string or a pin). Make sure the class has representation from Producers, Consumers - both plant eaters (herbivores) and animal eaters (carnivores), and Decomposers. Have some field guides and photos of plants and animals available for students to review, so they can draw their species as well as providing its name.

B.6. Activity 8: Chains and Webs

4) Have students share their "new identity" briefly with the class.

5) Wearing their ID cards, students form a circle facing each other. Begin by giving one student the ball of rope or string and ask them to hold one end of it and identify another student who represents a species that they are somehow connected to (the mouse could be eaten by a hawk or eat seeds of a palm, the butterfly could fertilize the flower, parrots could spread seeds of plants, the moss or ferns could live on the mahogany tree, the lizard could eat the ant, the beetle could eat the dead plant or animal, etc). The ball of wool is then tossed or rolled to that student, and she/he is asked to identify another organism that she/he is connected to.

6) Discuss the relationships that are found between each connection to be sure all are clearly understood. Continue this until all students are connected to the web that is created.

7) Have one person in your food web back away from the circle, letting go of the yarn (i.e. the trees could be "cut down", the black snapper "fished out", etc.) Discuss what happens when one thing was removed from the web. All participants will be able to feel their connecting yarn being pulled and the web unravelling.

Discuss the following questions:

• What is the source of energy for the entire food web? (the sun)

• What other elements are necessary for life in this web? (air, water, soil)

• What are some of the threats to this ecosystem? (urban development, invasive species)

• Discuss the representation made by this web, that all things in natural systems are interconnected and interdependent.

• Discuss what would happen if one species were removed from the web (it would unravel). Following this, identify if any of the species in the circle are at-risk or endangered - meaning they are threatened due to the continuing loss of their habitat, or home.

• How does an increase in biodiversity affect an ecosystem web? (more members, more complexity, stronger web)

Assessment:

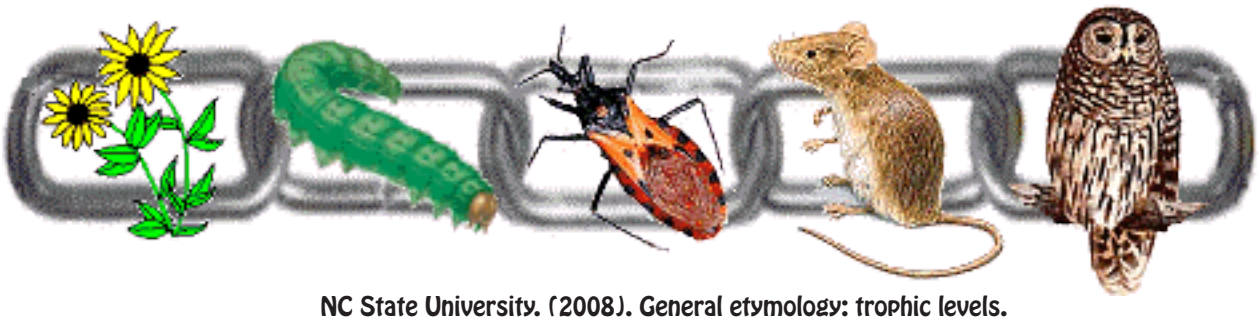
Students create a food chain of at least four living things found in a chosen ecosystems.

Students list four non-living components of an ecosystem.

Concept Review:

• List the major components of all ecosystems.

• Distinguish between biosphere, ecosystem, population and community, and give an example of each. Rank them by increasing complexity, or level of organization of matter.



NC State University. (2008). General etymology: trophic levels.
Retrieved from: cals.ncsu.edu/course/ent425/library/tutorials/ecology/trophic_levels.html.

B.7. Activity 9: Ecosystem Postcards!

Objective:

Students select a specific local animal or plant, research its ecosystem and habitat, and design and present postcards that illustrate their species and its surroundings. The goal is to create a postcard which focuses on the selected animal/plant, and gives a good picture of the habitat and ecosystem where it is found.

Materials:

- A list of local plants & animals, cut into strips
- Resource books on Caribbean plants and animals
- Class copies of Student Worksheet
- Materials for making postcards (big index cards or pieces of cardboard)

Time required:

2 periods plus research time

Procedure:

1) Review the plants and animals list to develop and pick one species per student, ensuring you have good representation from the main ecosystems of the Caribbean:

- Open-Ocean Ecosystem
- Coastal Ecosystem
- Coral Reef Ecosystem
- Mangrove Swamp Ecosystem
- Tropical Forest Ecosystem

Cut up the list and toss them into a hat for students to choose one each, OR have students choose their own species off the list, using it as a signup sheet.

2) Review a map of the Caribbean and discuss the different ecosystems. Explain that the region has been divided into ecosystems based on their characteristic climate, plant life, and soil type.

3) Hand out the student worksheets and resource books, and ask students to find out as many details about their animal/plant and its habitat as they can. The goal is to create a postcard, which focuses on the selected animal/plant, and gives a good picture of the habitat and ecosystem where it is found.

4) Have students review the completed postcards in pairs and guess the ecosystem it comes from. Has enough information been included to identify the specific ecosystem? What could be included/ taken out?

Critical question:

Why might finding a unique plant or animal in an ecosystem be important in decision-making about protection of natural areas? Explain your reasons.

Extensions:

Get Outside!

Plan a field trip to a park or site that has some representative characteristics of a local ecosystem, and have the students develop a tour guide itinerary of all the highlights.

What Ecosystem am I?

Collect the completed postcards and clip one (not their own!) to each students' back. Students mingle and figure out by asking yes/no questions what ecosystem they're from (display a list of the ecosystems to refer to).

Biodiversity Mail!

Students could prepare postcards from their own community and exchange with a class in a different region or island.

Assessment:

Set the Criteria Together

An effective way to review assignment expectations with your students is to build the evaluation criteria together through a class brainstorm activity. This helps students understand exactly what is required of them and increases their buy-in. Post the agreed-upon list of criteria in class for the

Use the list on the student worksheet ("Things to include on your postcard") to check for the required categories: postcards that include the first five elements meet assignment expectations, while clues about shelter, movement and behaviour earn extra marks.

B.7. Activity 9: Ecosystem Postcards! ~ Guess the Ecosystem!

For this activity, you'll be choosing a regional plant or animal and designing a postcard showing it in its ecosystem.

Background on the Ecosystems:

From sand beaches and rocky shores to the wet rainforest ecosystem, coral reefs and rich mangrove swamp ecosystem, the Caribbean is rich in biodiversity. To help ensure that we protect these habitats and the species that live there, scientists classify areas according to their natural features and ecological processes.

Postcards from the ?? Ecosystem: Making the Cards

Select plant or animal to research, and design a postcard as if your species had sent it to you. Do some research and get creative – draw, paint or make a collage of your species hanging out in its ecosystem home. On the back, write a note as if your species was describing its home to you – where it lives, activities, favourite foods, neighbours, whatever! **Don't write the ecosystem's name on the card though:** the object is for someone to try and guess the ecosystem from your information!

Things to include on your postcard *(on the front or back)*:

- Scientific & common names of your plant or animal
- Size of the animal or plant and what it looks like
- What it eats, what eats it, and how it gets its food
- Who are some of its neighbours?
- Where does it find shelter?
- What does it do to protect itself?
- If it is an animal, how does it get around?
- How big is its home range or territory?
- How does it find a mate?
- What are some interesting or unique things about it?

Remember!! **NO ecosystem name (!)** but include at least **three** good clues, such as its temperature, landscape, vegetation, and other animal life. Your text and drawing should let someone guess the ecosystem that the species lives in.

Caribbean Ecosystems: Some Plants & Animals

The plants and animals selected for this activity have been chosen to represent the main ecosystems in the Caribbean, and to provide an interesting mix. *(see following page)*

Jamaican Green Lizard
Photo supplied by: Rick Searle, EKOS Communications, Inc.

B.7. Activity 9: Ecosystem Postcards! ~ Guess the Ecosystem!

OPEN OCEAN ECOSYSTEM	COASTAL ECOSYSTEM	CORAL REEF ECOSYSTEM	MANGROVE SWAMP ECOSYSTEM	TROPICAL FOREST ECOSYSTEM
whale shark *(Rhincodon typus)*	**manatee grass** *(Syringodium filiforme)*	**staghorn coral** *(Acropora cervicornis)*	**Red mangrove** *(Rhizophora mangle)*	**Orchid** *(Stelis micrantha)*
stingrays *(Dasyatidae ssp.)*	**turtlegrass** *(Thalassia testudinum)*	**lettuce coral** *(Agaricia lamarki)*	**black mangrove** *(Avicennia germinans)*	**Guzmania** *(bromeliad)*
eagle rays *(Myliobatidae ssp.)*	**shoal grass** *(Halodule wrightii)*	**elkhorn coral** *(Acropora palmata)*	**white mangrove** *(Laguncularia racemosa)*	**John Crow bush** *(Bocconia frutescens)*
manta rays *(Mobulidae ssp.)*	**brittle stars** *(Ophiomastix variabilis)*	**star coral** *(Montastrea faveolata)*	**buttonwood** *(Conocarpus erecta)*	**Tree fern** *(Cyathea)*
barracuda *(Sphyraena ssp.)*	**green turtles** *(Chelonia mydas)*	**brain coral** *(Colpophyllia natans)*	**yellow warbler** *(Dendroica petechia)*	**Soapwood** *(Clethra occidentalis)*
West Indian manatee *(Trichechus manatus)*	**longsnout seahorse** *(Hippocampus reidi)*	**scleractinian coral** *(Montastrea annularis)*	**bicolored conebill** *(Conirostrum bicolor)*	**Bitter Plum** *(Picrodendron baccatum)*
black jack *(Caranx lugubris)*	**northern seahorse** *(Hippocampus erectus)*	**greater star coral** *(Montastrea cavernosa)*	**clapper rail** *(Rallus longirostris)*	**Cedar** *(Cedrella odorata)*
nurse shark *(Ginglymostoma cirratum)*	**bluestriped grunt** *(Haemulo sciurus)*	**shet coral** *(Agaricia lamarcki)*	**great-tailed grackle** *(Cassidix mexicanus)*	**Mahogany** *(Swietenai mahagoni)*
humpback whale *(Megaptera novaeangliae)*	**redtail parrotfish** *(Sparisoma chrysopterum)*	**zoxanthellae algae** *(Symbiodinium microadriaticum)*	**spotted tody-flycatcher** *(Todirostrum maculatum)*	**Whistling Warbler** *(Catharopeza bishopi)*
sperm whales *(Physeter macrocephalus or Physeter catodon)*	**great barracuda** *(Sphyraena barracuda)*	**rainbow parrotfish** *(Scarus guacamaia)*	**rufous crab-hawk** *(Buteogallus aequinoctialis)*	**St. Lucia Oriole** *(Icterus laudabilis)*
spinner dolphins *(Stenella longirostris)*	**blue land crab** *(Cardisoma guanhumi)*	**queen angelfish** *(Holacanthus ciliaris)*	**crab-eating raccoon** *(Procyon cancrivorus)*	**Martinique Oriole** *(Icterus bonana)*
hawksbill turtle *(Eretmochelys imbricate)*	**Caribbean hermit crab** *(Coenobita clypeatus)*	**yellowtail damselfish** *(Chrysiptera parasema)*	**American crocodile** *(Crocodylus acutus)*	**St. Lucia Black Finch** *(Melanospiza richardsoni)*
Kemp's Ridley turtle *(Lepidochelys kempii)*	**spiny lobster** *(Panulirus argus)*	**clown fish** *(Amphiprion clarkia)*	**arboreal snake** *(Corallus hortulanus)*	**St. Vincent Bush Anole** *(Anolis trinitatis)*
Atlantic deep-sea lobster *(Acanthacaris caeca)*	**calf cowrie** *(Cypraea vitellus)*	**french Angel Fish** *(Pomacanthus paru)*	**common egret** *(Casmerodius albus)*	**Dominica Anole** *(Anolis oculatus)*
Blue Marlin *(Makaira nigricans)*	**common limpet** *(Scutus unguis)*	**angel fish** *(Pomacanthidae ssp.)*	**black vulture** *(Coragyps atratus)*	**St. Vincent Solitaire** *(Myadestes genibaris)*
Yellowfin Tuna *(Thunnus albacares)*	**Orangespot sardines** *(Sardinella brasiliensis)*	**Caribbean reef shark** *(Carcharhinus perezii)*	**brown pelican** *(Pelecanus occidentalis)*	**West Indian mahogany** *(Swietenia mahagoni)*
	needlefish *(Belonidae ssp.)*	**triggerfish** *(Balistidae ssp.)*	**scarlet ibis** *(Eudocimus ruber)*	**Candle Tree** *(Dacryodes excelsa)*
		trumpetfish *(Aulostomus maculatus)*	**Caribbean flamingo** *(Phoenicopterus ruber)*	**West Indian Evergreen** *(Podocarpus coriaceus)*
		butterfly fish *(Chaetodontidae ssp.)*	**Cayman crocodile** *(Caiman crocodilus yacare)*	**C.A. Wooly Opossum** *(Caluromys derbianus)*
		blue tang *(Acanthurus coeruleus)*		**green tree lizard** *(Anolis bimaculatus)*
		puffer fish *(Tetraodontidae ssp.)*		**tree frog** *(Eleuthrodactylus martinicensis)*
		Moray eel *(Muraenidae ssp.)*		**Grenada Blindsnake** *(Typhlops tasymicris)*
		porcupine fish *(Diodon hystrix)*		**Fer De Lance** *(Bothrops caribbaeus)*
		balloon fish *(Diodon holocanthus)*		**St. Lucia Pygmy Gecko** *(Sphaerodactylus microlepis)*
				Blue-headed hummingbird *(Cyanophaia bicolor)*
				Mountain Chicken *(Leptodactylus fallax)*

B.8. Activity 10: Create your Own Ecosystem Creature!

Background:

All living things have a habitat that provides them with their essential needs. Animals are adapted to the habitats in which they live. In this activity you will create an imaginary animal that would be able to have a healthy life in a local ecosystem of your choice. Keep in mind all the characteristics of your ecosystem when you are designing your animal, and get creative!

Materials:

Students journals, class copies of activity, art supplies.

Procedure:

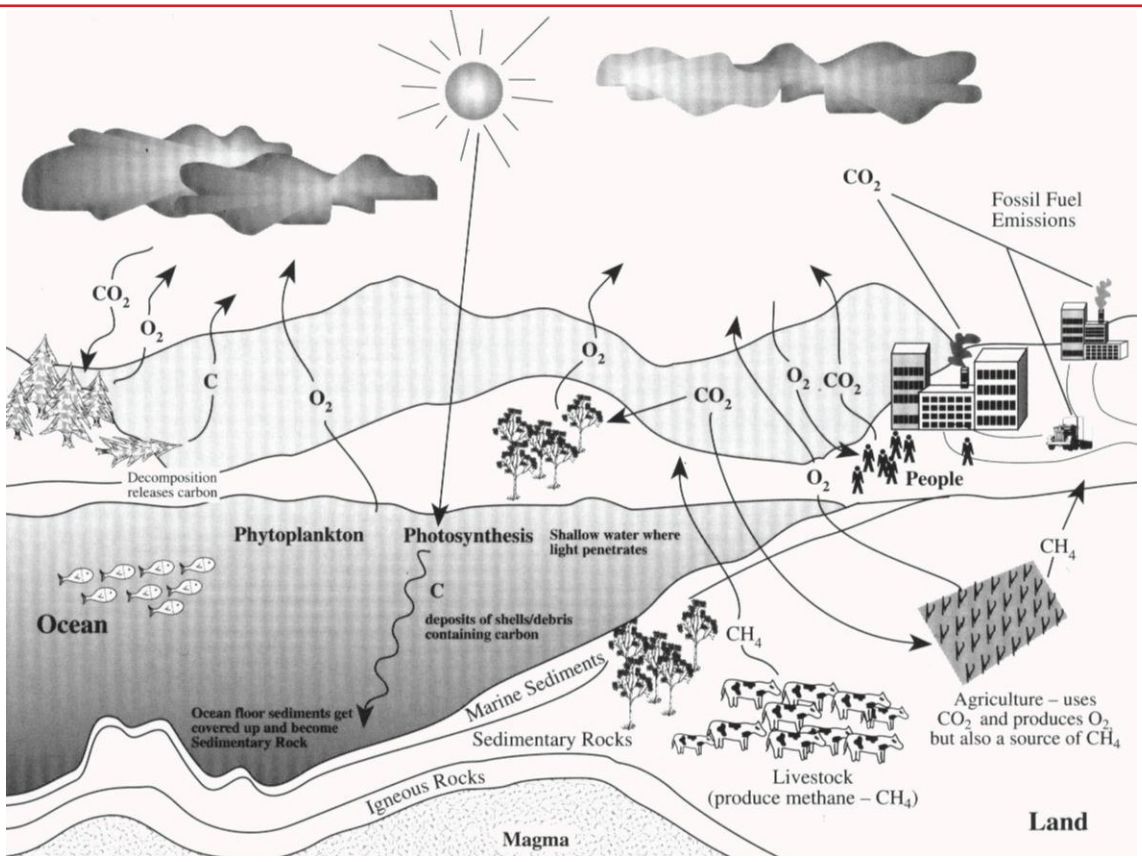
1) First, choose a local Caribbean ecosystem to use as your animals' home. Review the specific characteristics of the ecosystem you have chosen. Animals living in ecosystems have adapted to their environments in many ways. They have learned to eat the food available to them, to protect themselves from predators, and shelter themselves from the weather. Describe your imaginary animals' habitat: its' food, water, shelter and space requirements.

Ecosystems where your animal could live include:
- Open-Ocean Ecosystem
- Coastal Ecosystem
- Coral Reef Ecosystem
- Mangrove Swamp Ecosystem
- Tropical Forest Ecosystem

2) Next, think about what your animal should look like in order to survive and thrive in this habitat. Think about the specific characteristics of your chosen ecosystem, and what adaptations your imaginary animal will need to possess. Your animal has to be able to gather food and water, hide from any predators, find shelter and move about its habitat.

3) Create a coloured picture of this animal, and give it a name. Underneath, write the following information:
a) how its needs are met? how it finds and consumes food/water?
b) how it finds shelter?
c) how it moves about its habitat?
d) what its predators are and how it protects itself from them?
e) how it finds others of its species to reproduce?
f) how it goes about raising its young successfully?
g) what three specific adaptations to its ecosystem does it have?

4) Create a class display of all your imaginary creatures and their ecosystems.



The Carbon Cycle
Earthscape. (n.d.). Carbon cycle. Retrieved from: earthscape.org/t1/nas25/nas25d.html

B.9. Nutrient Cycles

In chemical terms, life can almost be summed up in 6 words: **carbon, hydrogen, oxygen, nitrogen, phosphorus** and **sulphur.** These six chemicals make up over 95% of the mass of all living organisms. Because we have a fixed supply of these nutrients, they must continuously cycle from the air, water and soil through the food webs of the biosphere and back again. Carbon, hydrogen, oxygen and nitrogen atoms are cycled between living organisms and the atmosphere. Phosphorus atoms enter the environment from sedimentary rock. The health of an ecosystem depends on the balance of these nutrients. In this section we will focus on two of these cycles, the carbon cycle and the nitrogen cycle. The water cycle is also reviewed as both a key ecological process and a nutrient cycle.

B.9.a. The Carbon Cycle

Carbon is the basic building block of the organic molecules necessary for life. All living things contain billions of carbon atoms in their cells. Carbon is stored in plants, animals, and in decaying organic matter in the soil. Carbon is also found in the atmosphere as carbon dioxide gas, and is stored in its dissolved form in the top layers of the ocean. Longer term storage of carbon is found in deep ocean waters, in coal deposits, and in oil and gas deposits, which formed millions of years ago from dead plants and animals.

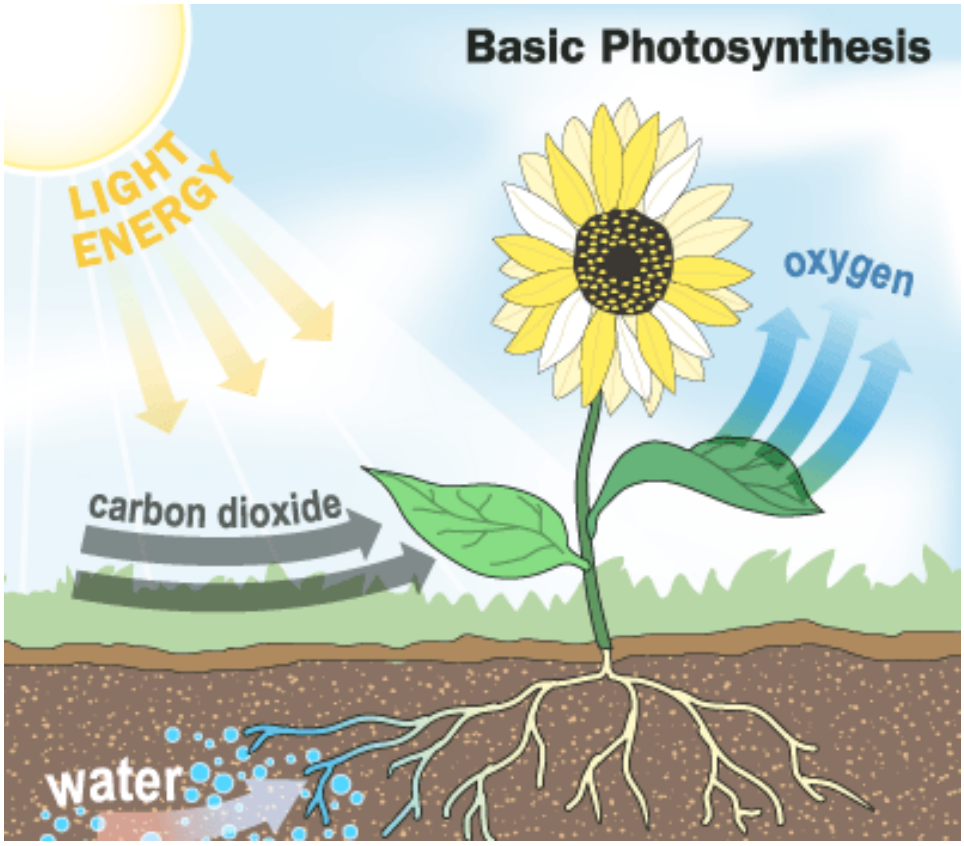
Carbon is an essential component in the chemical reactions that sustain life, and a variety of processes move carbon through ecosystems. These include photosynthesis, respiration, decomposition, ocean processes and events such as volcanic eruptions and large scale forest fires.

Photosynthesis

Photosynthesis is a key life process, where carbon and oxygen are cycled through ecosystems. Photosynthesis is a chemical reaction that converts solar energy into chemical energy. Carbon dioxide enters through the leaves of plants and reacts with water in the presence of sunlight to produce energy rich sugars (carbohydrates) and oxygen.

Energy (sunlight) + carbon dioxide ($6CO_2$) + water ($6\ H_2O$) = sugars ($C_6H_{12}O_6$) + oxygen $6O_2$

Photosynthesis makes useable energy for producers in the form of carbohydrates. By eating plants, consumers obtain energy and take carbon into their cells. Carbon is released back into the atmosphere as carbon dioxide through respiration and the decomposition of dead plants and animals.



Speck, S. (2003). How stuff works: basic photosynthesis. Retrieved from: home.howstuffworks.com/irrigation.htm.

Cellular Respiration

Cellular respiration provides the energy plants and animals need to live. It is the process by which plants and animals release carbon dioxide back into the atmosphere by converting carbohydrates and oxygen into carbon dioxide and water. Energy is released within the cells of organisms and is available for growth, repair and reproduction. Carbon dioxide gas is released as a waste product.

$C_6H_{12}O_6$ (carbohydrates) + oxygen ($6O_2$) =
carbon dioxide ($6CO_2$) + water (6 H_2O) + energy

Decomposition

Decomposition refers to the breaking down of dead organic matter. Decomposers such as bacteria and fungi convert organic molecules such as cellulose (a type of carbohydrate found in plants) back into carbon dioxide, which is released into the atmosphere.

Discussion questions

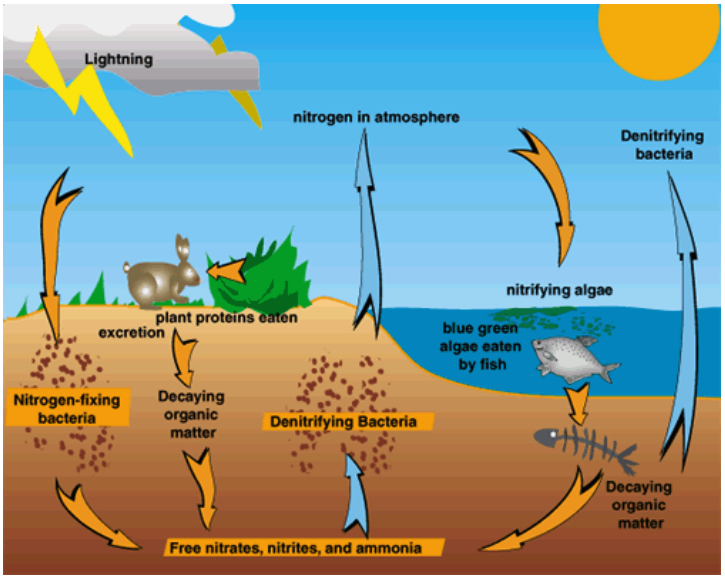
1) Where is carbon stored in Earth?

2) Describe the chemical reactions of photosynthesis and respiration.

3) Why is decomposition important to the carbon cycle?

B.9.b. The Nitrogen Cycle

Nitrogen is necessary for many of our bodies' essential molecules, such as proteins, nucleic acids, vitamins, enzymes and hormones. The largest store of nitrogen is in the atmosphere, where it exists as nitrogen gas (N_2) and makes up 78% of Earth's atmosphere. Other major stores of nitrogen include oceans and organic matter in soil. Although there is a lot of nitrogen gas in our atmosphere, most organisms can't use nitrogen in that form. Therefore, much of the nitrogen cycle involves processes that make nitrogen available to plants, and eventually, to animals. These processes are nitrogen fixation and nitrification.



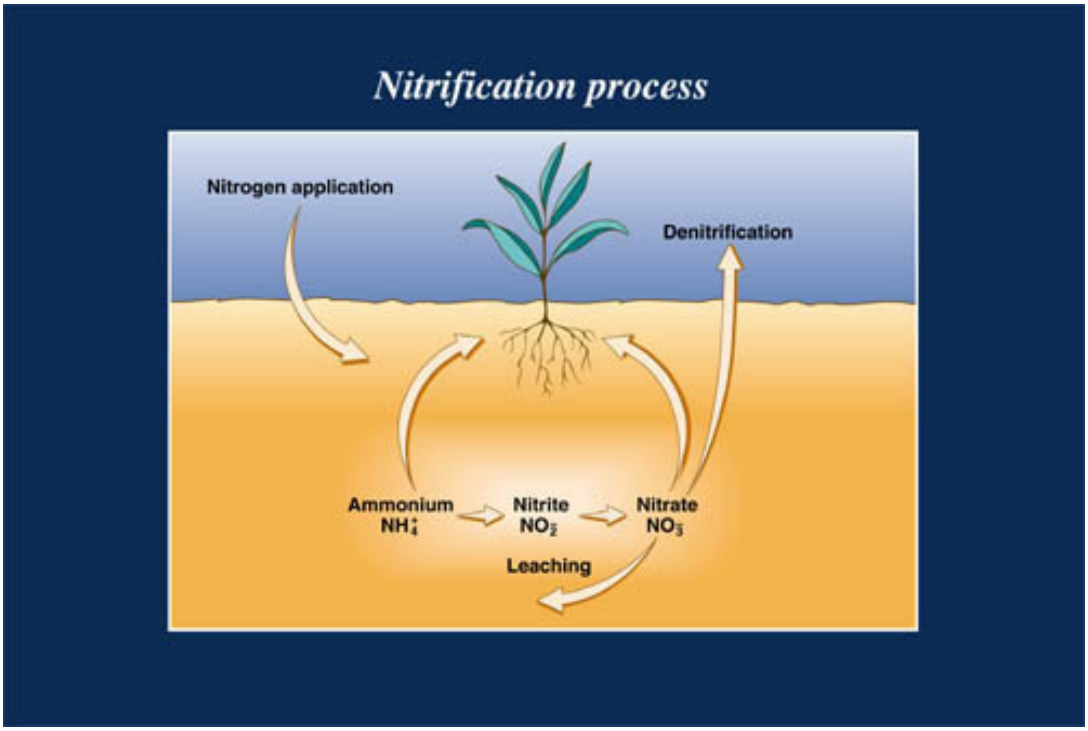
Nitrogen Cycle
Todd, A. (n.d.). Nitrogen cycle. Retrieved from: fossweb.com/resources/pictures/16327852.

Nitrogen Fixation

Nitrogen fixation is the process in which nitrogen gas (N_2) is converted into compounds that contain nitrate (NO_3) or ammonium (NH_4). Both of these compounds are useable by plants. Nitrogen fixation occurs in the soil when nitrogen gas is converted into ammonium (NH_4) by bacteria during the decomposition process. Certain species of bacteria, called "nitrogen-fixing bacteria" play an important role in this process. For example, Rhizobium is a species of nitrogen-fixing bacteria that lives in the root nodules of plants such as peas, beans, clover and alfalfa. The plants supply the bacteria with sugars and the bacteria supply the plants with nitrogen in the form of ammonium (NH_4).

Nitrification

Other plants obtain their nitrogen through nitrification. In this process, ammonium (NH_4) is converted into nitrate (NO_3) by nitrifying bacteria. Once nitrates are made available by nitrifying bacteria, they can enter plant roots and eventually be incorporated into plant proteins. When herbivores and omnivores eat plants, they incorporate nitrogen into the proteins in their tissue. Still other types of bacteria and fungi are able to take the nitrogen trapped in the proteins of dead organisms and convert it back to ammonium (NH_4), therefore making it available once again for plants to use.



University of Illinois. (n.d.). 50 ways farmers can protect their groundwater. Retrieved from: thisland.uiuc.edu/50ways/50ways_5.html.

B.9.c. How Changes in Nutrient Cycles Affect Biodiversity

In this section, you have seen how ecosystems function, and the role of plants in the carbon and oxygen cycles. Bacteria fix nitrogen from the atmosphere, and other bacteria play important roles in cycling nutrients through decomposition. Changes in nutrient cycles can affect the health and variety of organisms that live in an ecosystem. For example, changes in the carbon cycle are contributing to climate change. Changes in temperature, rainfall and wind patterns may have serious effects on biodiversity if some plants and animals can no longer survive in their altered habitats.

Increased levels of nitrogen can seriously affect plant biodiversity in both terrestrial and aquatic ecosystems. Plant species that are adapted to higher nitrogen levels can out-compete species that can't tolerate high levels. For example, grasses thrive in high nitrogen environments, and out- compete tree seedlings.

Chemical fertilizers that are rich in nitrogen can enter lakes and streams, increasing the amount of dissolved nitrogen in these ecosystems. This causes **eutrophication** – a process where increased nutrients cause increased plant production and decay. In a nitrogen-rich, or **eutrophic** environment, algae grow very quickly, often forming huge masses, or algae blooms. Excessive algae growth deprives other aquatic plants of sunlight and oxygen. When the algae die, the oxygen used in decomposition can deprive the lake water of oxygen, and can lead to the death of all the fish in a lake.

Discussion Questions:

What effects do each of the following activities have on nutrient cycles?

- o Driving a car
- o Piling cattle manure near a stream
- o Forest fire
- o Composting

B.10. Water Worlds

B.10.a. The Water Cycle

Our planet is truly a watery world-- the dominant colour of the earth as seen from space is blue. Perhaps we should have called the planet "Ocean" instead of "Earth", as more than 75% of it is covered with water. Water is a major connector between all living things, as all things need water to survive. As with all the world's resources, there is a limited supply of water on the planet. Over 97% of the planet's water is salty. Two percent of all the planet's water is frozen in the polar icecaps. Therefore, there is less than one percent of the planet's water available to living things to drink. Water is continually cycled through the atmosphere, the oceans, the land and all living things on the planet, through the water cycle.

The **water cycle** is driven by the sun. Through **evaporation**, water is lifted into the atmosphere as water vapour. As it condenses, it forms clouds and coalesces into rain drops. Only when a droplet grows to a raindrop size, at least 0.5 mm in diameter, is it big enough to fall out of the cloud. Water leaves the atmosphere mainly as rain or snow. It may fall directly into the oceans, or it may fall onto the land, where it begins a downhill journey through streams, lakes, underground channels, and rivers, eventually reaching the ocean. All along its journey, some water may return to the atmosphere through evaporation. Therefore, there is a cycle of water movement from the air to the land and seas, and then back up into the atmosphere.

Plants and animals get their water at various points in this cycle. Animals get most of their water by drinking and eating, and plants by absorbing it from the soil. Water forms a major part of all living things; humans are about 75% water, most plants are about 85% water. As well, most of the chemical processes that occur in living things, such as photosynthesis, and digestion, require water.

On land, living things lose water directly to the atmosphere. Plants lose water mostly through their leaves. Animals lose water through breathing, perspiration, evaporation, and in their waste products. Eventually, all water taken in by living things is returned to the water cycle, through the processes mentioned above, or finally, through death and decomposition.

B.10.b. Physical Properties of Water

Water is an incredible substance – one that we rarely think about. What other substance has a tough skin, can make a mountain of sugar disappear, can keep an elephant cool and crack giant boulders?

Water is one of the few substances on Earth that can be naturally found in all three states: solid, liquid and gas. More things dissolve in water than in any other substance. It is also polar – water molecules attract each other and tend to stick together in drops. The negative and positive charges of a water molecule allow it to move into small spaces in soil and be absorbed easily by the roots of plants. The surface of water acts like a "skin" – a layer of water molecules held tightly together by hydrogen bonds. This is why water forms drops, and why some insects can "skate" on the surface of water. These properties of water are critical to life as we know it, and are the basis for the water cycle processes. Much of water's usefulness and "magic" stem from its remarkable physical properties .

1) Water has a high boiling point

Without this property, water would be a gas rather than a liquid at normal temperatures. There would be no oceans, lakes, or rivers, or plants or animals on earth.

2) Water has the highest heat of vaporization of all liquids

This means that it takes a lot of energy to evaporate a given amount of liquid water. This is a significant factor in distributing the sun's heat over the world. Huge amounts of solar energy stored as heat in evaporated water are released over the earth when water vapour condenses and falls as rain and snow. This property also helps us to regulate our own body temperature,

as our bodies can eliminate heat by evaporating water through perspiration.

3) Water can store heat better than almost anything else
This means that a given amount of water only increases slightly in temperature when heat is added to it, so water heats and cools more slowly than most other substances. This property of water prevents extreme global climatic temperature changes. It also makes water an excellent coolant for everything from electrical power plants to cooking!

4) Water is less dense as a solid than as a liquid
This is perhaps water's most amazing property. When most substances freeze, their volume decreases, so their density as a solid is higher than when they are in a liquid form. However, when water is cooled below 4 degrees Celsius, it expands and its density decreases. This is why ice floats! Without this property, lakes and ponds would freeze solidly from the bottom up, and most aquatic life could not exist. Arctic land and marine animals also rely on floating ice floes as a critical component of their habitat.

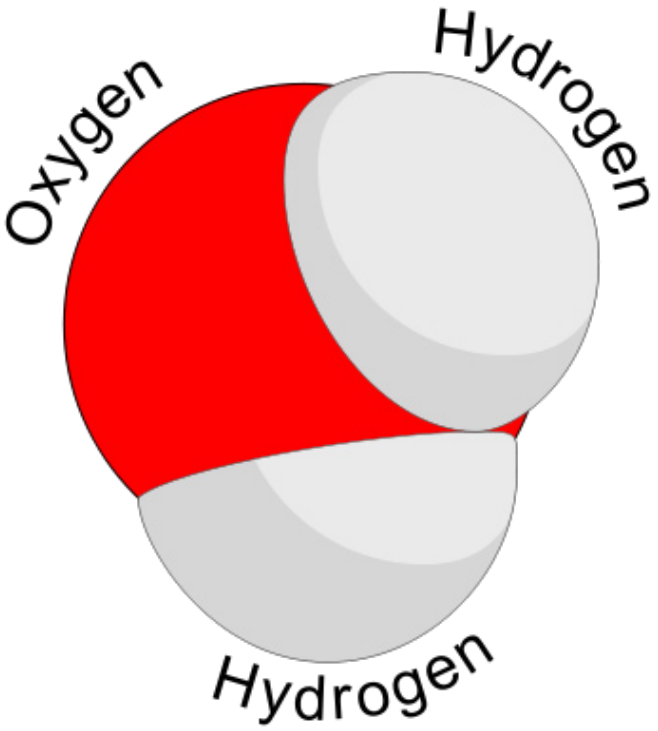
5) Water is an amazing solvent
Water dissolves an incredible variety of substances. This enables it to carry nutrients through the bodies of plants and animals, to be one of the best cleansers, and to remove and dilute water soluble wastes. However, because water dissolves so many things, it is also easily polluted.

Water Density

The difference between each of the three states of water is density: how close water molecules are to each other. The amount of particles (mass) within a certain space (volume) determines the density of the substance. Water vapour is the least dense of water states because the molecules are furthest apart from each other. The molecules of warm water are less dense (less compact) than cold water. However, ice is less dense than liquid water. Therefore, cold water will sink and warm water will rise. Since the molecules of cold water are closer together, they can support the less dense layer of warm water above it. This layering effect of water in rivers, lakes and oceans plays an important role in ecosystem structures.

Water molecules in ice are farther apart from each other in ice than in liquid form. When water freezes, the molecules spread out and are arranged in a lattice –like pattern, which increase the distance between the molecules.

When you add certain materials, such as salt to water, it increases its density. Pressure also increases the density of water. Deep water has greater density than surface water. The water temperature also decreases with depth, and cooler water has greater density than warmer water. A large body of water contains many density levels, each providing a certain habitat in which plants and animals may live.



Water Molecule
Shanghai Institute of Applied Physics. (2008). Workshop on water at biological interfaces. Retrieved from: sciencelearn.org.nz/contexts/icy_ecosystems/sci_media/images/water_molecule.

B.10.c. Water and Weather

On our planet, the poles and the equator show the greatest temperature differences. Warm air and water vapour rises from the equator and flows towards the cooler poles, while cold air at the poles sinks and flows towards the equator. The earth's rotation modifies this constant atmospheric flow into eddies and wind currents, causing varying weather patterns. The large amounts of water that evaporate into the atmosphere eventually return to the earth as precipitation, usually rain or snow. Sometimes, rain never reaches the ground; often a torrent may spill out of the clouds high above a desert, only to evaporate entirely on the way down. Drizzle, or rain made up of little drops, falls from relatively low clouds. Bigger raindrops come from big, dense clouds. In order for snow to form, a cloud must be chilled to a few degrees below 0° Celsius. The cloud droplets freeze together into crystals that mat together into snowflakes when they collide. Rain that starts in warm air and falls through a cold layer does not turn into snow but becomes sleet . Frozen raindrops from high clouds that get hurled about in violent updrafts pick up concentric layers of snow and ice, and finally fall as hailstones.

B.11. Activity 11: Water Experiments

Procedure:

Work in small groups to carry out these experiments that explore the properties of water – they can be set up as stations around the classroom.

i) Temperature and Density

- Clear glasses or beakers
- Hot and cold water
- Red and blue food colouring
- Towels for wiping up spills

Get a glass of cold water and a glass of hot water (be careful to not burn your hands). Put a drop of red food colouring in the hot water glass and a drop of blue food colouring in the cold water. Gently tilt both glasses so that the liquids almost touch. Allow the hot water to flow over the cold water. Look at the containers from the side. Draw a picture of what you see.
Which is more dense, cool water or warm water?

ii) Missing Water

- Kettle or pan
- Stove
- Measuring cup

Place a measured amount of water in a pan and bring it to a boil. Let it boil for several minutes, but don't let the pan boil dry. Let the pan cool and measure the remaining water. Find out how much water is left. Remember the Law of Conservation of Matter: matter cannot be created or destroyed! Explain what happened to the rest of the water.

iii) Salinity

- 2 glasses
- A hard boiled egg
- Box of salt
- Spoon

Fill two glasses with water. While stirring, add salt to one of the glasses until no more salt dissolves. Place a hard boiled egg in each glass. How does salt affect the density of water?

iv) Cohesion

- A coin
- Eye dropper
- A cup of water
- Towel
- Fork
- Paper clip

Using an eye dropper, place as many drops of water on a penny as possible without spilling any over the edge. Count the number of drops and record your score. Repeat several times, keeping rack of the number of drops each time. Describe or draw how the water appeared on the penny before the drop collapsed.

Place a paper clip or sewing needle on the end of a fork. Now gently lower the clip onto the surface of a glass of water. What happens to the paper clip?

Discussion: Biodiversity and Water

1) Answer the questions at each of the water stations.

2) Thinking about the three states of water and their importance in ecosystems, describe a plant or animal habitat that depends on a specific state of water (E.g. liquid: aquatic; ice: Arctic/ Antarctic, gas: cloud forests).

3) Describe the role that water plays in creating and maintaining biodiversity in different ecosystems.

B.12. Activity 12: Water Wings[1]

Objective:

Through a guided imagery activity, students will illustrate the water cycle, explore the importance of water to all life, and describe the interrelatedness of the world's waters through artwork and poetry.

Materials:

Taped recorded calming music or water sounds; art materials (water-based paints, brushes, paper, containers for water); writing materials or student journals.

Background:

There is, in a sense, one body of water on planet Earth. Its' rivers reach out from the hearts of every continent to merge in the seas and oceans. All water, everywhere, is somehow connected. We can see this universal body of water by turning on a water faucet or by looking at clouds moving high in the sky. Lakes, ponds and inland seas are webbed together by waters flowing across the surface of the land or in the seeping flow of **groundwater**. People seldom think of the waters of the world as being connected into one body. Maps emphasize the continents and political boundaries on land. Geographers have named dozens of seas which really can't be separated from each other - similar to the way that boundaries on land tend to be more political than geographical.

Through evaporation, **condensation** and precipitation, the atmosphere transports water from place to place. Plants also are an active part of the water cycle in many ways - including by transpiration. **Transpiration** is a process where plants evaporate moisture through the surfaces of their leaves. The continuous dynamic movement of water is called the water cycle. The concept of the water cycle is a way to view the moving connectedness of water in its many forms.

Human beings are linked to the planet's watery world. Our bodies are approximately 75% water. In the past, molecules of our bodies' water may have flowed in streams, been trapped in clouds or frozen in glacial ice. Other animals and plants are also tied to the planet's waters, as all life depends upon water in some way.

This activity includes a guided imagery story of the water cycle, which can set the stage for a study unit on water and ecosystems, and to prepare for or conclude a field trip.

Procedure:

1) If at all possible, the students should visit a real stream, pond or beach. Try to choose one that is quiet and not too busy. If possible and not dangerous, allow the students to touch the water during the guided imagery story.

2) If a field trip is not possible, look for recordings of natural ecosystem; the sounds of oceans, waves, rivers, and streams, are often available on tape. Classical music can be substituted.

3) Do a few stretches and relaxation exercises together, and darken the classroom if possible. Have students relax, and give them time to get comfortable with their eyes closed and their heads on their desks. Now read the Water Wings story in a calm, relaxed voice, pausing often.

Water Wings Story (to be read aloud)

"You are to try to imagine the things you will hear me describing. Sit comfortably and close your eyes. . . Relax, and do your best to imagine what I am describing. . .

Imagine in your mind's eye that you are in your favorite place - your favorite natural spot that includes a body of water.... this could be by a lake, next to the ocean on your favourite beach, beside a favorite stream or river.... wherever you like to go to be near water....

Now imagine that it is nice and warm, hot out in fact. Get comfortable beside your favorite watery spot ... you have your shoes off and your bare feet are immersed in the clean, clear water. . . The water feels good, cool, smooth against your skin . . .

You feel a current washing over your feet, pulling at them. . . Think about the water flowing past your feet and its connections to other bodies of water - streams, rivers, the ocean. . . . The water here connects you to the large flowing bodies of water on the planet. . . Feel the current now - feel its more powerful flow against your feet. . .

Look around you and See the green ribbon of trees and plant life all along the edge of the water . . the animals, insect life, birds that live nearby.... Now listen... what sounds do you hear??

"Now stretch your mind and realize that you interconnect with all the world's oceans. . . You are now touching one single body of water that stretches all around the world. . . Your own body contains water that is part of this system. . . the air you breathe has water in it... molecules of water are all around you

Your watery touch laps against the shores of the Caribbean Sea, it flows into the Atlantic, , up the coast past the port cities of Miami, New York, around North America, and it leaps and plunges around oil drilling platforms in the North Atlantic. . .

it travels further north, to the ice-covered islands in the Arctic, Baffin Island and into Hudson Bay.

B.12. Activity 12: Water Wings

It pours from the sky as a storm rages dark and grey on the coast of Greenland. . . .

Wet snow drenches an Inuit who shivers on the Arctic shores before her parka begins to warm her. . .

"Water connects your feet with every stream flowing into the oceans around the world. . You can reach up the rivers to the hearts of all the world's continents. . .

Your feet feel the flow of the current of the kilometres-wide Amazon River in South America, the ancient Nile River pushing north through Africa, the Colorado River swirling with a boatful of river rafters through the Grand Canyon, the St. Lawrence River penetrating into the heart of Canada, and the five Great Lakes, largest freshwater bodies in the world, the majestic Niagara Fall thundering over high cliffs. . .

You swirl around a manatee, gracefully swimming in the shimmering turquoise waters off Jamaica . .

You can feel the tremor of the hippopotamus that just dove into an African river. . .

You are part of the water glistening on the back of a Greek boy who tugs fiercely on fishing nets in the warm Mediterranean Sea.

You are inside the white, heaving centre of a huge curling wave, crashing atop a coral reef…

You spray from a fountain into a luxury resort's swimming pool on a Caribbean island…

You can see water, thousands of tonnes of it, in great drifting fleets of heavy white clouds over the Himalayas. . .

You are part of a gentle ocean swell, rising up under the belly of a Green sea turtle as she heads towards a nearby beach to lay her eggs….

You are boiling in a kettle in a high rise apartment in a big city, ready to make morning coffee…

You feel the water, pouring out of the sky on a grey windswept winter day, drenching the rainforests, the beaches, the cities and towns....

Your watery embrace wraps all around the Earth. . .

And, of course the water flowing over your feet connects you with everyone else who is now sitting, with their feet dangling in the water, wondering where the water goes. . .

"It is time to come back. . . Bring the limits of your senses back from the world's rivers and oceans. . . Back to the surfaces of your feet. . . Back to where you are. . .

When you feel ready, you may open your eyes."

When you feel ready, you may open your eyes."

4) Once the imagery is complete, ask the students to open their eyes. Tell them that they each had their own private journey even though they all heard the same words. Tell them that in a moment you will ask them to close their eyes again to find one place on the journey through the world's water that was their favourite -and you will ask them to try to remember what that image was like.

5) Ask them to relax again and have them try to re-create the picture in their minds. Tell them to look at the detail, the colours, the plants and animals, and to try to capture it all in one scene. Have them pay particular attention to the role of water in the lives of people, plant and animals.

6) When you feel they have had enough time, ask them to open their eyes. Provide the art materials and ask them to each get paint sets and paper to quietly paint the image of their favourite place.

After the story ends, brainstorm some of the characteristics of the water cycle that students visualized, and list the components and processes (precipitation, transpiration, photosynthesis, condensation, evaporation). Then have students draw the water cycle in their journals.

Extensions:

1. Water Poetry

Story-telling and field trips provide an opportunity for creative writing such as poetry. Have students write a haiku or cinquain poem about their experiences through the guided imagery story. A Haiku is a Japanese poem of three lines, the first and third lines have five syllables, the second has seven.

Example:

Gentle and playful
Soft waves dancing with beach sand
Friendly wind blowing.

A Cinquain consists of 5 lines, each of which has a purpose:
First line states the title in 2 syllables.
Second line describes the title in 4 syllables.
Third line describes action in 6 syllables.
Fourth line expresses a feeling in 8 syllables.
Fifth line restates the title in 2 syllables.

B.12. Activity 12: Water Wings

Example:

Rain Cloud
Large and spreading
Reaches for the hilltop
Spreading over trees and valleys
Water falls

2.Find out the annual rainfall and climate in the area you chose to paint.

3. Trace the migratory path of a sea turtle, tuna or whale and describe the qualities of the different water environments that the animal experiences.

4. List at least ten ways that you use water every day.

Photo supplied by Jennifer Goad

B.13. Activity 13: How Wet Is Our Planet?[2]

Objective:

Students calculate water volumes using percentages, to determine the amount and distribution of water on the earth in oceans, rivers, lakes, groundwater, icecaps and the atmosphere.

Materials:

A large map of the world; a 30 centimetre diameter globe (one showing the ocean bottom is best); an apple or orange, knife, writing materials; one litre (1000ml) container, measuring cup and 10 ml dropper for every three students.

Background:

Planet Earth should really be called the water planet! Between two-thirds and three-fourths of its surface is water. The earth's water can be seen in rivers, ponds, lakes, oceans, locked in the northern and southern icecaps, and drifting through the air as clouds. Water that has seeped into the earth's crust (groundwater) is more difficult to see, yet all these forms of water are part of a dynamic interrelated flow that we call the water cycle. Each of the segments of the water cycle shares a portion of the total amount of water on the planet. We tend to think of the water on the planet as being limitless – we can easily forget that there is only a very small proportion of this limited resource which is accessible to us. Water is finite – the earth is essentially a closed system in which the water cycle operates. Whatever amount is available to humans and wildlife depends largely on how its quality is maintained. Human beings have a responsibility to conserve water, use it wisely and protect its quality.

Procedure:

1) Using a map of the earth, begin a discussion of how much water is present. Ask the students to comment on why the earth is called "the water planet". Call the students; attention to the statistic that between two-thirds and three-fourths of the surface is covered with water. After general discussion, provide the students with the following statistics:

Water on Earth	
Oceans	97.1%
Icecaps/glaciers	2.15%
Groundwater	.61%
Freshwater lakes	.009%
Inland seas/saline lakes	.008%
Soil moisture	.005%
Atmosphere	.001%
Rivers	.0001%
Total	**99.8831%**

2) Demonstration: Cut an apple or orange to demonstrate the amount of fresh, drinkable water on earth. Cut an apple into four equal pieces. Take one piece and cut it into five equal parts (leave the peel on). Take one of the 5 small sections – this represents the amount of **fresh water** on earth, in all forms. The rest of the apple pieces represent the amount of salt water on earth.

Take the small piece which represents the world's fresh water, and cut it into three equal sections. One section represents the total amount of fresh water that is frozen. The two remaining sections represent all of the world's underground water.

Finally, take one of the three tiny sections and carefully peel it. Cut the peel into three pieces. One of these pieces of peel represents all the surface, non-frozen, available fresh water on earth.

3) Discuss the relative percentages from the above data. Ask the students to calculate the estimated amount of fresh water potentially available for human use:

Groundwater	.61%
Freshwater lakes	.009%
Rivers	.0001%
Total:	.6191%
including icecaps/glaciers	2.15%
Total	**2.7691%**

4) In discussing these figures, emphasize that the usable percentage of existing fresh water is reduced by pollution and contamination. Also, all the groundwater is not available and icecaps certainly are not readily available. Discuss the needs of humans for usable fresh water. Ask the students to consider what other life forms need both fresh and saline (salt) water. Remind students that we can't "make" more water – what is contained on the planet is all there is.

5) Another powerful way to demonstrate the amount of surface fresh water available on earth is to have students do the measuring. In groups of three, have students follow the instructions below:

- Start with 1000 ml of water in a beaker.
- Pour out 28 ml to represent the fresh water on earth
- From the 28 ml pour out 23 ml to represent the frozen water tied up in glaciers and ice caps.
- That leaves 5 ml
- From the 5 ml pour out 4 ml to represent the ground water in aquifers and underground streams
- From the 1 ml remaining, pour out 0.8 ml to represent water in the air and in the soil.
- You will have approximately 2 drops left, which represents all the surface water in lakes, rivers, streams and wetlands!

B.13. Activity 13: How Wet Is Our Planet?

6) Consider the fragile nature of the fresh waters, wetlands and oceans of our planet. Discuss how all species depend upon this minute percentage of water for their survival. Discuss the problems that water pollution and erosion cause to water systems.

7) Summarize the activity by using an earth globe to illustrate that if the earth were this size (30 centimetres in diameter), less than 125 millilitres, or one-half cup, of water would fill all the oceans, rivers, lakes and icecaps. Close by emphasizing the importance of keeping the earth's waters clean and healthy and, when we do use water, using it wisely and responsibly.

Extensions:

1) Have students keep a personal log of how much water is used at school and/or in their homes every day for a period of one week. As a class, make a list on the board of all the uses of water that you can think of. Have students create a data chart to list and calculate water use every day for 7 days.
eg.

Use	**Amount of Water**
Cooking food	___ litres
Flushing toilets	___ litres
Drinking	___ litres
Washing clothes	___ litres

Have students present their findings to the class, and develop a personal plan for conserving water at home and at school.

2) Watershed Discovery - Have students sketch their water supply: draw a flow diagram from its source to your home. Where does the water come from? What gets done to it before it gets to your home / to school? Is the water source protected? How?

B.14. Activity 14: Wildlife and Water

Objective:

The major purpose of this activity is for students to increase their perceptions of cause-and-effect relationships affecting wildlife in their communities, and to recommend some personal and community actions that could benefit habitat and wildlife. Students will investigate their neighbourhoods for cause-and-effect relationships that help and hinder wildlife in their community and identify changes in their community that could benefit biodiversity.

Materials:

- Community Habitat Scorecards
- Resource materials on aquatic environments and wildlife

Procedure:

1) Over a one or two week period, look for "cause and effect" relationships in your local neighbourhood or community that seem to help or hurt wildlife - especially aquatic wildlife, but including terrestrial organisms also. These could include road building or repair, dredging of wetlands or mangroves, industrial activities, recreational activities on or near bodies of water, community water uses, farming, etc.

2) Use the Community Habitat Scorecard to keep a score of each item noticed for a period of two weeks, or longer. At the end of the record-keeping period, tally and score the personal sightings.

For example:

Cause	Effect	Hurts	Helps	Neither	Date
Farm field irrigation runs into stream	Polluting stream with fertilizers, causing algae to grow	X			March 22
Person planting trees beside stream	Helping prevent erosion, forming habitat for wildlife, shading stream		X		March 24

3) Write a brief summary, considering the following:

- What were some of the most surprising observations you made? What kinds of actions are people taking that directly affect aquatic environments and wildlife? Which, if any, of these actions seem harmful to wildlife?
- Which, if any, of these actions seem helpful to wildlife?
- Which, if any, seem to have no effect?
- How do these actions affect humans, directly and indirectly?
- What problems affecting aquatic systems were identified?
- How do you know there are problems?
- If there are problems, are they apt to get better or worse in the future?
- Are there any actions that can be taken by individuals and by the community--to reduce or get rid of these problems?

4) Form small groups to share what you identified as cause and effect relationships and whether the effect hurts or helps aquatic systems and wildlife in the community.

Brainstorm actions that could be taken as individuals and as a community to improve the "Community Score." What actions, if any, need to be taken to maintain the quality of the local aquatic environment? How could the group implement such actions?

5) Pool the ideas, eliminating duplicates and make one list representing the group's ideas.

Present your findings to the local council or municipal government.

Evaluation:

Describe three actions taken by members of your community that are helpful to aquatic habitats. Describe three actions that might be taken in your community that could benefit these habitats, explaining what would happen and why it would be helpful. Devise an implementation plan.

Identify what seems to be the greatest short-term problem for aquatic ecosystems in your community and the greatest long-term problem. Identify what might be done, if anything to reduce or eliminate these problems, and how students could help to initiate the proposals (ex. representation to proper authorities).

B.14. Activity 14: Wildlife and Water

COMMUNITY HABITAT SCORECARD
Biodiversity

NAME: ______________________________

CAUSE	EFFECT	HURTS	HELPS	NEITHER	DATE

B.15. References

1. *Adapted from*: Canadian Wildlife Federation (1998). *Project WILD: activity guide*. Western Regional Environmental Education Council, Ontario Canada.

2. *Adapted from*: Canadian Wildlife Federation (1998). *Project WILD/Project WET: activity guide*. Western Regional Environmental Education Council, Ontario Canada.

Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Andrew Ross (Seascape Caribbean)

Part 1 / Section C

Ecosystems & Action for Biodiversity

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

Table of Contents

Introduction

These activities explore concepts of biodiversity with an emphasis on the effects of human activities on the environment. The unit also focuses on efforts to conserve biodiversity through monitoring, research, personal action and eco-tourism. Activities involve students in community research around biodiversity past and present, land use decision-making through a case study, and researching sustainable tourism. A section on Action for Biodiversity has students exploring personal and community actions they can take to conserve biodiversity and help spread the word about its importance.

Photo supplied by: Sirah Ferdinand (OECS Secretariat)

CXC Learning Outcomes Matches

This section meets the learning outcomes of the CXC syllabi, as follows:

BIOLOGY

Section E –Environment and Human Activities

General Objectives

Students should be able to demonstrate:

4. Appreciation of the finite nature of the world's resources
5. Understanding of the effects of human activities on the environment

Specific Objectives

Students should be able to:

3.2. Illustrate using examples that human populations are subject to the same constraints as other natural populations
4.1. Describe various resources and their limits
4.2. Discuss the importance of, and difficulties encountered in recycling manufactured materials
5.1. Discuss the negative impact of human activity on the environment
5.2. Discuss the implications of pollution on marine and wetland environments
5.3. Discuss means by which environment could be conserved and restored

GEOGRAPHY

General Objectives

Students should be able to demonstrate:

1. Interest in the nature of Natural and Human Systems and their interaction
2. Understanding of the processes at work in Natural & Human Systems
3. Understanding of the inter-relationships between the natural and human environment
4. Awareness of the need for the sustainable use of our resources
5. Knowledge and understanding of geography at the local, regional and global scales
6. Awareness and understanding of factors influencing patterns and changes in economic activity
7. Appreciation for the relationship between the natural and human systems

C.1. Activity 15: Biodiversity Stories from Your Community

Objective:

In this activity, students identify and discuss the changes which have occurred in their community over time and which may have affected its biodiversity. Students develop interview questions to ask older family or community members who have lived most of their lives in the community. Students' interview skills are developed and practiced, and class presentations and/or posters are made to share findings.

Materials:

- Paper and pens
- Class copies of Do an Interview! Student Worksheet

Time required:

- 1 period to complete student worksheet, out of class time to conduct interviews,
- 1 period for activity-sharing and summary.

Background:

Most Caribbean communities have experienced many changes over the years, due to development, the increasing numbers of people and the effects of human activity such as tourism, industry, cars and house building. Often these changes were made without any consideration of the natural environment and local ecosystems. The old time residents in your community can tell you about these changes. Through interview research and class presentations, students will explore the changes to their regions' biodiversity and natural heritage.

Procedure:

1) **First Period:** Tell students that they will be interviewing one or two older people in the community about what they remember about the changes that have occurred over the years. Brainstorm some ideas with the class about people they could interview: i.e. grandparents, friends, community members, or this could be part of a trip to a local senior's centre, where students could interview the residents.

2) With the class, brainstorm a list of questions students could ask about their community. For example, they might ask what the land and beaches were like in the community when they were young. What kind of trees and other plants grew there? What types of wildlife did they see in their neighbourhoods or in the forests? Did they go fishing or hunting? What did they catch? How are the beaches and shorelines different now? How did the natural life change from season to season? List the questions on the board, and have students record them on paper or in their journals.

3) Have students work in pairs and give each student a Do an Interview! student worksheet. Ask students to develop their list of questions further and try them out on their partner to make sure they are clear and well understood. Students can then finalize their list of interview questions. Allow several days for students to complete their interviews with the community members.

4) **Second Period:** Once the interviews are completed, ask students to share their stories in small groups or with the class. Have them describe the main changes in the community that their research discovered, and anything else they have learned. Encourage students to think about ways that biodiversity could be protected in their community.

Assessment:

Student presentations should be clear and thoughtful, with precise vocabulary and varied sentences. Look for logical organization and relevant use of details that convey the personality and experiences of the person interviewed.

Collecting information for a beach profile
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

C.1. Activity 15: Biodiversity Stories from Your Community

Do an Interview!

Interviews are a great way to find out information about issues, opinions, history, and change. To help you get the right information in an organized way, follow these steps for a great interview.

Step 1: Figure Out Your Audience

Think about the people you'll want to talk to. Who would be best to ask about changes in your community– grandparents? Parents? Other relatives? Maybe it's a friend or community member? You may want to do more than one interview to get more information. List all the people who may be able to help you. Can you interview them in person, or will you be phoning or emailing them? If the phone call will be long distance, be sure to get permission.

Step 2: Figure Out Your Questions

Write down all the things you want to know. Now make them into questions that are short and sweet. A good rule is to ask about only one main idea in each question. (E.g. What kinds of things did you do as a young child outdoors? What did the swimming beach look like when you were young? What sort of wild animals did you see?)

Step 3: Practice with a Partner!

Try out your list of questions on a partner to make sure they are clearly worded and easily understood. Check each other's questions to see that you've asked about all the information you'll want to get. Talk about any problems you might have had understanding questions, and work to make your interview questions better.

Step 4: Get Interviewing!

Set a date and time for your interview or phone call. When meeting in person or on the phone, make sure you have a quiet spot in which to talk. Have plenty of paper to take notes on. Write down as much as you can in note form and don't worry about neatness – as long as you can read it! If you have a tape recorder, you could record the interview to make sure you get all the details – be sure to ask permission first.

Step 5: Organize Your Data

When you're finished the interview, organize your notes and answers as soon as possible, so you don't forget anything. If you taped the interview, listen to the tape again, and fill in any details and descriptions you remember. Add any the other information you may have collected through emails or other interviews. Is there a photo you could include, or a drawing you could make?

Now organize your information into a presentation:

- Use your questions as headings to tell the story of the changes in your community.
- List the person's name and their connection to you.
- Describe the experiences of the person you interviewed.
- Talk about the most interesting piece of information you found out.
- What is the biggest change noticed by the person you interviewed, and why did it occur?

C.2. Activity 16: St George's Goes to School!

Objective:

In this activity you will review the St. George's Declaration (see student information sheet) and work to apply its principles to your school.

Procedure:

Read through all the principles, and think about how they might apply to your school. Now, in small groups, rewrite the principles so they apply to your school's rules, school grounds and school policies. For example:

1 Better Quality Of Life For All Students

The school will strive to have a healthy environment, serve healthy food that is organic / locally produced, and enable students to get exercise daily.

2 Integrated School Planning

All school plans will include environmental, social, cultural and economic factors such as raising money through a recycling program, building a community garden, working with seniors in the community, etc.

3 More Effective School Laws

The school rules will be changed to reflect environmental protection: i.e. no spraying of pesticides on school property, no littering, no idling of vehicles on school property, etc.

4 Student Participation In Decision-making

Students will be able to participate in school planning and policy decisions as part of committees and student councils.
Etc., etc.

Once your group has completed your new School Principles, get together with another group and share your lists. As a class, create a combined list of St George's Principles for Schools – and present it to the school administration.

Discussion:

1) What Principles are most directly related to conserving biodiversity in the region and why?

2) What principles have been adopted by your country? Do some research online to find out about any current biodiversity programs and strategies, visit www.oecs.org/index.html.

C.2. Activity 16: St George's Goes to School!

What Do the Laws Say?

The St. Georges' Declaration Of Principles for Environmental Sustainability in the Organization of Eastern Caribbean States *(OECS)*

This Declaration sets out the broad framework to be pursued for environmental management in the eastern Caribbean region. The peoples and governments of the Eastern Caribbean states came together to develop these principles, and all citizens are encouraged to take action to help implement them.

It was signed by the OECS Ministers of the Environment in April 2001. The St. George's Declaration contains 21 Principles. OECS Member States have developed National Environmental Management Strategies (NEMS) to implement the declaration's principles at the national level. (OECS 2007)

You can see the entire document on the OECS web site:
oecs.org/esdu/SGD.htm;
ccanet.net/

Litter on the Beach
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

The Principles

1 Better Quality Of Life For All

The people and the governments of the region will together strive to reduce poverty, create jobs, improve on health and welfare. In so doing, care will be taken not to destroy the environment and introduce changes at a rate to which people cannot adapt.

2 Integrated Development Planning

All local, national and regional development policies and plans will be fully integrated to include environmental, social, cultural and economic factors, which affect the small island systems of the region.

3 More Effective Laws And Institutions

The national and regional institutions which are responsible for the management of the natural resources in each country, will be strengthened to implement programmes, decisions and to enforce appropriate laws relating to the environment.

4 Civil Society Participation In Decision-making

All public and private sector organizations responsible for the environment will ensure that all people, whether as groups or individuals, participate in decision-making on natural resources management and in the implementation of these decisions. They will be given every opportunity to share traditional knowledge on environmental management.

5 Meaningful Participation By The Private Sector

Governments and the private sector will work together to ensure that business and commercial activity do not negatively affect human health and the environment. The private sector will be allowed input into the design of sustainable development activities and also be held accountable for negative impacts of their activities on the environment. Good environmental management practices make good business sense.

6 Economic Benefits From Environmental Management

New ways and means will be adopted to ensure that environmental priorities are reflected in economic development programmes and also ensure economic returns from the use of the natural resources. In all cases where individuals and institutions damage natural resources, they will pay for rehabilitation. Incentives will be provided for proper environmental management.

7 Broad-based Environmental Education And Awareness

The public of the region have the right to information, training and education on environmental management in forms which they can easily understand and obtain at minimal costs. In particular, information on the practices and products which have a negative impact on the natural and cultural environment and on public health, will be shared.

8 Preparation For Climate Change

Governments will enact laws, create organizations and institutions and provide money to assist people and communities to adapt to the impact of climate change.

9 Integrated Disaster Management

Governments will integrate disaster management initiatives with environmental priorities to help the peoples of the region in their preparation for and management of the impacts of natural and man-made disasters.

10 Preventing Air, Water And Land Pollution

Measures will be taken to prevent, reduce and control waste generation and disposal, as well as pollution of land, rivers, sea and the air. The people of the region will always strive to harmonise their approaches to waste management and recycle waste products.

11 Using Available Resources Wisely

The resources of the region must be used for the economic and social benefit for all, in a manner which will ensure that others who come after can also benefit from their use of these resources. There will be precaution against over exploitation. OECS governments will work together to guard those resources which are under the control of all the islands.

12 Protecting Natural And Cultural Heritage

Governments, organizations and individuals will conserve and rehabilitate cultural monuments, which are important to the peoples for cultural, scientific, aesthetic and spiritual reasons.

13 Protecting Plant And Animal Species

The flora and fauna and the ecosystems of the region will be conserved and protected. At the same time, the people and authorities must prevent the introduction of alien and modified species which may have a negative impact on the environment and their health. Endangered species and their habitats will be secured and protected.

14 Sensible And Sustainable Trade

The people and governments of the region will only engage in trade which does not lead to waste of natural resources or negatively affect conservation practices. The prices of all raw materials produced in the region must include their environmental costs.

15 Cooperation In Science And Technology

Our understanding and application of science and technology must take into consideration the natural and cultural environment. Research techniques will be harmonised and scientific and technical information will be shared on a regular basis, among the various interest groups in the region.

16 Using Energy Efficiently

The promotion of energy conservation through the use of energy efficient technologies and systems will be high priority for everyone in the region. However, the people of the region will expand their use of renewable energy sources such as solar and wind power.

17 Joint Decision-making On International Environmental Agreements

The governments and peoples of the region will become increasingly active participants in international agreements on the environment. Joint regional positions will be reflected in these agreements.

18 Coordinated Work With The International Community

Environmental management programmes in the region, including those managed by international agencies, will be coordinated to avoid duplication of effort and ensure the efficient use of scarce funds. At the same time, the region will clearly and collectively present its needs to the international agencies.

19 Putting The Principles To Work

The OECS governments will develop and adopt environmental management strategies to guide the implementation of these principles. There will also be cooperation and collaboration in areas where environmental issues and problems affect more than one country.

20 Obligations Of Member States

The Member States of the OECS will recognise their commitment to the principles and put measures in place to ensure their implementation. Governments will report on progress of implementation at the annual meeting of the OECS Ministers of the Environment Policy Committee (EPC).

21 Review And Updating Of The Principles

The principles will be reviewed after three years of implementation. Governments and the people of the OECS will then determine whether they will become binding on all Member States.

C.3. Activity 17: Green Tourists? An Industry Study

Background:

Tourism is a major industry of the Caribbean, and a key element of the regions' economy. The ecosystems, plants and animals of the region are a main attraction for people visiting from around the world.

Objective:

In this activity you will be surveying an actual tourist industry facility - a local hotel, resort, tourist attraction or event – and researching ways in which it could become more sustainable.

Materials:

- A contact list of local tourist resorts, hotels and attractions
- Class copies of the Eco-Tourism Background Sheet and Student Interview Worksheet

Procedure:

First Class Period:

Get into pairs or small groups – this will be your Eco Tourism research group. With your group, review the list of local tourist resorts, and select one to study. Student groups should sign up for one resort or attraction each, so as to have only one group of students researching each facility.

As a class, review the Eco Tourism Background Sheet. Review the list of Ecotourism criteria, and make sure that all elements are clearly understood. Then follow the directions on the Student Worksheet and practice the interview questions.

Out of Class:

Use some out of class time to set up and conduct the interview(s) with staff at the tourist facility that you chose. Call the resort first to explain your project and inquire who the best person would be to talk to. If possible, visit the facility with your Eco Tourism research group to conduct the interview, get a tour of the facility and pick up any brochures or other information that might be useful.

Compile your interview data and any other information you may have discovered about the tourist facility – e.g. brochures, website information, marketing information, etc. Develop a display on the tourist facility using poster board, and summarizing your findings from the interview. The display should include a photo of the facility, answers to the survey questions, a "green" rating of the facility out of 10, reasons for your rating, and 5 main ways that the facility could improve its eco tourism rating.

Second Class Period:

Present your display to the class along with your eco tourism rating and your suggestions for improvement. If possible, invite members of the tourist facilities being presented, other tourism association members and community groups to the presentation. If possible, provide the facility with your display once you have completed it.

Resources:

ecotourism.org
International Ecotourism Society.

ec3global.com/products-programs/green-globe
Green Globe is a worldwide certification program for sustainable tourism.

greenhotels.com
Supports hotels trying to be more sustainable.

blueflag.org
Blue Flag is a voluntary eco-label awarded to over 3200 beaches and marinas in 37 countries across Europe, South Africa, New Zealand, Canada and the Caribbean. The Blue Flag Programme is run by the non-profit organisation Foundation for Environmental Education (FEE).

turismo-sostenible.co.cr/EN/home.shtml
Costa Rica has developed a Certificate for Sustainable Tourism that evaluates aspects of any tourist operation against a set of best practices in sustainability for the tourism industry.

C.3. Activity 17: Green Tourists? An Industry Study ~ Eco-Toursim

What is Eco Tourism?

"Environmentally responsible travel to natural areas, in order to enjoy and appreciate nature (and accompanying cultural features, both past and present) that promote conservation, have a low visitor impact and provide for beneficially active socio-economic involvement of local peoples."

~ Nature Conservancy and the World Conservation Union (IUCN)

Ecotourism: Responsible travel to natural areas that conserves the environment and improves the welfare of local people[1]

There are three primary goals of ecotourism:

1. Threats to conservation targets are reduced.
2. Income is generated for conservation.
3. Local communities are benefited.

What Makes it Different from other forms of Tourism?

Most tourism in natural areas today is not ecotourism and is not therefore sustainable. Ecotourism emphasizes conservation, education, traveler responsibility and active community participation. Specifically, ecotourism has the following characteristics:

- Conscientious, low-impact visitor activities
- Promotes awareness and appreciation of local cultures and biodiversity
- Sustainable economic and environmental benefits to local communities
- Educational components for the traveler, tourism workers and local communities
- Provides direct financial benefits for conservation
- Reduced threats to protected areas, wildlife and natural communities

Some Negative Impacts of Tourism[2]

- Cruise ships in the Caribbean are estimated to produce more than 70,000 tons of waste each year.
- An average 18-hole golf course soaks up at least 525,000 gallons of water a day - enough to supply the irrigation needs of 100 small farmers.
- There are 109 countries on Earth with coral reefs. All are being damaged by cruise ship anchors and sewage, by tourists breaking off chunks of coral, and by commercial harvesting for sale to tourists.

Why Eco Tourism?

- In Dominica, in the Caribbean, "stay over" tourists using small, nature-based lodges spent 18 times more than cruise passengers spend while visiting the island.
- United Nations Environment Programme (UNEP) and Conservation International have indicated that most of tourism's expansion is occurring in and around the world's remaining natural areas.
- 80% of money for all-inclusive package tours goes to airlines, hotels, and other international companies. Eco-tourism lodges hire and purchase locally, and sometimes put as much as 95% of money back into the local economy.

Ecotourism is growing at a rate of 20 - 34% annually, as estimated by the World Travel and Tourism Council (2007)[3]

C.3. Activity 17: Green Tourists? An Industry Study ~ Eco Tourism & Your Community

Do an Interview!

Interviews are a great way to find out information. To help you get the right information in an organized way, follow these steps for a great interview.

Step 1: Figure Out Your Audience

Think about the people you'll want to talk to at the hotel or tourist facility. A manager or information officer would probably be the best people to talk with. You may want to do more than one interview to get more information. Can you interview them in person, or will you be phoning or emailing them? If the phone call will be long distance, be sure to get permission.

Step 2: Figure Out Your Questions

Review the list of survey questions at the end of this sheet and make sure they are clear and well understood. Add any questions for things you would like to know more about.

Step 3: Practice with a Partner!

Try out the list of questions on a partner to make sure they are clearly worded and easily understood. Check each other's questions to see that you've asked about all the information you'll want to get. Talk about any problems you might have had understanding questions, and work to make your interview questions better.

Step 4: Get Interviewing!

Set a date and time for your interview or phone call. When meeting in person or on the phone, make sure you have a quiet spot in which to talk. Have plenty of paper to take notes on. Write down as much as you can in note form and don't worry about neatness – as long as you can read it! If you have a tape recorder, you could record the interview to make sure you get all the details – be sure to ask permission first.

Step 5: Organize Your Data

When you're finished the interview, organize your notes and answers as soon as possible, so you don't forget anything. If you taped the interview, listen to the tape again, and fill in any details and descriptions you remember. Add any the other information you may have collected through emails or other interviews. Is there a brochure you could include?

Now organize your information into a presentation:

- Use your questions as headings to summarize the facility's eco-tourism efforts.
- List the person's name and their position at the facility.
- Talk about the most interesting piece of information you found out.
- Rate the facility's efforts to be more sustainable: give it a mark out of 10.

C.3. Activity 17: Green Tourists? An Industry Study ~ Eco-Toursim Survey

Questions

Hello. My name is _____. I am a student at _____ School and we are studying biodiversity and the role of eco-tourism. I would like to ask you a few questions about your tourist facility for a school project on eco-tourism. Who at your facility would be the best person to speak with?

The survey should only take 10 or 15 minutes. I appreciate your help very much.

Date:
Name of Tourist Facility / Hotel:
What is your name?
What is your position with the facility? (your title?):
How long have your worked at the facility?

Section 1: Green Facility Programs that Reduce Threats to Conservation

1. These first questions are about any programs or things that the facility does to support conservation. For example:
Does your facility have:
( ) a recycling program
( ) a water conservation program
( ) an energy conservation program
( ) a composting program
( ) a "green garden" – a no pesticides / herbicides program

2. What about the cleaning products you use:
• Are they non-toxic, phosphate-free, biodegradable?
• What about paper towels and paper products in the bathroom – do you use unbleached paper products? Recycled paper products?

3. What about the paper products you use in the office and around the facility:
Do you use recycled paper in the office? For any of your publications and brochures?

4. Do you have live potted plants in the buildings to keep the air healthier?

C.3. Activity 17: Green Tourists? An Industry Study ~ Eco-Toursim Survey

5. What about new furniture – do you have any policy about what type of wood furniture you buy?
E.g. All newly purchased furnishings are of non-hardwoods

If the facility is a hotel: ask about these "green guestroom" items:
(skip to question 7 if it is not a hotel)

6. A checklist for "Green" Hotel Rooms:
Do you have any "No smoking" rooms in the hotel?
Do the bathrooms have:
( ) Low-flow sink aerators
( ) Low-flow showerhead (2.5 to 3.0 gpm)
( ) Low-flush toilet or toilet adaptations to save water
( ) Bulk dispensers for amenities (no small plastic bottles)
( ) Amenities: 100% natural, biodegradable, vegetable-oil base, , natural scents or scent-free

• Laundry detergents: do you use non-toxic, phosphate-free, biodegradable, chlorine-free products?

• Glass water glasses, no paper covers

• Ceiling fans as an option to air conditioning

• Cloth laundry bags, Baskets to return clean laundry

7. Do you market your facility as "green" or "eco-tourist" friendly?
Do you have any brochures or other information that you could provide me with?

8. Has your facility has done any ecotourism planning, or any environmental assessment of its site, resource use, and impacts on the local ecosystems?

9. What are the primary natural resources of this area?

C.3. Activity 17: Green Tourists? An Industry Study ~ Eco-Toursim Survey

10. Does the facility have an eco-tourism management plan?
If so, ask if it is possible to get a copy?

Section 2: Income Generated for Conservation

These questions are around donating money from the facility to support conservation projects.

11. Do you give any portion of your income to local conservation programs?
For example: A percentage of room or meal fees, entrance or visitor fees to a site, food concession sales, or donation box for conservation programs on site.

12. Where does the money go to and what is it used for?

13. Do you have any partnerships with local conservation groups?
If so, please tell me about them.

Section 3: Benefits to the Local Community

These are my last few questions for you –

14. Do you provide environmental education training to your staff?
E.g. Training programs that highlight environmental awareness and conservation.
If so, can you tell me a bit about it?

15. Do you provide any environmental education for tourists?
E.g. Nature guides, Visitor Centres, Nature programs, hikes or talks

16. Do you provide any environmental education for locals or school students?
E.g. Opportunities for students and community members to participate in programs and activities

17. Is there anything you would like to ask me?

18. Would you like to see a copy of the project when it is complete?

Many thanks for your help with my project today!

C.4. Activity 18: Decisions, Decisions: The Green River Watershed[4]

Objective:

Students will work in small groups to make some development decisions around a fictitious river and watershed area using a collage.

Materials:

For each group of three students: Scissors, tape, glue, paper, a set of land use cut outs, copies of Student Background Sheet, large piece of paper on which to fasten the cutouts.

Background:

Every human use of an area affects ecosystems, positively or negatively. What humans do with land is a reflection of human priorities and lifestyles. Sometimes, "development" that benefits humans has disastrous effects on the plants and animals living in the area.

At the centre of land use issues is the concept of growth. Growth in ecosystems has natural limits, set by the availability of energy and other life-supporting factors. Due to these limits, all components of the ecosystem are able to live in harmony and in balance. Human activities can often go beyond the natural limits of a system. Humans build dams to create power, take water from rivers to irrigate farms, drain wetland areas to build homes and buildings. All of these activities affect the habitats of the plants and animals living in the ecosystems.

Mangroves, for example, are often seen as swampy, "wasted" land, yet they are important elements of the coastline, and nurseries for hundreds of species of plants and animals. Mangroves prevent erosion, filter nutrients, and provide protection for the coast from severe weather. Mangrove trees are unique as they can survive in salt water and can tolerate their roots becoming exposed due to tidal shifts and wave action. Estimates are that 90% of commercial fish species use mangrove ecosystems at some point in their **life cycle**. Many birds, snakes, insects, and plants also make their home in mangroves. However, hundreds of hectares of mangroves are lost each year to draining, dredging, filling and pollution.

A major challenge now facing humans is how to have a more responsible impact on the ecosystems we depend on. This activity presents these concerns through decisions that you and your group will make around a river and wetland area.

Procedure:

1) Look at the cut-out sheets - you'll see boxes labelled with "grocery", "gas station", "restaurant", "houses", "fruit tree plantations", "chicken farm", "bleach factory", "park", "highway" and "hotel". You will be responsible for arranging the pattern of land use around the river and wetland in such a way that its health and sustainability is preserved.

2) As a class, brainstorm all the pros and cons for each of the land uses. Write the lists up on the board so everyone can see them. For example, farms produce food, have economic value, and provide jobs, but they also often use pesticides that may damage people and the environment, cause spoil erosion, and use chemical fertilizers that can pollute the water supply. Hotels and businesses provide employment, provide commerce, and create economic stability, but they also produce wastes and sewage, use a lot of water, may pollute the environment (detergents, chemicals, pesticides, fertilizers), and generate wastes and sewage.

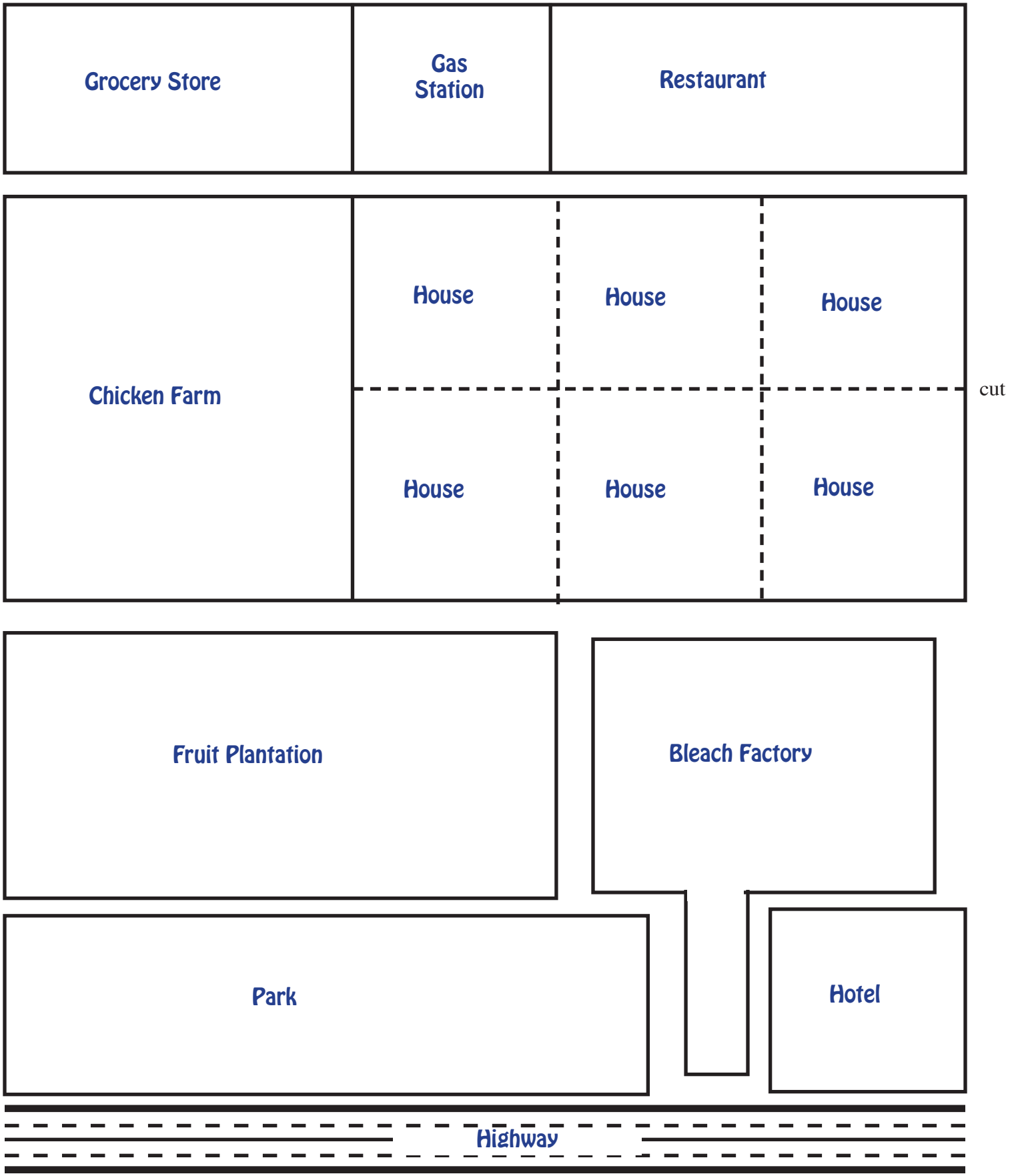
3) Cut out the land use pieces and the outline of the river and mangrove area. Your job will be to place the river and mangrove onto the large sheet of paper, and then arrange all the land use cutouts around the site. ALL the land use pieces must be used; however you may reduce their size by cutting them. They can touch but they must not overlap. You may also create additional land use choices if you wish.

The objective of your development decisions is to come up with the best possible land use plan: allow all the land use to occur, while preserving the mangrove and river biodiversity, as well as preventing any water pollution from occurring. For each of the land uses, make some decisions as to how the people in charge will minimize the damage to the ecosystem. There are difficult choices to make here – discuss the consequences of your decisions: for example, shutting down the bleach factory would harm the economic viability of the area. Closing down the farm takes away local food production and employment. What are some ways that the farm and businesses can exist while protecting as much wildlife habitat and water quality as possible?

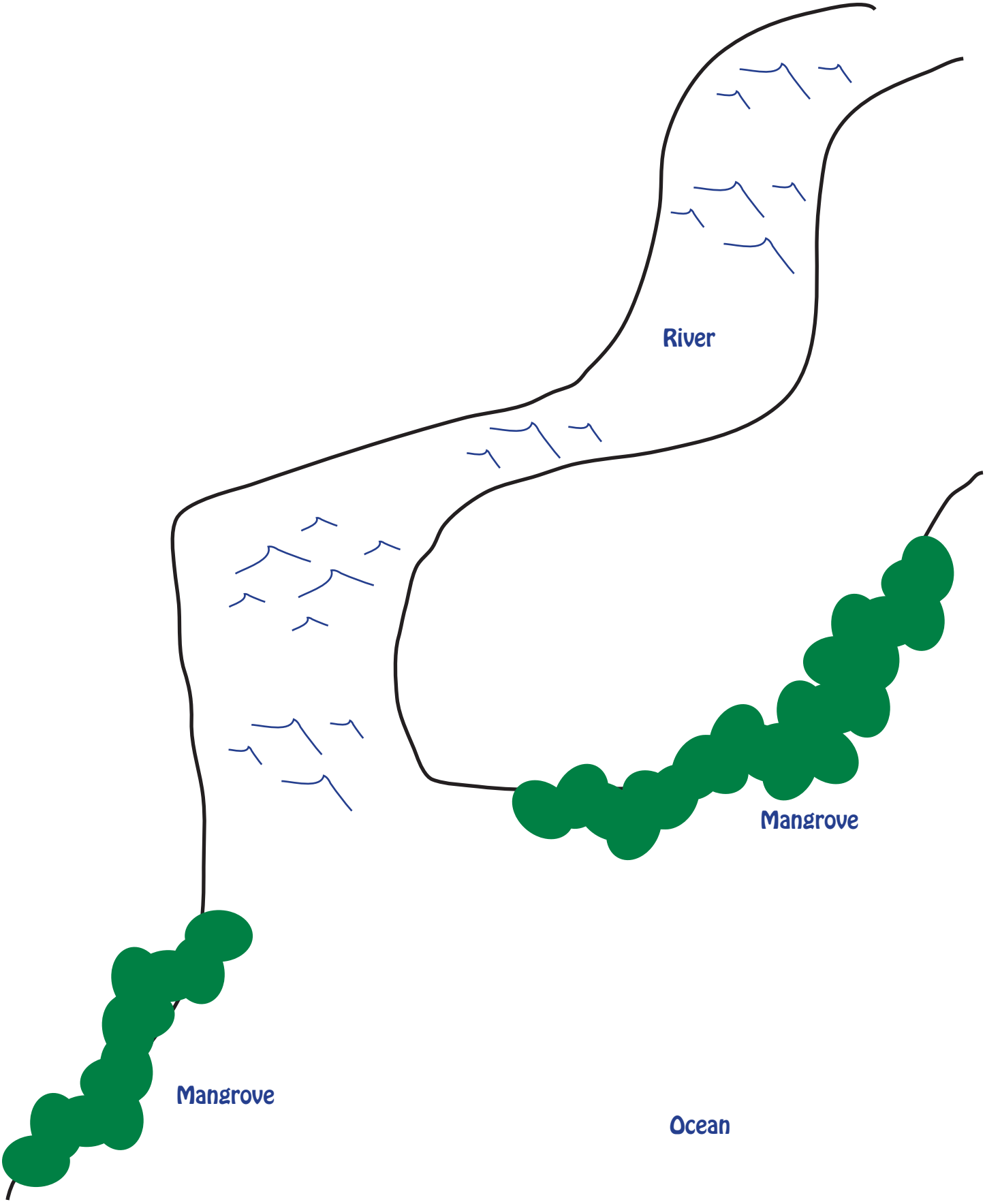
4) Move the land use cut outs around your "site", and use small loops of tape to stick them down so you can change your mind. When you have your final plan, glue the cut outs to the large sheet of paper.

5) Present your proposal to the class, explaining how each of the land uses will prevent damages to the system while being able to operate successfully. E.g. perhaps you need to add a "waste treatment plant" to treat the **effluent** from the hoes, hotel and bleach factory?

C.4. Activity 18: Decisions, Decisions: The Green River Watershed



C.4. Activity 18: Decisions, Decisions: The Green River Watershed



C.5. Action for Biodiversity: Just Do It!

To the Teacher:
What is an Environmental Action Education Project?

Environmental action projects involve students in tackling an environmental issue or problem, or working to improve an environmental setting. An action project can be as simple or as complex as you want to make it: from making and maintaining a community notice board of environmental events to developing a plan for buying local produce for the school cafeteria. Action projects are often most successful when focused at the local community level, where contacts, issues and efforts usually have the most relevance.

Why Do Action Education?

As educators, we nurture awareness of the environment, and teach students about ecological systems, habitats, biodiversity, interdependence and cultural connections. Yet what of the action component – does having knowledge about an issue lead directly to taking action? Do we really prepare students to actively address real-world problems? Schools are traditionally seen as places for learning about things, rather than how to do things. Action projects provide avenues for skills development, practice and field-testing, and support students in actually taking responsible action on issues and problems that affect them and their community.

Action learning is an important part of education because it:

Helps students develop control over their lives.
Too often students are left feeling overwhelmed at the enormity of environmental problems, and disconnected from "the system" and society as a whole. Through taking action on a problem, students begin to understand that they have the power to bring about positive and significant change. Studying biodiversity can be a daunting and depressing topic, unless students see some way they can have an impact on the problems they encounter.

Enhances creative and critical thinking skills by making learning relevant, alive and real.
Students have opportunities to practice skills of enquiry, values analysis, clarification and problem-solving in relevant, real life situations.

Integrates diverse subject areas.
Science, social studies and language arts are at the core of many environmental issues. Students who work to save a wetland area may study the plants and animals that live there, apply geography and mapping skills to chart the area, research and write articles about the human impacts that threaten the area, and create murals of historical and present use of wetlands.

Connects students to the broader community.
When students develop more community perspective and commitment they become "bonded" to their communities and enhance their sense of place, of belonging to something beyond their families and school.

The Action Projects Gallery activity is a good place to begin exploring the idea of action projects. It introduces students to action projects by having them review and categorize different case studies. Current research shows that students gain a great deal of knowledge and decision-making skills from reviewing real case studies, as well as inspiration and a range of ideas for tackling an issue.

The Teacher's Role in an Action Project

Your role in an action project changes from being the main conveyer of information to being a facilitator for action skills development, a contact for information sources, and a coach in student decision-making and implementation of proposed solutions. Your first step is to help students select the problem they feel is important to address. This can be challenging, for the action project must come from the learners themselves, in order to have relevance and meaning.

C.5. Action for Biodiversity: Just Do It!

Teach and Practice Action Skills

Action education researchers such as Hammond (1993) and McClaren (1995) have identified a basic set of action skills that can be learned and must be taught, practiced and applied. These include:

- identifying, researching and investigating the selected problem or issue
- communication (letter writing, phone calling, public speaking) and lobbying skills
- presentation skills
- leadership and group organization skills
- conflict resolution skills
- ability to determine support and opposition, and select appropriate methods, strategies and tactics for implementing action

You know your students best. Assess what action skills they have and what they might need to learn or practice in order to be successful in their action project.

Identify Realistic Stages

One of your most critical roles is to coach students to plan in a manner that breaks their "end goal vision" into a subset of realistic steps or milestones. In this way, if time constraints delay attaining the ultimate goal (and projects always seem to take longer than we think), students will still have a positive sense of accomplishment. Remind students that an environmental problem that took years to form cannot be solved in days or weeks.

Write it all Down!
The Importance of Case Studies

Case studies are important tools that increase students' exposure to multiple instances of problems and solutions. Research tells us that having students (and teachers) read about and discuss case studies about what others have done to solve environmental problems are important strategies for success in action projects. Keep a record of your projects' progress, timelines, successes and challenges. The stories also make great media press releases that help to profile the work you and your class are doing. Also, classes in subsequent years can choose to pick up well-documented projects and continue them, building on past student work and furthering the end goals. The Guidelines for Action student page will help students select an action project and guide their efforts – make copies for all class members when you are working towards choosing an action project.

C.6. Activity 19: Action Projects Gallery

Objective:

There is a wide range of action projects to choose from. Reviewing and categorizing many types of action projects helps provide inspiration, options and ideas. This activity will get you thinking about the range of action project ideas, and may provide some inspiration for a project of your own.

Materials:

Sets of the 4 Student Sheets for small group work: "Action Projects Gallery activity page," "Types of Action Projects," "Action Project Cards" and "Take Action for Biodiversity" and some chart paper.

Procedure:

1) In your group, check out the sheet called Types of Action Projects.

Now read through the Action Project Cards and sort them by type of action project, using the headings on the sheet (Educate and Inform, Raise Money, etc.). If you've been involved in action projects, know of others, or have an idea for one you'd like to do, make a card and add it to the appropriate pile. Remember that projects are often made up of smaller projects and may overlap several categories or not fit at all.

Discussion questions:

- What category of action projects did you like the most? Why?
- Which project surprised you the most?
- Can you think of different ways to tackle some of the environmental problems presented in the case studies?
- How many of the action projects targeted biodiversity, and in what ways?

2) Read through the "Take Action for Biodiversity" examples as a group. Now, come up with a project or action that seems most interesting to your group and be ready to share it and describe why you chose it.

3) In your group, discuss an action project that interests you. Write down some ideas as to how you might carry it out. In order to share with the class, write your groups' action project idea on a piece of flip chart paper or the blackboard.

4) **Presentation:** In your presentation to the class, describe why you chose the action project, what you'd like to accomplish, and a brief overview of a suggested plan of action. Post each group's summary to create a class display of possible projects.

C.6. Activity 19: Action Projects Gallery[5]

Types of Action Projects

1. Educate and Inform

Projects that teach other people about an issue. Examples include writing newspaper articles, pamphlets, plays, poems and songs, making posters, murals and advertisements, and hosting school celebrations (e.g. Earth Day, Beach Cleanup Day).

2. Consumer Choices

Personal decisions you might decide to make, like refusing to buy things that have more than one layer of packaging, bringing your own bags and containers to the store, buying locally-made and locally-grown products; buying organic, buying used items, reducing what you buy, etc.

3. Raise Money

Raising money for a cause, like buying land for conservation, or adopting an animal like a Polar Bear or a parrot through a non-profit group. Or, fundraise to make your own project happen.

4. Political Action

This sounds pretty serious (!) but includes things like meeting with school administrators and local government people about issues, speaking at school and public meetings, developing and passing around petitions, and writing letters to the editors of newspapers.

5. "Get Down and Dirty" Projects

These action projects make direct changes to the environment, like greening your schoolyard, tree planting, stream and beach clean-ups, gardening, etc.

6. Lifestyles Choices

These include decisions like walking, biking or taking public transport over taking a car, choosing "low-impact" recreation like hiking and swimming versus riding all-terrain vehicles and speedboats.

7. Other ?!

Your choice – anything that doesn't fit into the above categories!

C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS[6]

A/ Synopsis of Canon Laurie Anglican School

Winner of the Bio-School Award for Best Practice in Solid Waste Management

This school undertakes many activities related to Solid Waste Management. They include :

- Discussions with the Solid Waste Management Authority to plan the way forward with respect to solid waste management at the school

- Clean-up exercises
- Presentations by staff of the Solid Waste Authority to the school
- School assemblies that focus on litter management
- Provision of waste receptacles in the school yard and classrooms
- Showcasing of litter management as "best practice" in exhibition, GLO-EX2 hosted by Education District 2
- Video documentation of some activities by Dove Marketing Inc.
- Tour of the Deglos Sanitary Landfill by the entire staff and student body
- Organisation of anti-litter march through streets of Castries and distributed messages to minibus operators and vendors
- Participation, regularly in Antilitter Schools' March and National Cleanup Campaign organized by the Solid Waste Management Authority
- Production of jingles, songs, poems, compositions and paintings focusing on litter management
- Engagement of students in Waste Management Research Project
- Production of craft items from waste materials and exhibited them
- Development of antilitter pledge for school : " With strong determination, pride and dedication, I vow not to litter and to encourage the people of my community and country to do the same, for the cleanliness and health of our nation, St. Lucia"
- Featuring of Littering in article of School Creed – " Just for today, I will not drop any paper and other litter in the classroom or on the playground"
- Appointment of "Secret Litter Agent" to help curb the incidence of littering on its premises. This method of monitoring the school's "Litter Bugs" has been a resounding success
- Production of a booklet entitled "Influencing and Developing Environmental Awareness for Life" ,Ideal Practices, which includes a compilation of press releases, students' work, the Secret Litter Agent proposal, lyrics to jingles, slogans and pictures
- The school is managed by Ms. Andrea Bourne

C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS

B/ Synopsis of La Guerre Combined Primary School Environmental Club

Winner of the Bio-School Award for Most Outstanding Primary School Environmental Club

The Environmental Club of this school was established in the year 2001. The school has an enrollment of 214 students and the school is located in the community of Babonneau.

The Environment Club of the school has twenty-five student members.

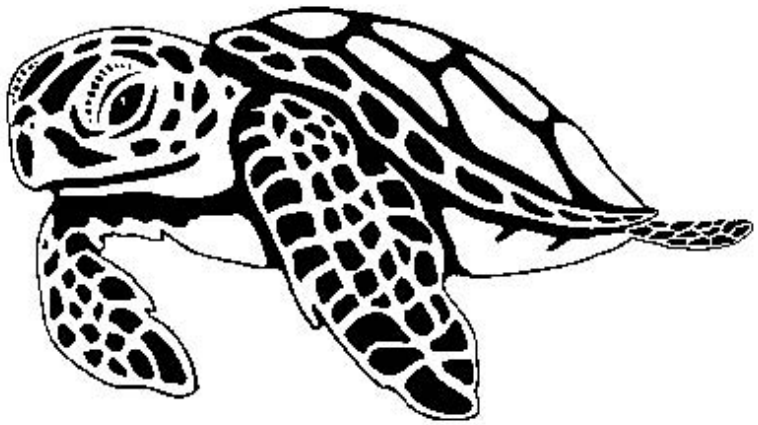
The main objectives of the club are to develop an awareness of the importance of the environment among students and to cultivate the need to protect valuable natural resources.

The members of the club are committed to the various activities organized by the group leader as well as the St. Lucia National Trust. These activities are geared towards enhancing the environment, thus making St. Lucia a better and healthier place to live.

Some of the activities which the club participates in, include the following:

- Clean-up campaigns
- Beautification projects which include planting flowers and painting public places like the Bus Shelter
- Participation in turtle watches
- Observation of Earth Day activities including Soleil Leve
- Touring of National Heritage sites and places of historical significance
- Guest lectures are organized for speakers to address the students on environmental issues, and
- Presentations at events organized to focus on the environment

The club is supervised by Mrs. Mary Francis, who has served as the leader of the club from its inception.



C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS

C/ Synopsis of Micoud Primary School

Winner of the Bio-School Award for Best Practices in Beautification

This school was established in 1975. The student population is 348. The school is a member of the St. Lucia National Trust. Students have been exposed to a number of environmentally oriented tours over the years. Sites visited include the Barre de L'Isle Forest Nature Trail, the Fregate Island Nature Reserve and La Tille Falls. Recently, the school observed a presentation and lecture series at which resource persons delivered environmental topics to students.

There are twenty active students which participate in the school's beautification project. Activities under this project include tree planting, maintaining the plants and related areas and producing labels with the names of the trees. The latter serves as an education exercise for both students and members of the community. The fruit trees and tree crops which have been planted in the school for many years have been well taken care of and not destroyed. There is a school garden which also provides produce for sale. The students also take part in on-going clean-up exercises. The school is under the leadership of Ms. Laurentia Canaii.

C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS

D/ Synopsis of Ciceron Secondary

Winner of the Bio-School Award for Best Practice in Water Management

A visit to this school will establish that the students take pride in their environment. Through a project involving an American non-governmental organization represented by Mary Beth Sutton, over the past twelve months, the students have been engaged in a watershed management project where they have been given a better appreciation of the need to conserve our valuable water resources through the processes that occur in a watershed. A watershed is the drainage basin of a river and in St. Lucia, our water supply mainly comes from our rivers. Through its environmental club, the school undertakes activities that impact positively on the conservation of the watershed of which their school is an integral part.

The Club began in September 2004 as a pilot project with the Caribbean Students' Environmental Alliance (Caribbean SEA). Presently they are 32 members strong, and are being assisted by 3 collaborating teachers. They believe that maintaining a healthy and secure natural resource base is the only way that we can ensure our environment's ability to provide for the needs of our growing population.

Their major objectives are to:

- Focus student education on their home watershed, emphasizing the need to retain environmental quality in a tourism based economy.
- Educate students on their personal connectedness to the environment and the balance that is needed between them.
- Initiate baseline monitoring of the natural environment.
- Undertake research projects involving testing innovative technologies, researching beneficial alternatives and monitoring impacts on the environment.

The Environmental Club also did a clean up of the school ravine after some heavy rains which brought down lots of garbage against the school fence even causing the fence to break. There was a large volume of garbage which consisted of mainly plastic bottles and plastic bags. That garbage came from the community. They prepared a brochure to let members of the community know how their garbage disposal affects the school, an important of the watershed.

Composting - They use biodegradeable waste from the school canteen, wood shavings from the building technology lab, plant clippings from maintenance of the school grounds as well as waste from the rabbit hutch to build up a compost heap. Based on this project, the school is now participating in a school greening programme with the St.Lucia Solid Waste Management Authority.

The school has an anti-litter patrol. Two members of the anti-litter patrol are responsible for each form level. Classroom inspections are done three times daily by members of the Anti-litter Patrol. We use a set of criteria which includes areas such as cleanliness of floors, corridors, desk and chairs to award points to each classroom.

...continued on next page

C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS

D/ Synopsis of Ciceron Secondary ...continued

At the end of each week, the classroom in each form level with the highest score is awarded a certificate.

The students visited the WASCO Treatment Plant and learnt how WASCO treats water before getting it into our taps. They feel safe drinking water from their taps. They also learnt how sewage water is treated before being released into the environment.

The students have also gone on forest walks and learnt about the importance of the forest in water production.

They visited the Soufriere Marine Management Area, SMMA, to get an appreciation for the collaborative management of a marine reserve.

As a result of these various activities, the students have obtained a better understanding of the processes that can impact on the conservation of a watershed and therefore the water supply.

Students are also becoming aware of water management including the impact of solid waste on the water supply and how they can prevent the water supply from becoming contaminated by garbage.

It is the intention of the school that a water quality monitoring program will be instituted during the approaching 2005-2006 academic year, to assess the levels of chemicals in the stream passing through their school on a regular basis. This information will later be presented to the school and community and exhibited nationally.

C.6. Activity 19: Action Projects Gallery ~ ACTION PROJECT CARDS

E/ Synopsis of Castries Comprehensive Secondary School Environmental Club

Winner of the Bio-School Award for Most Outstanding Secondary School Environmental Club

This school takes pride in being an accomplished environmentally educated institution. Over the years, it has seen a number of environmentally conscious initiatives come on stream. These have been manifested through the establishment of a number of clubs/organizations/groups.

Examples include :

- The Red Cross Group established in 1991 which has organized and taken part in Simulation exercises to increase consciousness for health and safety.
- The Young Leaders Club which has won several awards including regional ones for the innovative idea of building a green house with plastic soft drink bottles. Members have also engaged in establishing murals at strategic locations around the school depicting the need to keep the environment clean.
- The Science Department's Annual activities such as Environmental Clean-Up and Water Awareness campaigns. A solar weed eater developed by Mr. Austin Philip of the Technical Department won second prize in this year's Science Fair. Over the years, Mr. Philip has developed several solar projects including a solar fridge, a solar iron, a solar cattle fence and a solar car.
- The general administration and staff of the school engage in the Rodent Elimination Project with the Rodent Coordination Unit (RCU) of the Ministry of Health.
- Several environment clubs established over the years, of which one will be singled out tonight. The main objective of this club is to protect the environment with a special emphasis on biodiversity. For the past ten years, members of the club have undertaken many projects aimed at ensuring the continual existence of our trees and animals.

Examples include:

- Caring for the mangrove on the northern boundary of the school and cleaning the river, which flows through it into the sea, in the hope of maintaining the life, birds and other wild life of that region.
- Planting trees around the school.
- Adopting the stretch of beach from the Wharf Restaurant to the Choc River.
- Monitoring the indiscriminate disposal of waste dumped into the Choc River, which flows into the sea.
- Controlling rat infestation.
- Linking with the Forestry Department to educate and save our pure water supply.
- Joining international groups on clean-up campaigns.
- Participating in the UNESCO Associated Schools' Sandwatch Project.
- Participating in the Biodiversity debate.

The club tends to involve the entire school in its activities, as well as educate the community especially through the PTA and the Young Leaders.

C.6. Activity 19: Action Projects Gallery

Take Action for Biodiversity!

Preserving the amazing biodiversity on this planet, and in the Caribbean is up to all of us. There are many things that individuals and schools can do to help. Check out the following list of Actions for Biodiversity.

Actions for Biodiversity: What You Can Do

Don't Buy Bottled Water

Bottled water may be a healthy alternative to soft drinks, but the plastic bottle has a hidden dark side: energy consumption, waste disposal, and other environmental concerns. As bottled water grows in popularity, these problems also proliferate. Easy solution: if you want to carry water with you, get a reusable bottle and refill it at the tap!

Buy Locally Grown Food

Visit farmers' markets and stock up on food in-season or join a community-supported agriculture group. Supporting local agriculture helps conserve farmland, bolsters the economy, provides fresh food to people, and reduces the pollution and energy use related to transporting food over great distances.

Don't Use Anti-bacterial Soap

Antibacterial soaps aren't any better than ordinary soap at preventing household illnesses. And traces of antibacterial soap in the water could even contribute to creating strains of resistant bacteria. So—why use them?

Garden with Native Plants

Landscaping with native plants requires minimal maintenance and enhances wildlife habitat. Contact your local botanical garden, arboretum, or native plant nursery for information about what grows best in your area and the habitat requirements of different plant species.

Choose Heritage or Heirloom Vegetables, Fruits and Livestock

Grow some of the old varieties of food crops and domestic animals. In the history of human agriculture, over 7,000 food crops have been raised for food. Due to industrial agriculture, only 15 plant and 8 animal species are relied upon for 90% of all human food.

Conserve Water

Freshwater is a precious, finite resource. Conserving water not only helps to preserve this irreplaceable natural resource, but also to reduce the strain on urban wastewater management systems, saving money and energy. There are many, easy ways to conserve our water resources into the future.

Control your Pets

Controlling non-native predators such as domestic cats is an important part of maintaining or creating native habitat. Free-roaming domestic cats are responsible for killing perhaps hundreds of millions of birds each year. Many groups maintain that keeping your cat inside makes for a healthier and happier feline as well.

Say No to Plastic Bags!

Plastic bags are everywhere—they get caught in trees and they clog our waterways. Paper bags come with a significant environmental impact as well, made out of tree pulp and utilizing energy to produce. Best is to bring a cloth bag instead of plastic or paper... or choose no bag!

Compost

Many things we throw away can be turned into compost, which you can use on houseplants or on plants outside.

Reduce the use of Pesticides and Herbicides

Minimizing such use keeps our waters clean, which is critical to life in streams and ponds as well as in estuaries and the ocean.

Calculate Your Carbon Footprint

Energy conservation—at home, at work, at school, and while traveling—reduces greenhouse gas emissions. The United States Environmental Protection Agency's emissions calculator gives you an estimate of your personal greenhouse gas emissions (or your family's). Then see if you can shrink your "carbon footprint"!

Choose Green Energy

Green power is supplied in whole or in part from renewable energy sources, such as wind and solar power, geothermal, and hydropower, all of which come with fewer negative environmental impacts.

UNPLUG!

Chargers for your cell phone, iPod, digital camera, and computer can all use significant amounts of power even when they're not charging the devices. Also use power strips to switch off televisions, home theater equipment, and stereos when you're not using them, as these products waste energy even when you think they are turned "off."

Go Vegetarian Once a Week

Not only does it consume enormous amounts of energy to raise cattle and transport meat to your supermarket, much of the world's deforestation is a result of clearing and burning to create more grazing land for livestock.

Don't Use Bug Zappers and Pesticides

They are not proven effective against pests and end up killing beneficial insects. The most important thing you can do to prevent mosquitoes in your yard is to find and eliminate all sources of standing water.

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Andrew Ross (Seascape Caribbean)

Part 2 / Introduction

The Caribbean: A Biological Diversity Hotspot

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

IV/ Part 2: The Caribbean: A Biological Diversity Hotspot

"The Caribbean Islands, comprising the Bahamas, Greater and Lesser Antilles and some islands located off the northern coast of South America, represent the most important insular system of the New World. As one of the 34 biodiversity hotspots…, these islands represent a global priority for conservation." [1]

~ Maunder et al

Introduction

This unit highlights the unique ecosystems of the Caribbean region and engages students in detailed case studies of their ecology, threats to their survival, and decisions that are needed to protect them. It is organized around five ecosystem types: open-ocean, coasts, coral reefs, mangrove forests and tropical forests. Each section consists of background information specific to the ecosystem type, a case study to illustrate key concepts with real world examples, and corresponding activities in support of the learning outcomes within the CXC syllabi for biology, integrated science, and geography. The concepts within this unit also mesh with the St. Georges' Declaration of Principles for Environmental Sustainability, particularly those pertaining to the protection of plant and animal species, protection of natural and cultural heritage, wise use of resources, and the prevention of air, water, and land pollution.

The Case for Case Studies

Environmental case studies are written accounts of events that have actually taken place and that demonstrate a process or series of events that students can analyze to learn more about different aspects of environmental problems.

For example, by having your students read and analyze a case study outlining how a community took action to solve a local environmental issue, students can discuss the processes that were used, what worked and what didn't, alternative strategies, and their own ideas for solving problems. Using case studies helps students evaluate real life situations and helps them decide how they might act in similar situations. Because they describe things that actually have happened in specific contexts and locations, real life case studies are also more relevant than textbook examples of issues.

The five sections described below can be treated as stand-alone resources.

A) Open-Ocean Ecosystems

This section focuses on the pelagic zone, or the open ocean. As this part of the ocean is not near the coast, it is not directly affected by activities occurring along coastlines or the land behind them. The section explores the biodiversity attributes of this **ecosystem**, examines the threats to it, and presents a case study concerning the use of a marine reserve to protect biodiversity. Activities provide students an opportunity to either engage in a marine park negotiation simulation, prepare a class presentation on the need for protection of an area, or encourage stewardship of the ocean.

Key Concepts

- The islands and oceans of the Caribbean are considered a biodiversity hotspot.
- An ocean ecosystem is body of salt water where currents, waves, and tides intermingle to create a distinct community of organisms that interact together in the physical environment.
- Ocean ecosystems are home to some of the most diverse life on Earth and hold a varied number of plants, animals, and micro-organisms.
- Oceans are divided into five zones (epipelagic, mesopelagic, bathypelatic, abyssal, and hadal zones) based on water depth and light penetration.
- Marine ecosystems are different from terrestrial ecosystems because ocean waves and currents allow for species and other influences (such as pollution) to easily move into, out of, and across multiple habitats.
- Ocean currents are created from forces such as planet rotation, wind, temperature, salinity differences, and the gravitation of the moon.
- Species within the ocean are interdependent on one another. All organisms in the ocean, from baleen whales to tiny plankton, are essential members of the marine food web.
- Human activities such as resource over-exploitation, habitat destruction, pollution and the production of greenhouse gas emissions impact the health of ocean ecosystems.
- Local and national governments, grassroots organizations, conservation groups, non-governmental organizations (NGOs), local inhabitants, and scientists are working together to develop strategies to protect and conserve ocean ecosystems.

Conservation Science Institute. (2007). Ocean change initiative. Retrieved from: conservationinstitute.org/oceanchangeinitiative.htm.Lucia

B) Coastal Ecosystems

Coastal ecosystems include coral reefs, mangroves, seagrass beds, salt marshes, wetlands, estuaries, bays, beaches, dunes, and rocky shores. However, this section focuses specifically on beaches, rocky shores, and seagrass beds. Coral reefs and mangroves are detailed in subsequent sections. This section explores the biodiversity attributes of this ecosystem, human activities that take place within it, and the natural and human influences threatening it. A case study explores the interests of stakeholder groups in protecting biodiversity in a marine reserve. Two activities engage students in developing their knowledge and understanding of the complexities of coastal ecosystems. The first activity uses the case study as a framework to engage students in role-playing a round-table discussion. The second activity focuses on inspiring students to create a personal code of environmental ethics and behaviour.

Key Concepts

- A coastal ecosystem is the area where land and sea join to create a distinct community of organisms that interact together in the physical environment.
- Coastal ecosystems include coral reefs, mangroves, seagrass beds, salt marshes, wetlands, estuaries, bays, beaches, and rocky shores.
- Seagrass beds, beaches, and rocky shores provide vital habitats for many species of plants and animals.
- Beach sand is made up of sedimentary, igneous, and metaphorphic rocks.
- Rocky shores and beaches can be divided into tidal zones (subtidal, intertidal and supratidal). Each tidal zone provides habitats for a variety of plant and animal species.
- Beaches and rocky shores protect the coastline from the erosive forces of wind and waves. They are also vital to the economic and social vitality of local human populations in the Caribbean.
- Seagrass beds are large areas of underwater marine flowering plants that resemble grasslands. Many species of plant and animal depend on seagrass beds for survival.
- Beaches, rocky shores, and seagrass beds are impacted by human activities such as recreation and tourism, construction, resource extraction, pollution, and climate change.
- Coastal ecosystems are highly complex, dynamic, productive environments that are in a constant state of flux. The health of each habitat and species within a coastal ecosystem is dependent on the health of other nearby habitats, species, and ecosystems, both marine and terrestrial.

C) Coral Reef Ecosystems

This section focuses on the coral reef ecosystems and their biological diversity, considering human uses of these ecosystems and threats associated with them. A case study presents the ecological threats and management concerns that face many coral reef ecosystems in the Caribbean and around the globe. Two activities have also been included. The first activity introduces students to the elements of a marine management plan, while the second activity advances students understanding of the ecological threats facing coral reefs through the introduction of environmental public education presentations.

Key Concepts

- A coral reef ecosystem is a community of different underwater plants, fish, and other marine life in a coral reef environment.
- Coral polyps form coral reefs.
- Tropical corals require sunlight and salt water to survive. Warm water corals require a specific range of temperatures.
- There are four different types of coral reefs: fringing reefs, platform reefs, barrier reefs, and atolls.
- Coral reefs are one of the most biodiversity rich ecosystems in the world.
- Coral reefs provide vital habitats for many species of plants and animals.
- Coral reef ecosystems have significant ecological, cultural, intrinsic, and economic value.
- Natural forces such as storms as well as human activities such as resource extraction, tourism, pollution, and climate change impact the health of coral reef ecosystems.
- Coral reef ecosystems are intricately connected within themselves and to other ecosystems, including coastal, marine and forest ecosystems.
- The protection of coral reefs within the Caribbean is essential to the well-being of coastal ecosystems and to all those that depend on them, including humans.

D) Mangrove Swamp Ecosystems

This section focuses on mangrove swamp ecosystems of the tropics and subtropics. Students will explore the biodiversity attributes of this ecosystem, human activities that take place within it, as well as the ecological threats and conservation activities taking place to protect mangrove swamps. A case study examines the environmental characteristics of a specific Caribbean mangrove swamp and the cooperative management strategies enacted by stakeholders to conserve the ecosystem. Activities provide students with opportunities to further expand their understanding

of the importance of maintaining biodiverse ecosystems while practicing debating skills and delivering creative presentations.

Key Concepts

- Mangrove swamp ecosystems are coastal wetlands of the tropics that contain trees, shrubs, vegetation, and an associated community of organisms, which exist in saltwater intertidal zones.
- Mangrove swamps can be found in estuaries, sheltered coastlines, and river deltas.
- In mangrove swamps, salt-tolerant species are found closer to the water and less salt-tolerant species are found away from the water.
- Mangrove trees (as well as other plant species) have uniquely adapted to exist in an environment with low levels of oxygen, high salinity, and constantly changing tides.
- Four species of mangrove trees are found within the islands of the Eastern Caribbean: red, black, white, and buttonwood mangroves.
- Mangrove swamps provide a rich habitat for thousands of species of birds, fish, shellfish, invertebrates, and plants, as well as nurseries for many important fish species, including those harvested for food.
- Mangrove swamps have an important ecological and economic role. They provide wood and non-wood forest products, coastal protection against the effects of waves and wind, tourism and recreation opportunities, and vital habitats to maintain biological diversity.
- Many mangrove swamps have been destroyed or degraded in the past, possibly more so than coral reef and tropical rainforest ecosystems.
- Mangroves are intricately linked to other ecosystems through exchanges of water with both upstream terrestrial ecosystems and downstream marine communities.
- People are beginning to realize the value of mangrove ecosystems and are initiating activities to conserve and protect them.

E) Tropical Forest Ecosystems

This section focuses on tropical forest ecosystems, including forest structures; key species; deforestation; and conservation, preservation and restoration activities. A number of case studies are presented, drawn from various regions of the Caribbean, which highlight challenges encountered in achieving sustainable forest management. Several activities engage students to further expand their knowledge and understanding of tropical forest ecosystems.

Key Concepts

- Forests can be defined using the concept of ecoregions. An ecoregion is a relatively large unit of land containing distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land use change.
- Caribbean forests are typically classified as Tropical and Subtropical Moist Broadleaf Forests, Tropical and Subtropical Dry Broadleaf Forests, or Tropical and Subtropical Coniferous Forests.
- Tropical forests are rich in biodiversity.
- Forests are made up of five distinct layers: overstory (emergent), canopy, understory, shrub, and forest floor.
- There are high rates of deforestation (the conversion of forest land into non-forest land) in the Caribbean region.
- Deforestation is the result of both natural events (i.e. earthquakes, tsunamis, volcanic eruptions) and human activities (i.e. agriculture, forestry).
- A number of organizations are working to reduce tropical forest destruction and to promote sustainable forest management.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

CXC Learning Outcomes Matches

The material covered in *Biodiversity in the Caribbean* meets the learning outcomes of the CXC syllabi as follows:

BIOLOGY

Section A – Living Organisms in the Environment

General Objectives

Students should be able to demonstrate:

5. An ability to apply knowledge of the interrelationships of organisms and their environment to identify environmental problems

Section E – Environment and Human Activities

General Objectives

Students should be able to demonstrate:

1. An understanding of the importance of the physical environment to living organisms
2. An ability to undertake a simple ecological study
3. Understanding of the factors that affect the growth of populations
4. An appreciation of the finite nature of the world's resources
5. Understanding of the effects of human activities on the environment

INTEGRATED SCIENCE

Section A – The Organism

General Objectives

Students should be able to demonstrate:

1. The interdependence of life processes
2. The relationship between an organism and its environment

Section B – The Home/Workplace

General Objectives

Students should be able to demonstrate:

1. The soil and the sea as two most important outdoor working environments in the Caribbean and that they are both natural resources as well as ecosystems
2. The relationship between humans and the environment in which they work

GEOGRAPHY

General Objectives

Students should be able to demonstrate:

1. An understanding of geomorphic, atmospheric and biotic processes
6. An appreciation of the relationship between the natural and human systems

The Caribbean: A Biodiversity "Hotspot"

The Caribbean Islands are a very special place on the planet. Very few other places in the world can claim to have as many **endemic** species – plants and animals native and completely unique to that place. The diversity of plants is exceptionally high, with more than 13,000 species, of which more than 6,500 are thought to be single-island endemics, or plants found on one island only. Perhaps as many as 205 plants are found nowhere else on Earth[2].

More than 600 bird species are found in the Caribbean Islands, of which an estimated 160 are endemic[3]. As many as 90 mammal species occur in the region, with more than 40 being endemic. The islands are particularly rich in reptile species, with more than 500 species making their home among them. A remarkable 94% (470) of these reptile species are endemic. Among the amphibians, roughly 170 species are native to the Caribbean Islands, of which all but a very few are endemic to single islands.

The exceptional level of endemism of the region includes 65 of an estimated 160 freshwater fish species, which are restricted to one or a few islands, and further to just a single lake or spring head[4].

A high level of unique species is only one factor that makes the Caribbean a **biodiversity hotspot.** The region also is also characterized by massive **habitat** loss and vulnerability to extinctions. Centuries of colonial agriculture and trade have resulted in the near complete destruction of lowland ecosystem types, especially the seasonally dry forests[5]. The Caribbean mahogany (*Swietenia mahaoni*) has been over-exploited throughout the region to the point of being **extirpated** in some parts of its former range. Thirteen bird species have already gone extinct and forty-eight species endemic to the islands are threatened with extinction.

Conservation efforts are currently aimed at high priority species such as the St. Vincent parrot (*Amazona guildingii*), the St. Lucia parrot (*Amazona versicolor*), and the imperial parrot (*Amazona imperialis*) of Dominica. Nineteen native mammal species have become extinct and the West Indian manatee (*Trichechus manatus*) is increasingly threatened by commercial fishing and fatal collisions with boats.

From the foregoing discussion, it is no stretch to claim that each Caribbean island is a unique in its species and habitats, but sadly the priceless treasure this represents is increasingly threatened with extinction and degradation. So much so that the region has the dubious distinction of being one of the world's six hottest biodiversity hotspots. While one of the region's ecosystems, the Tropical and Subtropical Coniferous Forest, has been pretty much wiped out (*see discussion within the Tropical Forests section*), there is still time to protect, conserve and restore the open-ocean, coasts, coral reefs, mangroves, and rainforests. But there is not much time.

Caribbean Regional Sea: Biodiversity Data

SPECIES	ENDEMIC	T	%
seagrasses	2	7	15
coral genera	9	25	23
molluscs	0	633	15
shrimps	0	45	13
lobsters	8	23	15
sharks	14	76	22
seabirds	1	23	8
cetaceans	9	30	34
sirenians	9	1	25
pinnipeds	-	0	-

where:

- endemic = restricted to the region
- T = total species richness in the region
- % = species richness in the region as a percentage of the world species richniess in each group of organisms
- - = no data available or not applicable

UNEP. (2009). Caribbean environment program. Retrieved from: cep.unep.org/issues/biodiveristy.html.

Caribbean Regional Sea: Regional Endemic Species

	Scientific Name	Common Name	Status
seagrass	*Halophila engelmannii* *Halophila johnsonii*		
lobsters	*Acanthacaris caeca* *Eurnephrops manningi* *Eurnephrops bairdii* *Eurnephrops cadenasi* *Metanephrops binghami* *Nephropides caribaeus* *Nephropides neglecta* *Thaumastocheles zaleucus*	Atlangic deep-sea lobster Banded lobster Red lobster Sculptured lobster Caribbean lobster Mitten lobsterette Ruby lobsterette Atlantic pincer lobster	
sharks	*Apristurus rivieri* *Apristurus canutus* *Apristurus parvipinnis* *Eridacnis barbouri* *Etmopeterus schultzi* *Oxynotus caribbaeus* *Parmaturus camphechiensis* *Pristiophorus schroederii* *Schroederichthys maculotus* *Scyllorhirus meadi* *Scyllorhirus boa* *Scyllorhirus torrei* *Scyllorhirus heperius*	Broadgill catshark Hoary catshark Smallfin catshark Cuban ribbontail cat-shark Fringefin lanternshark Green lanternshark Caribbean roughshark Campeche catshark Bahamas sawshark Narrowtail catshark Boa catsharck Dwarf catshark Whitesaddled catshark	
seabirds	*Pterodroma hasitata*	Black-capped petrel	Endangered

UNEP. (2009). Caribbean environment program. Retrieved from: cep.unep.org/issues/biodiveristy.html

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1. Maunder, M., Leiva, A., Santiago-Valentin, E., Stevenson, D.W., Acevedo-Rodriguez, P., Meerow, A.W., Mejia, M., Clubbe, C., and Francisco-Ortega, J. (2008). Plant conservation in the Caribbean island biodiversity hotspot. *The Botanical Review. 74*, 197-207. Retrieved from: articlearchives.com/environment-natural-resources/ecology/1865829-1.htm

2. Conservation International. (2007). *Biodiversity hotspot: Caribbean islands*. Retrieved from:biodiversityhotspots.org/xp/hotspots/caribbean/Pages/biodiversity.aspx#http://www.biodiversityhotspots.org/xp

3. Santiago-Valentín, E., and Francisco-Ortega, J. (2008). Plant evolution and biodiversity in the Caribbean islands–perspectives from molecular markers. *The Botanical Review, 74*(1), 1-4.

4. Conservation International, 2007.

5. Maunder et. al, 2008.

Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

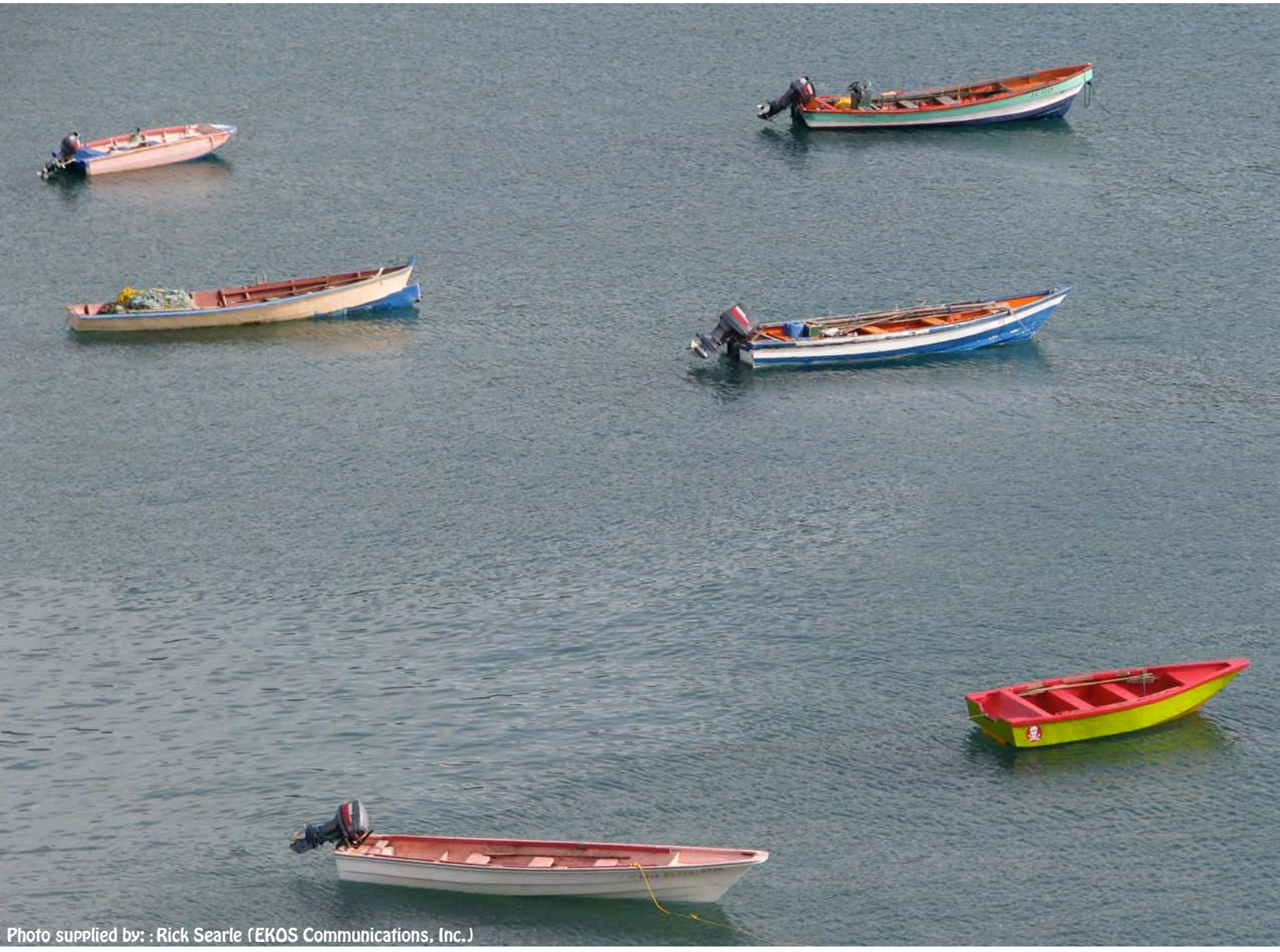


Photo supplied by: : Rick Searle (EKOS Communications, Inc.)

Part 2 / Section A

Open Ocean Ecosystems

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

Table of Contents

A.1. What is the Ocean?

An **ocean ecosystem** is a body of salt water where currents, waves, and tides intermingle to create a distinct **community** of organisms that interact together in the physical environment. Ocean ecosystems are home to some of the most diverse life on Earth and hold a varied number of plants, animals, and microorganisms[1]. Due to the size and complexity of ocean ecosystems, many of their species are still unknown to scientists. With their rich biodiversity, ocean ecosystems are essential to the economic, social, and cultural life of those countries interspersed among them.

Ocean or marine ecosystems are different from terrestrial ecosystems in the great extent and rate of dispersal of nutrients, materials,and **holoplanktonic,** organisms that live their entire life in the sea, floating in the water between the bottom and surface. Marine ecosystems tend to be more open than their terrestrial counterparts, in that they exhibit higher rates of movement in and out of areas as a result of the forces of ocean waves and currents[2]. Ocean ecosystems differ in size, form, and species diversity depending on their location around the globe. Oceans, however, are important for all humans as they are key influences on climate and weather and produce extensive food for human consumption.

The Caribbean Sea, an arm of the Atlantic Ocean, is a partially enclosed sea in the Western Hemisphere bounded by North, South, and Central America. The Caribbean encompasses an area of 3,274,085 square kilometers[3]. The average depth of this sea is 2200 metres, with the Cayman Trench at 7535 metres being the greatest depth measured to this date. It is estimated that 40% of the Caribbean's human population lives within two kilometers of the coast[4]. The ocean ecosystem is an essential factor in the social, cultural, economic, and political lives of all Caribbean people.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Caribbean Sea Large Marine Ecosystem
NOAA Fisheries: Northeast Fisheries Science Center. (2003) Large Marine Ecosystems: Caribbean Sea. Retrieved from: na.nefsc.noaa.gov/lme/text/lme12.htm

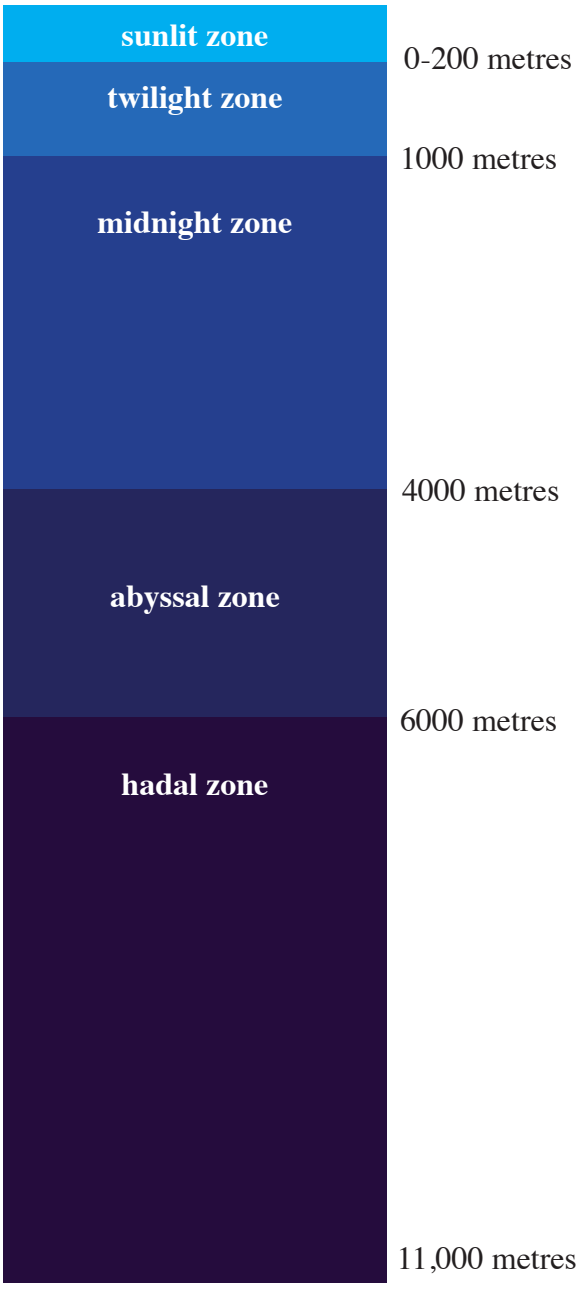
A.2. Ocean Zones

The Caribbean Sea, like all oceans, is divided into five zones based on water depth and light penetration.

1. The **epipelagic**, or sunlit zone, is the top layer of the ocean where enough sunlight penetrates for plants to carry out **photosynthesis**.
2. The **mesopelagic**, or twilight zone, is a dimly-lit zone where some light penetrates, but not enough for plants to grow.
3. The **bathypelagic**, or midnight zone, is the deep ocean layer where no light penetrates.
4. The **abyssal zone** is the pitch-black bottom layer of the ocean where pressure is immense and water temperature is almost freezing.
5. The **hadal zone** is the water found in the ocean's deepest trenches.

While plants only exist in the sunlit zone (approximately five percent of the ocean) where photosynthesis can occur, animals and microorganisms are found at all depths of the ocean, though their numbers are greater near the surface where food is readily available. Over 90% of all species dwell on the ocean bottom, however, and one rock can provide habitat to over ten major groups such as corals, molluscs and sponge[5]. Oceanic species can either be **pelagic** or **benthic**. Pelagic species live in the open sea, away from the sea bottom, whereas benthic species live on the bottom of the ocean.

Ocean Zones



A.3. Influences on the Ocean

The ocean's movement is controlled by currents. **Ocean currents** are created from forces such as planet rotation, wind, temperature and salinity differences, and the gravitation of the moon acting upon the water.

Winds are created as warm ocean currents from the tropics move towards the poles releasing warm air, and cold ocean currents move from the North and South poles towards the tropics bringing cool air. Wind drives the currents and waves found in oceans, which are necessary to circulate food.

The main oceanic current in the Caribbean Sea is an extension of the North Equatorial and South Equatorial currents, which enter the sea in the southeast and flow in a northwest direction. These currents are created by the sun warming the ocean water at the equator.

Because of these currents and the Caribbean's proximity to the equator, the water temperature here ranges from 25.5 degrees Celsius in the winter to 28 degrees Celsius in the summer[6].

The Caribbean Sea is a central area for many of the hurricanes that occur within the Western Hemisphere. Hurricanes and other tropical storms are caused by warm water and moist, warm air, which are readily found in the tropics.

A.4. Oceanic Species

The Caribbean region represents the greatest concentration of marine biodiversity in the Atlantic Ocean Basin[7]. Since the Caribbean nations depend on the condition and the beauty of the natural world to generate income, the conservation of the region's biological diversity is not only linked to social, cultural, and political conditions, but also to the economic realities of the region. Although the marine component of biological diversity is of immense importance to humankind, knowledge about the status of marine living resources and ecosystems is less complete than that of terrestrial ecosystems.

The ocean is much richer in species than the land. The Caribbean Sea marine ecosystem has the highest number of regionally endemic species in the world[8]. This is due to the geographic isolation of the Caribbean Sea from other oceanic regions. Atlantic deep-sea lobster (*Acanthacaris caeca*), Caribbean lobster (*Metanephrops binghami*), Bahamas sawshark (*Pristiophorus schroederi*), and Caribbean roughshark (*Oxynotus caribbaeus*) are several examples of endemic marine species found in the Caribbean Sea. All species of marine turtle, except for the flatback (*Natator depressus*) breed in the region. The critically endangered Kemp's Ridley sea turtle (*Lepidochelys kempii*) and the West Indian Manatee (*Trichecus manatus*) exist only in the region.

Hawksbill Turtle (Eretmochelys imbricata)
National Environment & Planning Agency. (n.d.). Your environment & you: biodiversity: protected animal species of Jamaica. Retrieved from: nepa.gov.jm/yourenv/biodiversity/species.htm

(Part 2/Section A) Open Ocean Ecosystems

The Caribbean has a large concentration of marine fish including parrotfish, barracuda, tarpon, snapper, spotted butterfly, porcupine, sturgeon, and damselfish. Smaller fish tend to remain in close proximity to coral reefs, a habitat in which they find shelter and food. Larger fish (which prey on smaller inshore coral reef fish) tend to have a larger habitat area and are found **offshore** from the Caribbean islands. Other commonly found inhabitants within the Caribbean Sea include a variety of conch and other molluscs, Green Sea, and Loggerhead sea turtles, a variety of lobsters and eels, black tip, hammerhead and leopard sharks, various species of jelly fish and sting rays, and many different species of whales, both baleen and toothed.

Species within the ocean are interdependent on one another. All organisms in the ocean, from baleen whales to tiny plankton, are essential members of the marine **food web**. The marine food web explains how all the species in the ocean depend upon each other for food. The web is organized by **trophic levels** (feeding levels) where the smallest primary producers, single-celled plants or phytoplankton, exist at the bottom and the tunas, sharks, and billfishes such as marlins exist at the top.

West Indian Manatee (Trichechus manatus)
National Environment & Planning Agency. (n.d.). Your environment & you: biodiversity: protected animal species of Jamaica. Retrieved from: nepa.gov.jm/yourenv/biodiversity/species.htm

Tropical Food Web
National Oceanic and Atmospheric Agency (NOAA). (2006). ECOPATH modelling.
Retrieved from: celebrating200years. noaa.gov/breakthroughs/ecopath/welcome.html

The fishing industry within the Caribbean occurs within the Caribbean Sea Large Marine Ecosystem. **Large Marine Ecosystems** or LMEs are the jurisdictional regions of the world's oceans, encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major ocean current systems. The Caribbean Sea LME produces an estimated catch of 0.5 million metric tons[9].

FISH CATCH BY COUNTRY

Venezuela	53.5%
Cuba	16%
Guyana	8%
Dominican Republic	3%
Remaining 34 countries	>2%

(NOAA Fisheries: Northeast Fisheries Science Center, 2003).

The principal modes of fishing within the nearshore ecosystem are traps and handlines, along with some netting and spear fishing. Within offshore waters, the principal modes of fishing are bottom trawls, purse seines, and traps.

Over 170 species are caught for commercial purposes, but most of the catch is comprised of less than 50 species[10]. The principal species harvested in the **nearshore** ecosystem are Caribbean spiny lobster (Panulirus argus), coralline reef fishes, and conch. The most important species harvested in the offshore Caribbean Sea are migratory pelagic species such as yellowfin tuna, skipjack tuna, Atlantic blue marlin, swordfish, kingfish, and dolphinfish.

Since the year 2000 , the most valuable fish harvested (in economic terms) were round sardinella species (herrings, shads, and sardines), marine pelagic species (tuna, marlin, and kingfish), and Caribbean spiny lobster and ark clams (Arcidae)[11].

A.5. Emerging Trends/Major Threats

A.5.a. Overexploitation

Species **populations** are not being harvested sustainably, which means more species are being taken than can naturally replace themselves through reproduction. The countries of the Caribbean depend on fishing activities for economic, social, and cultural reasons. Increasing fishing pressure has resulted in widespread overexploitation and declining catches[12]. Fisheries within the area primarily catch small and large pelagic finfish, reef fishes, coastal finfish, crustaceans, and molluscs. As the inshore reef fishery resources become over-exploited, attention is directed to offshore resources, which tend to be highly migratory, trans-boundary, and

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

difficult to monitor. Since many marine species are migratory, international cooperation is necessary to conserve populations from over-exploitation.

Species which mature slowly and produce few young, such as sea turtles, sharks, whales, manatees, and sea birds, are particularly vulnerable to over-exploitation because these species do not produce enough young quickly enough to sustain their populations.

As over-exploitation continues, a phenomenon called "*fishing down the food chain*" occurs. According to Pauly[13], fishing down the food chain has occurred in the Caribbean where there is a decline of the mean trophic level of reported catches and a reduction in the abundance of species at higher trophic levels.

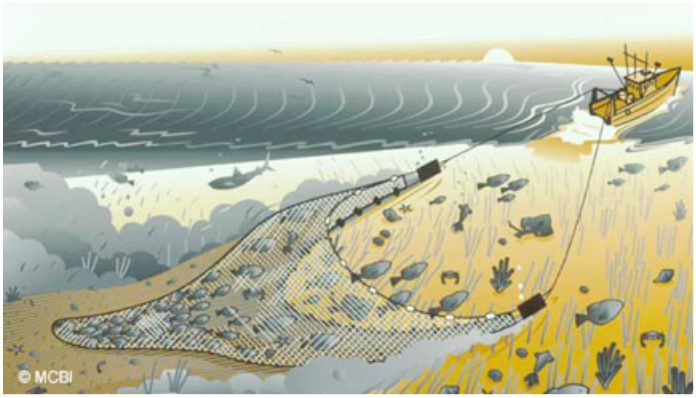
According to calculations done by the Sea Around Us Project (2008), the average maximum length of fish caught within the Caribbean Sea in 1950 was 88.02 centimetres[14]. The average maximum length of fish caught in 2004 was 51.87 centimetres. Essentially, as fishers harvest large fish, the only fish left in the sea are smaller and smaller fish.

By-catches and discards remains another problem. In the effort to harvest certain target species, other populations that often grow more slowly are over harvested. In some cases, this non-targeted species or **by-catch** constitutes the majority of the catch. According to a 1994 estimation by the Food and Agriculture Organization (FAO), by-catches and discards accounted for 25% of the annual estimated total catch. Shrimp fishing, an important fishery in the Caribbean, produces the largest amount of discards at an estimated 9 million tonnes annually. The FAO also estimated that Caribbean Region has the highest percentage of discard of any of the major fishing areas, with nearly half of the catch believed to be discarded[15]. Within the Caribbean this by-catch includes marine mammals, sea turtles, seabirds, finfishes, and invertebrates.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

A.5.b. Habitat Destruction

One of the most important threats to the ocean ecosystem in the Caribbean is the loss or destruction of marine habitat. Trawling for shrimp and lobster can disturb the seabed and the habitat of benthic species, re-suspend sediments, and cause turbidity currents[16]. In marine areas used extensively by recreational visitors and tourists (such as divers, snorkelers, and boat users), impacts such as habitat destruction and community disturbance can be substantial. Since organisms are adapted to certain environments and conditions, changes to these will result in changes to a species population.



Bottom Trawling
Lophelia.Org. (2005). Bottom trawling.
Retrieved from lophelia.org/images/ jpeg/bottomtrawling.jpg

Ecosystems have no clear boundaries and the effects of change to one ecosystem will be realized in other ecosystems that are some distance away. For example, clearing mangrove forests makes the coast more vulnerable to erosion and destroys the habitat of many fish species. For many commercially important fisheries species, such as lobster, the nursery grounds of the young will also be destroyed. Without habitat, these species may not develop to become adults. This has serious repercussions on the entire food chain. Additionally, mangroves buffer the nearshore marine environments from certain land-based impacts, including pollution and sediments. The loss of these functions may result in a deteriorating quality of ocean ecosystems, but also a deteriorating quality of coral reef and coastal ecosystems.

Construction activities on land in the Caribbean can alter the patterns of sediment transport and can cause erosion. Erosion causes sedimentation, which has a negative impact on coral reefs and the ocean ecosystems. Suspended sediments decrease water clarity and as a result affect photosynthesis of plants. This can stress suspension-feeders such as coral by making them expend energy in ridding themselves of sediment. Biodiversity of corals, other invertebrates, fish, and algae is reduced as a result.

A.5.c. Pollution

Within the Caribbean, the main sources of marine pollution are sewage, oil hydrocarbons, sediments, nutrients, pesticides, solid waste, marine debris, and toxic substances. The ocean also acts as a repository of sorts for all the land-produced debris.

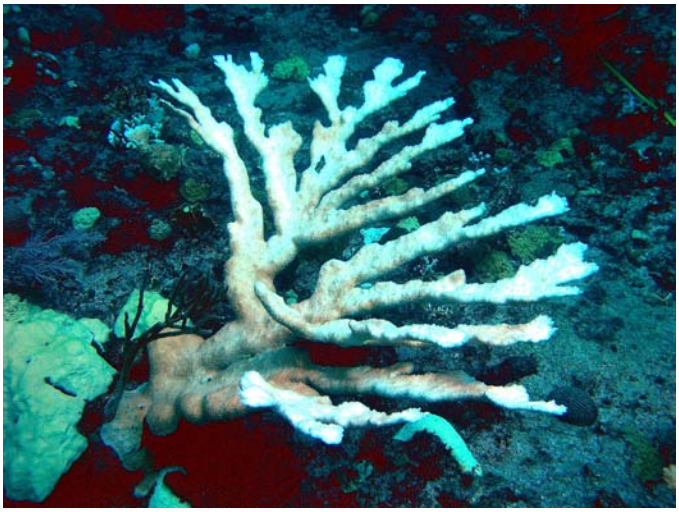
Pollution is a significant contributor to marine ecosystem degradation in the Caribbean. One particular problem within the areas of limited water circulation is a phenomenon called eutrophication. **Eutrophication** is the over-enrichment of a water body with nutrients, resulting in excessive growth of algae (often **agal blooms**) and depletion of oxygen concentration. This causes changes in the aquatic community structure, including decreased biological diversity, and increased fish mortality. Eutrophication can occur naturally, but is occurring in the Caribbean as a result of the excess runoff of nitrogen and phosphorus compounds from agriculture fertilizers and sewage flowing into the ocean. Interestingly, only 10% of all sewage entering the Caribbean Sea is treated. Because of the bay-like geography of the Caribbean Sea, large quantities of water do not flow into or out of it. When eutrophication occurs, the ecological and aesthetic quality of the environment is changed, potentially impacting the ecological health of the ecosystem as well as people's ability to use the area for cultural, economic, and recreational purposes.

A.5.d. Climate Change

What may be the most significant threat facing the ocean of the Caribbean is the expected impacts of climate change. One consequence of climate change to the Caribbean Sea is **sea level rise**. With a rising **sea level**, habitats of marine species may be altered. Other expected impacts of climate change are changes in rainfall and soil moisture, and a possible increase in the number and severity of hurricanes and ocean tropical storms[17]. Increased coastal erosion is also expected with climate change, which will increase the turbidity and quality of the ocean ecosystem.

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Just as land temperatures are increasing, water temperatures are too. Warming temperatures are also considered one of the primary factors causing the massive **coral bleaching** events experienced within the Caribbean's waters[18]. The ocean is a large buffer for temperature change and when temperatures increase, the effects are not felt immediately because of the size of the ocean. However, increases in temperature pose a significant risk to the plants and animals which have a specific **range of tolerance** (optimal range of abiotic factors which an organism needs to survive). Once water temperatures move outside of a species' range and remain there for extended periods of time, then extinction becomes likely. Complementing the problem is that scientists' knowledge about the range of tolerance of many marine species is incomplete.



Bleached elkhorn coral
National Oceanic and Atmospheric Agency (NOAA). (2008).
NOAA coral bleaching monitoring network now global.
Retrieved from:noaanews.noaa.gov/stories2008/20081009_coralbleaching.html

Healthy elkhorn coral
National Oceanic and Atmospheric Agency (NOAA). (2008).
NOAA proposes critical habitat for threatened Elkhorn and Staghorn corals.
Retrieved from: noaanews.noaa.gov/stories2008/20080207_corals.html

Oceans also serve an important role as storehouses of atmospheric carbon dioxide (CO_2). Oceans serve as biological pumps transporting the atmospheric carbon dioxide to the depths of the oceans where tiny oceanic plants, **phytoplankton**, take up dissolved carbon from the water during photosynthesis. The carbon dioxide, which is incorporated into the tissues of the phytoplankton as carbon, will be taken to deeper waters or to the ocean floor as the organisms die or are eaten.

With the uptake of excess carbon, the planet's oceans are becoming increasingly acidic. According to Orr et. al "Surface water pH values have already dropped by about 0.1 pH units from preindustrtial levels and are expected to drop by an additional 0.14 – 0.35 pH units by the end of the 21st century."[19] While the amounts do not sound like much, they are significant increases for sensitive processes such as shell-formation critical to many forms of marine plants and animals, including corals, plankton, snails, clams, oysters, lobsters, and crabs.

When carbon dioxide reacts with seawater, carbonic acid is formed which, in turn, releases hydrogen ions, reducing pH. The additional hydrogen ions bind to carbonate (CO_3), decreasing the amount of carbonate in the water. Less carbonate makes the process of forming calcium carbonate ($CaCO_3$) – the essential mineral building block – very difficult for these life forms. If the pH falls too low, the already formed $CaCO_3$ will begin to dissolve!

Additionally, evidence is emerging that larval and juvenile fish are also susceptible to changes in pH. Clearly, the potential effects of global climate change on the oceans of the world are far-reaching and very significant, underscoring the importance of achieving dramatic reductions in greenhouse gases emissions over the next few years.

A.6. Conserving Ocean Ecosystems

To ensure sustainability of the Caribbean's ocean ecosystems, an **integrated management approach** with local stakeholders and government as well as with other nations is needed.

The ocean ecosystem is an ecosystem shared with and influenced by many other nations and so international support is essential for gaining broad conservation of resources. Intergovernmental and trans-boundary agreements need to negotiated in order to fully ensure the sustainability of ocean ecosystems in the Caribbean.

While there are significant stresses to the ocean ecosystem of the Caribbean, there is a growing awareness about the necessity to protect the marine ecosystems and biodiversity within them. Local and national governments, grassroots organizations, conservation groups, **non-governmental organizations** (NGOs), local inhabitants, and scientists are all contributing to the protection of this ecosystem and its inhabitants.

Photo supplied by: Jennifer Goad

A.7. Case Study:
Folkestone Park and Marine Reserve (FPMR), Barbados[20]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Folkestone+Marine+Park+and+Museum,+Barbados&sll=13.872747,-60.869751&sspn=0.622615,1.07666&ie=UTF8&t=h&z=16

Case Study:
canari.org/folkstone.pdf

Background

Located on the west coast of the island of Barbados, the Folkestone Park and Marine Reserve (FPMR) stretches 2.2 kilometres, extending at its widest point to 950 metres off shore, and 660 metres at it narrowest point. FPMR consists of a recreational facility, visitor centre and a marine reserve. It also contains a play park, a picnic area, and souvenir and water-sport shops.

The Marine Reserve is divided into four zones:
a) **Scientific Zone:** Designated for marine research. No motor power craft access is allowed unless permitted for research or enforcement, and then speeds are limited to five knots.

b/c) **Northern/Southern Water Sports Zone**: Designated for fast speed watercraft use such as water skiing, jet skiing, parasailing etc.

d) **Recreational Zone:** Designated for recreation, including swimming, snorkelling and fishing. There are no restrictions on watercraft entry; however, speed is reduced.

To ensure the stability of the marine reserve, several activities have been prohibited including dynamiting of the reefs, emission of waste into the marine environment, and the fishing and harvesting of coral.

The park was established in 1981 by the Designation of Restricted Areas Order, and the Marine Areas (Preservation and Enhancement) (Barbados Marine Reserve) Regulation (Coastal Zone Management Unit of Barbados, 2008).

Map of Folkstone Park and Marine Reserve
Cumberbatch, J. (2001). Case study of the Folkestone Park and Marine Reserve, Barbados. Technical Report Number 281. Trinidad: Caribbean Natural Resources Institute (CANARI). Retrieved from: canari.org/folkstone.pdf

Environmental Characteristics

Within the Reserve, there are four well-developed fringing reefs, several patch reefs and an offshore bank reef. The fish abundance is low due to historical over-fishing, poor habitat quality, and a severe disease that targeted reef fish in 1994. Sand areas separate the three reef types within and beyond the boundaries of the Reserve. Benthic fauna in these areas include worms (*Bispira variegata*) and occasional urchins (*Tripneustes ventricosus*).

The foreshore area along the length of the Reserve does not fall under the management authority of the FPMR. The foreshore area of the FPMR is situated in a low-lying flat coastal area that has been modified extensively from its natural state and is subjected to extensive human use. In fact, the West Coast is Barbados's premier tourism zone, noted for its up-market hotel facilities and the attendant commercial activities. There is also substantial residential development on or near the shoreline.

Within the Reserve there is an extensive area of intertidal sandy beach habitat with the associated interstitial fauna (animals that live between grains of sand i.e. oligochaetes, harpacticoids, archianellids and nematodes). Some terrestrial wildlife also frequent the area. These include the hawksbill turtle, the green vervet, monkey, the mongoose, the green lizard, and bats. Several bird species, local and migratory, have been observed in the area. Of particular importance is the roost of cattle egrets in a small remnant stand of white mangrove.

There is little natural vegetation along the foreshore. Most of the vegetation communities that do exist comprise mainly non-

native species that were introduced to the island. The remaining mangrove lagoon has been highly modified and disturbed. What exists is merely a remnant of a habitat type that once dominated the area, and one of the few remaining mangrove lagoons in Barbados. White mangrove (*Laguncularia racemosa*), Mahoe (*Thespesia populnea*), Casuarinas (*Casuarina equisetifolia*), Clammy cherry (*Cordia obliqua*), Castor oil (*Ricinus communis*), Mimosa (*Mimosa pudica*) and at least 45 other plant species are relatively common. The faunal composition is diverse, and includes several species of crabs, insects, spiders, snails, birds (at least fifteen species), fish, reptiles and mammals.

The actual land component of the FPMR extends only a few hundred metres north-south along the western coastline, and in the west-east direction the park contains the area lying between the high water mark and the highway. The terrestrial site at the park covers 1.9 hectares in a roughly wedge-shaped land parcel owned by the government. The park provides a variety of recreational opportunities for local residents and visitors and is a major public access to the beaches along that portion of the coastline.

Ecosystem User Groups
A wide range of stakeholder groups influence activities that take place in the FPMR.

- Residents
- Businesses (including hotels located on the foreshore)
- Water sports operators
- Fishers
- Government agencies with responsibility for the area
- Beach users (locals and tourists)

Management Issues

When the FPMR was established in 1981, major stakeholders were not consulted. Fishers, in particular, had no input and their issues were not taken into consideration. This neglect generated a lack of compliance in the way locals used the marine reserve. As a result the FPMR was not functioning as an effective protected area. The reefs were in a state of deterioration, fish abundance was low, and there were a number of user-related conflicts.
In 1997 the Government of Barbados sponsored a study to determine the feasibility of upgrading and enhancing the facilities at FPMR that revealed the following issues:

The size of the reserve

The Marine Reserve covers approximately 11 percent of the length of the West Coast of the island and has a total area of 2.1 square kilometers. The percentage of coastline within the reserve was lower than that typically suggested as necessary to be effective as a marine reserve.

The external impacts on the reserve

While fishing was strictly restricted in the reserve, and there were limitations on water sports and users in the scientific zone, there were a number of other land-based impacts that have not been adequately controlled over the years. For example, groundwater feeding into the FPMR was contaminated with domestic waste from local suck wells and with chemicals from fertilizers and pesticides used in the agriculture and golf course activities within the watershed.

The management focus

There had been a considerable emphasis on the recreational aspects of the FPMR over the years, as opposed to the conservation objectives. Visitors were given no information as to what was considered acceptable environmentally sustainable activities within the FPMR. As a result, users were often seen engaging in damaging acts such as standing, sitting, or walking on the crest of the fringing reefs.

Management capacity

The FPMR had suffered from limitations in funding and maintenance over the years. The demarcation buoys, the markers of the snorkelling trail, and most of the other infrastructure common in marine parks were destroyed as a result of storms, corrosion, theft, and vandalism. Park naturalists and rangers lacked formal training in marine park management.

Enforcement

Enforcement of regulations in the FPMR was ineffective and inconsistent. The Barbados Coast Guard, the Barbados Police Force, and the NCC park rangers all shared responsibility for enforcement in the FPMR. The rangers were not trained in the relevant areas such as regulations, legislation or enforcement techniques.

Inclusion of the stakeholders in the planning and management processes

When the FPMR was established, many of the major stakeholders were not consulted, and there was no public awareness or education program. It appeared that the first attempt at public consultation occurred six months after the FPMR was established. The fishers, in particular, were excluded, not only from the consultation, but also from fishing in the area. This led to deep-seated feelings of resentment and mistrust towards the FPMR management and the enforcement officers.

Conflict among user groups

The major source of conflict emanated from the use of Jet Skis. Complaints from other users included violation of speed restrictions, near misses/accidents with other watercraft, and unskilled riders. To ensure the safety of their guests from the watercraft, a number of hotels in the area received permission from the Harbour Master to place buoys in the water to create safe swimming areas. This resulted in limited access for water sports operators and created the false impression that the boundaries of the park and reserve had been extended. Due to confusion over the location of boundaries in the water, enforcement agents had apprehended and charged fishers for being in the reserve when in fact they were not.

Divers were accused of spear fishing and of destroying reefs to collect coral for souvenirs. Hoteliers, commercial enterprise agents, and water sports operators complained that beach vendors walking along the foreshore were harassing visitors. They were also concerned about the lack of control over the items being sold and the prices at which they were being sold.

Visitor crowding was also a serious problem especially during peak times of the day (10:00 a.m. to 2:00 p.m.) and on cruise ship days.

Questions for Consideration

1. What types of habitats exist within the Folkestone Park and Marine Reserve coastal ecosystem? What are some of the key species that exist in this ecosystem?

2. What types of human activities take place within the FPMR? What impacts might these activities have on the organisms that inhabit the coastal ecosystems of the FPMR?

3. Why is the FPMR an important coastal ecosystem?

4. Of the issues that need to be addressed in the management of the FPMR, which ones pose the greatest risk to biodiversity in the region?

5. What possible impact could the destruction of the FPMR ecosystem have on the tourism industry in Barbados?

6. Imagine that you are responsible for improving the functioning of the FPMR as a protected area:
   - What are the key issues that need to be addressed?
   - Who are the key stakeholders that need to be involved?
   - How would you go about getting stakeholders involved in the improvement of the FPMR as a protected area?
   - What conservation measures would you suggest to improve the FPMR as a protected area?

7. Identify a coastal ecosystem in your country that is being threatened by human activity. Give a brief description of the area, the threats and the stakeholders involved. What do you believe needs to happen to improve the situation? What conservation measures would you suggest?

A.8. Activity 1: Coastal Activities

Objective:
Students will develop an appreciation for keeping water clean.

Methods:
Students participate in field trip, use observation, documentation skills and problem solving skills to assess health of nearby marine ecosystems.

Materials:
- Transportation to nearby beaches
- Pen and paper per student
- Access to resources for research

Time:
4-6 class periods

Background:
Ocean ecosystems can be damaged beyond repair by human activities. Healthy ocean ecosystems are critical to the sustainable survival of all Caribbean islands, communities and biodiversity. With more than 6% of the Caribbean labour force depending on the marine environment for their economic survival, it is paramount that our marine ecosystem be protected.

Procedure:
In this activity, students (in groups) will visit four different beaches on their territory. (One beach could be in an area developed for tourism, another close to the city, one close to an industrial area, and one at the estuary of a river).

The students will walk along the selected beaches and make a note of the various human activities taking place at and around each beach. While visiting the beaches, students will use garbage bags and gloves to pick up any garbage they come across – a great opportunity to learn good conservation practice and leave the beaches in better shape than before the visits.

(a) For each activity, students will do the following:
1. Describe two (2) ways in which the marine ecosystem can be affected by each activity they have found.

2. Develop at least five (5) strategies which can be implemented to combat the problems which can arise.

(b) Students will draw a map of their country or of the area in which the beaches are located. The maps must show the following information:
- The beaches visited
- The activities taking place along the beaches
- Next to each beach, the students will list the possible effects that the activities can have on the marine ecosystem

Upon completion of their maps, each group will list their findings on the board, following which, the class with the aid of the teacher, will develop a conservation plan for the beaches they visited.

Coastal Community
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

A.9. Activity 2: Caribbean Fish Who's Who?[21]

Objectives:

Students will be able to:

- Recognize and identify the major species of fish that live in the Caribbean ocean
- Describe various values of fish species in the ocean ecosystem
- Locate specific habitats/places where fish species occur

Methods:

Students develop an inventory of fish species, research information about the species and their habitat, and locate fish species on a map.

Materials:

- Student worksheets
- Pen and paper per student
- Access to resource materials for research
- Map of Caribbean Sea and nearby islands
- Tape, string, and pins (one for each fish biography completed by students)

Time:

2-3 class periods

Background:

Fish have an important role in the Caribbean Sea. There are many fish species in the Caribbean Sea and each has a unique influence on the ocean ecosystem. Some fish are predators, some feed on plant material, some scavenge and feed on detritus, some deposit eggs in special nests, and some have live young.

The purpose of this activity is to expand students' knowledge of the different species of fish that occur in the Caribbean Sea.

Procedure:

1) Ask the students what fish they believe inhabit the Caribbean Sea. What fish species have they seen, caught, heard about, or read about? Make a list of the different types of fish and post in the classroom. Aim to have a list of approximately ten fish species.

2) Obtain or have students make a large map of the Caribbean Sea and its associated islands.

3) Divide the students into teams. Have each team identify possible sources of information about fish and fish habitats in the Caribbean Sea. Have teams develop a plan for researching information about fish and fish habitats. Some suggested resources include information from family and friends, government organizations, fishers, non-profit organizations, scientific or research groups, the Internet, and the library.

4) Student teams should then use available resources to develop fish biographies for the identified fish species. Teachers can provide students with worksheets to guide the specific biographical information that will be collected for each fish species. Multiple copies of student worksheets , up to 10 for each group, would be useful.

5) Once biographies have been completed students groups should meet up and compare the information they have collected. In some cases, information collected may differ. Students should discuss why difference might exist. The purpose of comparing research is for students to learn about collecting and comparing data from different sources, as well as how to improve accuracy and completeness of research.

6) Students should then tape strings to the biographies and tie a pin to the free end of the string. Students should then pin biographies to the identified geographical area on the Caribbean Sea map. Place tape on the back of the biographies as well, and stick to map or board backing map. Objective is to create a visual network of geographical location of habitats for various fish species. If possible, exhibit the map and fish creations for the school and community to view.

A.9. Activity 2: Caribbean Fish Who's Who?

Fish Species Common Name:	
Fish Species Scientific Name:	
Description of characteristics and adaptations of fish species:	
Draw a sketch of fish species noting any significant features:	
Description of area of Caribbean Sea that Fish species is commonly found:	
Description of fish habitat:	
Description of what fish eats:	
Are other plant or animal species dependent or interdependent on this fish species?:	
Do humans have an interest in this fish species?:	
Why is fish valuable or important (may include ecological, scientific, recreational, economic, political, cultural, aesthetic, or intrinsic reasons)?:	

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Jennifer Goad

Part 2 / Section B

Coastal Ecosystems

USAID
FROM THE AMERICAN PEOPLE

February 2009

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Table of Contents

B.1. What is a Coastal Ecosystem?

A **coastal ecosystem** is the area where land and sea join to create a distinct community of organisms that interact together in the physical environment. Coastal ecosystems may include coral reefs, mangroves, seagrass beds, salt marshes, wetlands, estuaries, bays, beaches, and rocky shores. They also include benthic communities (from the bottom of the sea) and pelagics (inhabitants of the open ocean). Coastal ecosystems are home to a diverse range of species (plants, animals and microorganisms) that are interdependent on one another and which often migrate between habitats.

Coastal ecosystems contain many resources that are vital for the social and economic life of nearby human populations. It is estimated that 40% of the human population in the Caribbean region resides within two kilometers of the coast[1]. The area of coastal water 12 nautical miles from the shoreline (**territorial waters**) is directly managed by the Fisheries Departments of the OECS.

Coastal ecosystems vary greatly in shape, size, and type of habitats and species diversity, depending on their location around the globe. For the purpose of this unit we will specifically examine the biodiversity and interconnectivity that exists in the coastal ecosystems of the Caribbean including habitats such as beaches, seagrass beds and rocky shores.

B.2. Habitats within Coastal Ecosystems

B.2.a. Beaches

The Caribbean is known throughout the world for the beautiful colourful beaches that distinctly outline the coastline. Beaches are found at the foot of cliffs and in the small bays between headlands, and are usually temporary deposits of rock particles or the remains of shells. Beaches are formed when waves and ocean currents move loose shells, rock particles or sediment along the shoreline. The amount of sand or rock on a beach changes with the season and with the type of wave and tidal patterns associated with them.

Beaches look different in their appearance depending on the activity of waves along the shoreline and the type of rock particles or sediment that is left behind. Beaches may appear sandy, pebbly, muddy or a combination of these.

- **Sandy beaches** are formed in coastal areas where the waves and currents are able to deposit sand faster than it can be carried away.
- **Pebble beaches** are formed from rocks that have been constantly pounded, rolled and polished by the active of waves.
- **Muddy beaches** are made up of fine particles of organic and inorganic matter, often carried downstream by rivers.

Coastal Community
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Pebble and sandy beaches are filled with three types of rock particles: sedimentary, igneous and metamorphic.

Formation of Pebble and Sandy Beaches

Over thousands of years wind and water currents erode pieces of the earth. These pieces of earth are then washed away and settle layer upon layer at the bottom of rivers, lakes and oceans. **Sedimentary rock** is formed when small pieces of matter and sediment are carried by wind and rain and are then deposited, compacted and cemented together. Sandstone, limestone (shells, coral, marine skeletons), shale, conglomerate and gypsum are examples of sedimentary rocks found around the planet. Coral sand beaches are formed when limestone is eroded. In the Caribbean the white sand beaches of the Bahamas and the pink sand beaches of Bermuda are examples of beaches formed from sedimentary rock.

Black Volcanic Sand Beach
Brodhead, J. (2008). Doing something great today?: sailing through the Caribbean Grenadines. Retrieved from: dosomethinggreat.net/travels/sailing_grenadines_08/02_st_vincent.htm

Ninety-five percent of the Earths crust is made up of molten rock, which is the result of the cooling of magma (lava) from volcanic eruptions. **Igneous rock** is the term used to describe the type of rock that is created when molten rocks cool. Granite, scoria, pumice and obsidian are examples of igneous rocks. In the Caribbean the black sand beaches of Saint Lucia, Grenada, Dominica, Nevis, St. Kitts, and Montserrat are examples of beaches formed from igneous rock.

Metamorphic rocks are rocks that have morphed or "changed" into another type of rock as a result of chemical and structural changes. Metamorphic rocks are sedimentary or igneous rocks that have been changed by intense heat and pressure. Some examples of metamorphic rocks are gneiss, slate, marble, schist and quartzite.

Life of the Coastal Ecosystem

At first glance it may not appear that many species of plants and animals depend on beach habitats; however, upon closer inspection the beach is brimming with life that is dependent on a healthy coastal ecosystem. Seabirds such as the masked booby (*Sula dactylatra*) and brown pelican (*Pelecanus occidentalis*) can be seen resting and nesting on shorelines. Seagrape (*Coccoloba uvifera*), coconut (*Cocos nucifera*), manchineel (*Hippomane mancinella)* trees line beach communities stabilizing the beach sand from excessive erosion and providing food and shelter for animals such as ghost crabs, beach mice, and sand fleas, as well birds. Seeds from these trees fall to the beach and are carried by ocean currents to other beaches, where they are left to germinate and grow.

During storms, plankton, seaweed and other organic debris are tossed onto beaches, proving food for scavengers such as crustaceans and beach fleas. If you dig into the sand you will find clams and bivalves buried deep. Beaches provide vital breeding and nesting grounds for sea turtles and iguanas that carefully lay and bury their eggs in sandy beaches.

B.2.b. Rocky Shores

Like beaches, rocky shores mark the boundary between land and sea. Rocky shores make up approximately one-third of the planet's coastlines[2.] In the islands of the OECS, rocky shores are mainly found on the windward or Atlantic coast, especially of the volcanic islands. The high waves of the Atlantic Ocean hit the rocks, washing over them repeatedly. Over long periods of time this shapes the characteristic features of the rocky coastlines. Washed by the ebb and flow of tides, rocky shores are a unique

Cattle egret (Bubulcus ibis)
Toussaint, A. (n.d.). Birding in St. Lucia.
Retrieved from: birdinginstlucia.org/index.htm

world of constant change. The upper or high parts of the shore are covered by sea for only a brief time at high tide. The lower part of the shore is almost always under water.

B.2.c. Tidal Zones

The beaches and rocky shores of coastal ecosystems can be divided into regions that are marked by the level of tidal activity that takes place. These regions are defined as **tidal zones.**

The area of the shoreline that lies below the low-tide mark is called the **subtidal zone**. Subtidal zones are the lowest level of tidal zones and are almost always under water. The plants and animals found here need to be almost permanently surrounded by water in order to survive (i.e. seagrass – see below for more information). Echinoderms such as Brittle stars (*Ophiomastix variabilis*), Caribbean starfish (*Oreaster reticulates*) and Caribbean sea urchins (*Diadema antillarum*) live off algae, plankton, bacteria and other organisms in the subtidal zone.

Above the subtidal zone, between the high tide and low tide marks, is the **intertidal zone**. As the tide rises and falls, this area is exposed to the sun or covered by water several times each day. Organisms that exist in the intertidal zone must be able to adapt to harsh, extreme changes in their environment such as varying degrees of sunlight exposure, heat exposure, changes in water salinity, exposure to oxygen and tidal inundations. Most intertidal zones can be separated into three subzones; high tide zone, middle tide zone and low tide zone. Each of these subzones is home to unique species of plants and animals. Seaweeds, barnacles, limpets, periwinkles, shore crabs, mussels, sea stars, rock crabs, turban snails, chitons and worms are only a few organisms to find shelter and food within the intertidal zone.

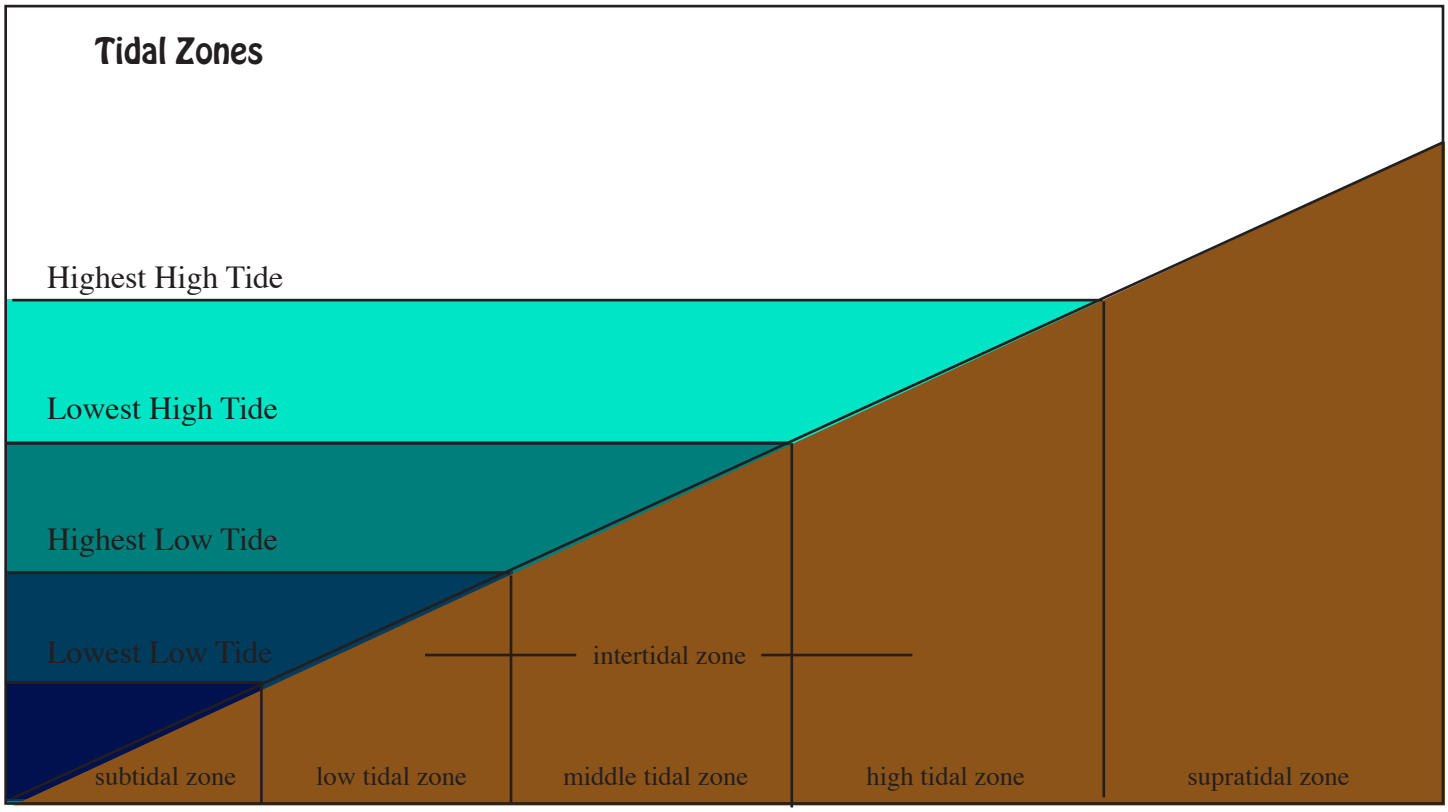
The **supratidal zone** or splash zone lies above the intertidal zone just beyond the reach of the water at high tide. This area is often splashed by ocean water, but is not submerged. It is almost always exposed to the sun. The organisms in this zone must be able to cope with exposure to air, rainwater, cold, heat and predation by land animals and seabirds. The dark damp security of caves often provides a save haven and shelter from the sun for sea anemones.

B.2.d. Importance of Beaches and Rocky Shores

Besides providing vital habitats, beaches and rocky shores protect the coastline from the erosive forces of wind and waves. For example, the progressive slope of a beach slows down the corrosive impact of waves.

Beaches and rocky shores are also vital to the economic and social vitality of local human populations in the Caribbean. These areas are often the focal point of tourism and industry. Beaches and rocky shores provide areas for residents and visitors to recreate, moor boats, sell goods and are the source of many building materials such as stone and sand.

Like most vibrant natural ecosystems, beaches and rocky shores are subject to the destructive forces of natural processes, as well as the impacts of human activity. Natural process such as hurricanes and storms can dramatically disrupt and erode beaches and rocky shores. Human activities such as hotel or marina construction, aquaculture and recreational overcrowding can result in eco-



system degradation. Offshore dredging, sand mining, vegetation removal and rising sea levels, due to climate change, all have the potential to significantly disrupt the ecological balance of beaches and rocky shores.

B.2.e. Seagrass Beds

Seagrass beds are large areas of underwater marine flowering plants (with long, narrow green leaves) that resemble grasslands. Seagrass typically grow in shallow waters (subtidal zones), or continental shelves landward of coral reefs. Seagrass anchors itself in sand or mud. In the Caribbean the main seagrass species are; Turtle grass (*Thalassia testudinum*), Manatee grass (*Syringodium filiforme*), and Shoal grass (*Halodule wrightii)*. Depending on the species type blades of seagrass can grow over 30 centimeters in length.

Seagrass beds provide important habitats for many species. Green turtles (*Chelonia mydas*), fishes, crabs, sea urchins, conch and migratory fowl depend on seagrass for food. Seagrass beds provide important protection for nursery species such as the Blues-triped grunt (*Haemulo sciurus*), Redtail parrotfish (*Sparisoma chrysopterum*) and Great barracuda (*Sphyraena barracuda*)[3]. Invertebrates and epiphytes, like algae, use seagrass blades to attach themselves to. Burrowing animals, such as worms, clams, cockles, pen shells and shrimp live in the mud under seagrass beds.

Seagrass beds also help to keep sand and mud sediment settled on the ocean floor, while their root system stabilizes sediment from becoming re-suspended. This helps keep the ocean water clear which is vital to the health of nearby coral reefs. Seagrass beds together with coral reefs, and mangrove swamps help to protect the shore from the full force of waves. Together these habitats act as a buffer zone reducing natural coastal erosion.

The interdependence of green turtles and seagrass beds is a good example of the importance of ecological balance in a coastal ecosystem. When green turtle populations are in balance with the amount of available seagrass for grazing, seagrass beds are healthy and abundant. However, when turtle populations are too low or too high, seagrass beds may die off due to increases in infections of slime mold, over-shading and disturbed sediment. Likewise, the health of green turtle populations (and many other species) is dependent on healthy seagrass beds[4].

Seagrass beds also are subject to a number of human disturbances. The construction of commercial and residential facilities (e.g. hotels and marinas) along beaches, often results in dredging and filling (clearing of the ocean floor and replacement with mud or sand) which destroys seagrass beds. Oil spills and pollutants from agricultural run-off or industrial discharge degrade seagrass too[5]. Human activities such as fishing, hunting and recreational boater use, also threatens the survival of seagrass beds and the organisms that depend on them. The noise from boat motors may frighten away some species and propellers can cause damage by ripping up leaves and unsettling seagrass root systems and sediment.

Sea Turtle feeding on seagrass
Retrieved from:
playa.info/playa-del-carmen-forum/24911-akumal-beach-resort-trip-report-aug-2006-a.html

Example of Coastal Development
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

B.3. Importance of Coastal Ecosystems

Coastal ecosystems do not exist in isolation. They are highly complex, dynamic, productive environments that are in a constant state of flux. The health of each habitat and species within a coastal ecosystem is dependent on the health of other nearby habitats, species and ecosystems, both marine and terrestrial. Unwary agricultural and forestry practices may result in rivers carrying pollutants or sediment downstream, impacting the health of coral reefs and beaches. Excessive fishing in one bay can impact the health of fish communities in another. Ocean currents may move industrial waste, or oil from a tanker spill from the coast of one country to pollute the coastal region of another.

Due to the rich biodiversity of coastal ecosystems, multiple human user groups or stakeholders depend on these areas for resource extraction and recreation. However, human activities such as aquaculture, marine transportation, fishing, tourism and recreation have potentially significant impacts on coastal ecosystems. To ensure the sustainability of coastal ecosystems in the Caribbean, an integrated approach to managing these areas is required. Social, governmental, economic and cultural factors need to be taken into consideration. Local stakeholders (residents, business, fishers etc.) need to work together with government officials to come up with management plans for local coastal ecosystems[6].

Protecting Coastal Ecosystems

Increasingly, the one strategy being used to protect ocean ecosystems is the establishment and development of **Marine Protected Areas** (MPAs). MPAs are coastal or open ocean areas in which certain uses are regulated to protect natural resources, biodiversity, or human livelihoods[7]. Marine research and training and public outreach and environmental education in the coastal communities is another important avenue in gaining a more sustainable approach to marine ecosystem management.

As a result MPA's typically define limitations on allowable human activities in those regions. Most MPA's in the Caribbean currently include coastal or near shore ecosystems[8].

It is important that we understand and protect the integrity of coastal ecosystems. This bountiful area where land meets ocean is a vital for both human livelihoods and recreation, as well as for the existence of biodiversity.

Protected Area Management Categories

IUCN has defined a series of six protected area management categories, based on primary management objective. In summary, these are:

CATEGORY Ia **Definition**	Strict Nature Reserve: protected area managed mainly for science Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.
CATEGORY Ib **Definition**	Wilderness Area: protected area managed mainly for wilderness protection Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
CATEGORY II **Definition**	National Park: protected area managed mainly for ecosystem protection and recreation Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
CATEGORY III **Definition**	Natural Monument: protected area managed mainly for conservation of specific natural features Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
CATEGORY IV **Definition**	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
CATEGORY V **Definition**	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.
CATEGORY VI **Definition**	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

IUCN (1994). Guidelines for Protected Areas Management Categories. IUCN. Cambridge, UK and Gland, Switzerland. 261. Retrieved from: www.unep-wcmc.org/protected_areas/categories/index.html

B.4. Case Study: Soufrière Marine Management Area (SMMA), St. Lucia[9]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=,+St.+Lucia&sll=13.909444,-60.978893&sspn=0.31126,0.53833&ie=UTF8&ll=13.831413,-60.986137&spn=0.155682,0.269165&t=h&z=12

Case Study:
canari.org/285smma.pdf

Background:

The town of Soufrière is located on the southwest coast of Saint Lucia. The coast and marine environment play a key role in the life and economy of Soufrière. The main settlements and infrastructure are located near the ocean shore and the beaches and the coral reefs and water are used extensively for recreation.

Historically, fishing was the area's most important economic sector, but currently, tourism has grown to rival it as the town's most important sources of income. Most of Soufrière's local fishery is divided between the inshore coastal fishery (such as jacks, balao, sardines, and flying fish, and other reef species) and an offshore fishery for migratory pelagic species (such as tuna, kingfish, marlin, and dolphinfish). However, because of Soufrière's distance from the migratory routes of the valuable pelagics (and the additional time and fuel costs that fishers must incur as a result), much of the fishery has been located closer to the shore[10]. Tourism is concentrated around snorkelling, diving, and yachting. Beginning in the 1980s, conflict between fishers and tourist users over the limited inshore marine resources and concern over the declining reef fish catches and reef health began to develop.

Within the Soufrière area, there are approximately 154 registered fishers who use the ocean ecosystem to gain their livelihood, with most of those fishers fishing on a full time basis, using pots, traps, seines, lines, trolling, and gill nets[11]. The area also houses two large resorts, four smaller hotels, and several guesthouses and restaurants, many of them focusing on the diving and the yachting sectors. Marine transportation, such as day charter boats and water taxis, is also an important economic driver, as it brings a large number of tourists from the northern, better-developed part of the island to Soufrière. As tourism gained popularity in the 1980s, conflicts began to escalate over the sharing of coastal and marine resources.

Compounding the problem was the growing concern over certain environmental impacts seen in the region. Those included:

1. Degradation of coastal water quality, with direct implications for human health and for the protection of the reef ecosystem;

2. Loss of the economic, scientific and recreational potential of coral reefs, particularly in the context of diving tourism;

3. Degradation of landscapes and general environment quality, notably on or near beaches;

4. Pollution generated by solid waste disposal in ravines or directly in the sea;

5. Yacht anchor damage to reefs;

6. Sedimentation of the reefs caused by runoffs from rivers and storm damage.

Establishment of the Marine Management Area

To manage the growing conflict, in 1986, the Government of Saint Lucia declared many of the island's major reefs as marine reserves (including Soufrière's) and controlled fishing and other sources of impact. However, the areas were never demarcated and no funds were made available for enforcement so the legislation provided the marine ecosystem with no real protection[12].

The following year, the Government put forward a proposal for the development of a National Park in the Soufrière area, to include both marine and terrestrial habitats; however it was not until 1992 that the various parties interested in management of Soufrière's marine resources renewed their efforts to establish a marine and coastal resource management area. These individuals, from both the tourism and fishing sectors formed a committee with representatives of the Soufrière Regional Development Foundation, Department of Fisheries and Caribbean Natural Resources Institute (CANARI). The existing reserves were put under review and the current uses (yachting and diving, fishing, local recreational use), the resource use conflicts and condition of coastal resources around Soufrière were identified. The Soufrière Marine Management Area (SSMA) was proposed and was legislated by the Government in 1995.

The SMMA extends over 12 kilometres of the coast between Anse l'Ivrogne in the south and Anse Mamin in the north, and extends 100 metres from shore, or to 70 metres depth, whichever is greater. It has representation of coral reefs, seagrass beds, and shallow ocean areas. It also has a characteristic sample of Caribbean shallow ocean species including spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*), penaeid shrimps (*Penaeidae*), snappers (*Lutjanus*), groupers (*Epinephelus*), reef fish, and continental shelf demersal fish. Additionally, the marine management area contains some deep slope and bank fish such as snappers and groupers.

Soufrière Marine Management Area (SMMA). (n.d.) SMMA zoning map.
Retrieved from: smma.org.lc/index.html

The SMMA area is divided into 5 types of zones:
1. **Marine Reserves:** These areas are set aside for protecting the natural resources they contain. All extractive activities are forbidden, but diving and snorkelling are permitted for a fee.

2. **Fishing Priority Areas:** These areas are set aside for maintaining fishing activities. Diving and other uses are permitted here but fishing takes priority.

3. **Yacht mooring areas:** These are areas containing mooring buoys provided for yachts to avoid damage to coral reefs and seagrass beds.

4. **Multiple use areas:** These areas are set aside for all uses (fishing, diving, and snorkelling), with the exception of activities forbidden throughout the SMMA such as jet-skiing, and coral extraction.

5. **Recreational Areas:** These are terrestrial (beaches) and marine (swimming and snorkelling) areas, which are reserved for public recreation.

Management Issues

The reef fishers found the first couple of years of management difficult. Fishers were unable to use some of their best fishing places and had to travel further offshore to reach fishing sites. This was significant as many fishers lacked outboard motors and in order to benefit from the larger offshore fish, they had to incur personal expenses to buy modernized equipment. Some fishers, who had come to rely on the now-closed areas, were angered that tourists gained access to the areas they would no longer be able to use. Illegal fishing ensued until enforcement was increased and compensation was paid to fishers who had previously relied on the marine reserve areas.

Fishers had to adapt to the changes in resource use which took time. Many fishers integrated tourism services into their traditional fishing activities, by using their vessels to tour visitors around the marine environment. Perceptions of the management area began to change when the costs of running it were born out of diving and snorkelling licenses and fisher's catches in other areas began to improve.

Achievements of the SMMA

The SMMA is overseen by the Soufrière Marine Management Association, which is a legal entity that was established under the fisheries legislation. This Association comprises a Board of Directors and a broad stakeholder committee. All key stakeholders, including fishers, hoteliers and management authorities sit on this Board and collaborate to manage this biodiverse area.

Initially, the goal in establishing the SMMA was to manage the local fishery and prevent further decline and overexploitation of the inshore coral reef fisheries. The establishment of the SMMA has been a great success for sustaining and enhancing the local reef fishery and increasing the catches of local fishers.

Annual monitoring of reef fish **biomass** (stocks) since the establishment of the management area has indicated a four fold increase in commercial fish biomass inside the marine reserves and a three fold increase in fishing grounds. Species whose numbers increased as a result of the management area include surgeonfish (*Acanthuridae*), snappers (*Lutjanidae*), grunts (*Haemulidae*), groupers (*Serranidae*), squirrelfish (*Holocentridae*) and parrotfish (*Scaridae*). This is significant, because initially, with the establishment of a protected area, it was the fishers who had the most to lose from the loss of fishing area.

The management area also achieved its goal of promoting conservation of coral reefs and sustainable development of tourism in the area.

Other achievements of the SMMA include:

- Reduction or resolution of conflicts among area's users.
- Improvement in communication between various user groups and among user groups, researchers, and management agencies.
- Improvement in the status of coral reefs.
- Increase in fish stocks in marine reserves and fishing priority areas.
- Collaborative management of the area, through the formation of a multidisciplinary Board, comprising government organisations, non-governmental organisations, community members, and resource users.
- Increased awareness about environmental issues.
- Availability of valuable area for scientific study for researchers, and more knowledge about marine ecosystems as a result.
- Provision of facilities (such as yacht moorings), which reduce physical damage to marine habitats.
- Generation of user fees from diving and snorkelling (leading to self-sufficient financing of the SMMA).
- Increased recognition (for example, the SMMA has been internationally recognised for its conservation efforts, including the 1997 British Airways Tourism for Tomorrow IUCN Special Award for National Parks and Protected Areas; and a position in the top five along with Algeria, USA, Spain and Canada for the 1997 World Underwater Confederation (CMAS) International Marine Environmental Award (GPIEM.)

- Recognition as a model for multiple use marine protected areas.

- Improved community cohesion.

Challenges

Unfortunately, certain problems remain which pose risks to the marine and coastal environment of the SMMA, which require resolution from broader organizations and governments. Certain issues cannot be address by the SMMA alone. These problems include:

- High sedimentation rates into the nearshore environment, resulting from run-off from the land and via rivers. This sedimentation continues to degrade coral reefs and marine habitat within the SMMA, especially during storms and heavy rains, and can cause algal blooms and coral bleaching[13].

- Pollution brought into the waters of the SMMA from external sources.

- Enhanced algal growth in some marine areas, due to enrichment of the water, likely because of improper sewage disposal. This poses direct risks to human health and to the integrity of marine ecosystems.

- Solid waste builds up from terrestrial sources, which contributes to coastal and marine ecosystem degradation.

- The degradation of coastal and ocean ecosystems as a result of the mass 'dumping' of tourists in the nearshore for snorkelling and other activities and on beaches adjacent to hotels.

- Overuse of certain dive sites, which may negatively affect marine species and habitats.

- Non-compliance with rules and regulations of the SMMA, especially by fishers from communities adjacent to Soufrière.

The case of Soufrière Marine Management Area is positive. It is encouraging that there is more awareness and knowledge of the importance of the ocean ecosystems and marine environment in Soufrière. The SMMA also stands as an exemplary public and private sector arrangement for natural resource management.

Questions for Consideration

1. What are some of the environmental impacts which prompted the creation of the SMMA?

2. How has the establishment of the SMMA been successful? How has it not been successful?

3. What are the positive and negative ecological impacts of establishing a marine management area in Soufrière?

4. Imagine that you are responsible for improving the functioning of the SMMA as a protected area:
   - What are the key issues that need to be addressed?
   - Who are the key stakeholders that need to be involved?
   - How would you go about getting stakeholders involved in the improvement of the SMMA as a protected area?

5. What impacts would the further degradation of the marine and coastal ecosystems of SMMA have on the economy of Soufrière?

6. What habitats and species exist within the SMMA ocean ecosystem?

7. What types of human activities take place within the SMMA? What impacts might these activities have on the organisms that inhabit the ocean ecosystems of the SMMA?

8. Can you identify marine areas in your county that are being threatened by human activity? Give a brief description of the area and the threat? What might the social and environmental consequences of the threat?

9) Can you identify other protected areas in the Caribbean region? How do they work compared to the SMMA?

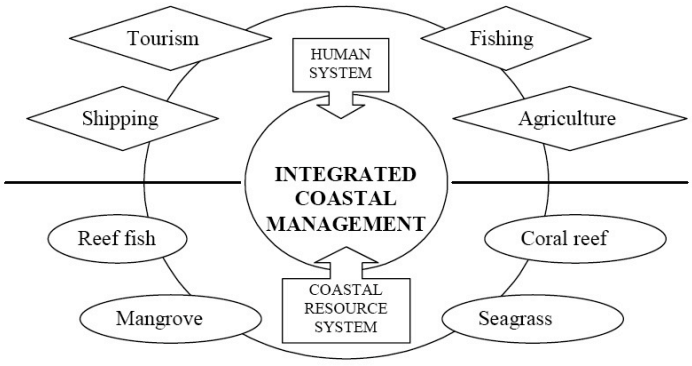


Figure 2.5 Integrated coastal management includes many types of relationships

Caribbean Conservation Association. (2003). Caribbean coastal co-management guidelines project. West Indies: University of West Indies Centre for Resource Management and Environmental Studies (CERMES) and Marine Resources Assessment Group, Ltd. (MRAG).

B.5. Activity 1: Cooperative Coastal Management

Objectives:

Students will be able to identify a variety of stakeholder groups, their interests, their impacts and their concerns about coastal ecosystems.

Methods:

Students practice their debating and negotiating skills roll playing in a roundtable discussion.

Materials:

- Copy of SMMA Case study (or other Case Study)
- Chalkboard/whiteboard or flip chart and marker
- Pen and paper per student for note taking

Time:

1-2 periods (approximately 1.5 hours)

Background:

See the SMMA Case Study (activity will also work with another case study).

Procedure:

1) Carefully review the case study with students.

2) Have students brainstorm and determine which SMMA management issues they think are most important in the case study. Make a list of the relevant management issues, post them for students to see and briefly review.

3) Using the list of relevant management issues outlined in step 2, have students determine as a group who the relevant stakeholders are in those issues. Make a list of relevant stakeholder groups, post them for students to see and briefly review.

4) Break students into groups that equal the total number of stakeholder groups identified. Groups of 2-3 students typically work best.

5) Assign student groups stakeholder characters as per the list identified in step 3 (i.e. fishers, hoteliers, vendors, tourists etc).

6) Inform students that they will be taking on the character of their stakeholder group and participating in a roundtable discussion to come up with some solutions to the identified issues.

7) Have students discuss in their small stakeholder groups what their interests are; what their impacts are; and what their concerns are in the SMMA case study. Students will need to write down what they perceive their interests, impacts and concerns to be, and designate someone to speak on behalf of the group.

8) Students should all make name tags with their new "identity" and the name of their stakeholder group. Have students come together in their groups and form a large circle. Have each group identify themselves and present their interests, impacts and concerns to the other stakeholder groups. If there is time, encourage students to bring costume items, tools, hats or other identifying items to add to the drama of the debate.

9) Once all groups have presented their thoughts, encourage discussion that attempts to resolve the previously determined issues. Ensure each group has the opportunity to provide some input and feedback in the discussion. Some questions you may wish to bring up to successfully lead the discussion include:

- Are there trends in the identified areas of concern among the stakeholder groups?
- As a stakeholder group in the SMMA which of your activities are you not willing to give up or compromise on?
- What activities are your stakeholder group willing to modify, give up or compromise on?
- What does your group recommend as a solution to the issues?

As with real life roundtable discussions, it can be a challenge to get all those present to come to a negotiated agreement. The purpose of this exercise is to provide students with the opportunity to experience the challenges of working with others of different opinions and perspectives to come to an agreement. Encourage discussion as long as the dialogue is productive, and for a feasible amount of time.

10) Before ending the activity, debrief with the students.

- Did they come to an agreed upon solution to the identified issues?
- What were some of the challenges of coming to a cooperative resolution?
- What were some of the benefits and challenges of using a roundtable discussion to resolve such an issue?

B.6. Activity 2: Ethics in Action[14]

Objectives:
Students will be able to distinguish between actions that are harmful and beneficial to coastal ecosystems and evaluate steps to change their own personal behaviours.

Methods:
Students develop and implement a personal code of environmental ethics and behaviors.

Materials:
Pen and paper per student.

Time:
1 period (estimate 45 minutes); Activity can be extended into larger project if desired.

Background:
Everything we do as human has some type of impact on the natural environment. Some of the activities we participate in have a direct impact on the natural environment. For example, littering not only makes the environment messy looking, but it can disturb, poison or destroy habitats and the species that dwell in them. Other activities we participate in have indirect impacts on the natural environment. For example, when you purchase food that has been grown using pesticides, the pesticides at the farm can runoff the soil and travel down nearby rivers to the ocean. The chemical pollution from the pesticides on a farm can damage or kill ecosystems miles away (i.e. coral reefs).

The main purpose of this activity is to provide students with the encouragement and opportunity to look at their own lifestyles and evaluate their personal impact on natural resources and the environment.

Procedures:
1) Engage students in a discussion about what activities they participate in on a regular basis that both directly and indirectly impact coastal ecosystems. Consider the possible impacts of everything from food, to clothes, to transportation, to products purchased, to types of recreation and entertainment.

2) Have students write a list of activities that they participate in that directly and indirectly impact coastal ecosystems.

3) Discuss with students what they believe a "Personal Code of Ethics" to be. The main point to emphasis is that a personal code of ethics is a set of values that are defined by specific actions and behaviours.

4) Have students review their list (as identified in step 2). Ask them to develop/write a personal code of ethics that defines which actions and behaviors they believe have the greatest environmental impact on coastal ecosystems. Have students write down what they believe they could do to reduce their personal impact. Emphasize the importance of the code being for the person who creates it.

4) Ask for volunteers to share their "Personal Code of Ethics." They might what the entire code or a segment of it. Encourage students to ask each other questions about the codes, in the spirit of learning more about each person's priorities, but not in a judgemental approach. Refer to the Activity 19: Take Action for Biodiversity (Part 1) for a list of conservation actions.

5) Encourage students to try implementing their code of ethics and track their progress. You may wish to encourage students to try making one change at a time, and have them evaluate (quantify and qualify) the total impact of their changed behavior over time (i.e. estimate the change in their ecological footprint). Have students report back on their successes.

Extensions:
- Have students evaluate their list of activities and personal code of ethics to determine what impact these actions may have on other ecosystems such as rainforests or open oceans.
- Have students keep a journal on their successes and challenges in implementing their personal code of ethics.
- Have students present a project about their successes and challenges implementing their code of ethics.

This activity can be modified to have the students imagine they are property owners (private/commercial) along the coast or a river. The same objectives and activities can be used to complete the activity.

Taking the students outdoors to observe human activities along or close to the coastal areas will be more effective in developing their appreciation of and also the need for protecting and maintaining biodiversity in coastal ecosystems.

B.7. Case Study:
"NO to Toco Port and Ferry Project," Trinidad & Tobago[15]

Google Earth Map:
maps.google.com/maps?hl=en&ie=UTF8&ll=10.725381,-61.397095&spn=2.520274,4.306641&z=8

Case Study:
unep.org/bpsp/Tourism/Case%20Studies%20(pdf)/Trinidad%20&%20Tobago%20(Tourism).pdf

Location

The location of the proposed port was at Toco Bay on the edge of which sits the village of Toco, the main town of the Northeast hinterland. In terms of biodiversity, the bay hosted coral reef communities and Toco was the gateway to the proposed Matura National Park, home of the most pristine rainforests of the country. The area had been designated as an ecotourism node in the Tourism Master Plan (TMP).

Project Evolution

The question of an improved ferry service between Trinidad and Tobago was an old one with important historical milestones:

- In 1974, the National Planning Commission undertook a survey of transportation between the two islands over the period 1965-71. This survey focused on the existing service between Port of Spain in Trinidad and Scarborough in Tobago and its improvement.

- In 1978/79, two route studies were undertaken by the Mitsui Group and the OAS at the height of the petroleum boom. The Mitsui study analysed two additional ferry routes from Trinidad to Tobago – Balandra on the East coast of Trinidad and Chaguaramas, the northwest peninsula of Trinidad. The OAS study only considered Balandra.

- In 1988, two studies were undertaken by the Institute of Marine Affairs (IMA) and a private sector consortium of consultants, which included the consulting engineering firm of Lee Young and Partners. The IMA study introduced a systematic treatment of the comparative aspect of site selection, thereby throwing into relief the criterion of least cost. The Newel Lewis study expanded the perspective to encompass both ferry link and route considerations as well as the matter of port development and site selection. Both pieces of work located the ferry terminal in the context of a multipurpose port capable of servicing the requirements of fishing in particular; and both studies took as their point of departure the notion that the introduction into the Northeast region of a port facility could be a catalyst for wider development of economic life embracing such sectors as tourism, agriculture and again, fishing.

- In 1990, under contract to the Industrial Development Consortium, an expanded consortium of private sector consultants, called the Sea Bridge Team, and still including the firm of Lee Young and Partners, produced a Feasibility Study for the establishment of a multi-purpose port in the Northeast region of Trinidad and a ferry link from the Northeast region to Tobago. This study identified Toco Bay as the best site for the port to accommodate a ferry terminal, a fishing depot, a marina, a Coast Guard facility and associated amenities.

Revived Project

In 1999, a new government enjoying its first term revived the project for a Toco Port and Ferry Service to Scarborough. The Government used a state enterprise, the National Insurance Property Development Company Limited (NIPDEC) to invite proposals on the project. NIPDEC issued a Request for Proposals to develop the port on a BOOT (Build, Own, Operate and Transfer) basis. In keeping with the principle of community participation in development, a community representative was appointed to the proposal evaluation team. This representative, however, was selected by the Ministry and not by the Community. He, therefore, did not have a mandate from the local community to represent them. Nor did he attempt to bring the community into the process as each time he held update meetings with them, he was unable to reveal detailed information on the grounds of confidentiality.

While proposals were being evaluated, the Minister held meetings with persons in the Toco area as a form of consultation. These meetings were organised by the leader of the Toco Foundation, a supposedly developmental NGO, which turned out to be a highly Government-backed NGO. (The leader of the Toco Foundation was the ruling party candidate for the Toco area in the General Elections of December 2000). The consultations organised by this person gave the Minister the impression that the project, details of which the Minister did not fully disclose, was welcomed by the people of Toco.

The engineering firm of Lee Young and Partners, was judged to have submitted the most acceptable proposal and became the preferred developers of the port and ferry project. Their proposal identified the need to optimise the development along the following lines:

- Fishing and fish exporting industries including by-products.
- International shipping re-fuelling.
- Tourism and internal traffic linkage between Trinidad and Tobago.
- Ecotourism and cruise ship traffic.
- Tourist attraction package for forest trail and ecotourism.
- Service centre for the offshore operation of gas and oil.
- Marina facilities.

The shipping re-fuelling and the cruise ship elements were new elements, which the preferred developer maintained were essential for the financial viability of the project. These additions to the original concept made the Toco port a massive undertaking that would entail the compulsory acquisition of private land.

The firm was required to prepare an Environmental Impact Statement, given the concerns expressed about the threat to the coral reefs of Toco Bay by major reclamation works. There was also concern about the environmental impact of mass cruise ship tourism on the biological resources of the area and social impact with respect to the compulsory acquisition of land.

Local Community Response

On 17 June 2000, a group of about 30 concerned Toco community members met at the Anglican Church in Toco. They came together to discuss two documents which had come into their possession:

- A Land Acquisition Notice published in a daily newspaper on 6 June, announcing the compulsory acquisition by the state of 17 hectares of land in the centre of Toco village.

- A scale drawing showing the layout of the proposed port and a list of the facilities to be constructed under Phase 1 of the development.

The group reviewed the available information with great alarm. They felt that the community had been deliberately kept in the dark about the enormous scale of the project, and the dire effects it would have on the natural and social environment. It was agreed that certain actions should be taken on an urgent basis. The wider community was to be made aware of the issues raised by the documents, and steps were to be taken to halt the development process until further information was made available.

A wide range of community members and other stakeholders were encouraged to attend a public meeting with the developers on June 24th to review the port proposal. The community was far from satisfied with the outcome of these discussions, and called a press conference at the Anglican School in Toco on July 8 to air its concerns. This was attended by over 100 community members, the vast majority of whom expressed strong opposition to the port proposal.

A decision was taken to set up a committee immediately to represent the interests of the affected communities. This committee became known as Stakeholders Against Destruction (S.A.D) for Toco.

Management and Co-ordination

At the July 8 meeting, individuals were nominated from the floor for the formation of the Committee which comprised representatives of the various economic interests (agriculture, fishing, ecotourism), the churches, long-term residents, new residents, residents whose property was due to be forcibly acquired, landowners, and representatives of other villages between Matura and Matelot. The Committee included some of the most educated and articulate members of the local community.

The Committee established connections, including by e-mail, with sympathetic national professionals and NGOs. These latter included Fishermen and Friends of the Sea, The Caribbean Forest Conservation Association, The Tropical Re-Leaf Foundation and Nature Seekers Incorporated.

Main Objectives

The Committee was mandated to halt the forcible acquisition of land, to oppose the granting of a final contract to the preferred developers, to seek proper consultation and transparency, and to put forward a more appropriate plan for the Toco area. S.A.D's long-term objective was for the Toco region to become known locally and internationally as a leader in the preservation and promotion of a healthy environment and as the green and clean corner of Trinidad.

In order to achieve their immediate objective, it was necessary for S.A.D. to expose the Minister to the true feelings of the Toco community through genuine local community participation in the decision-making process. Accordingly, they embarked on an intensive mobilisation exercise to make sure that the entire Toco community came out to any future public meetings. In the meantime, they engaged a professional environmentalist to conduct a review of the developers' Environmental Impact Statement.

Achievements

The preferred developers called a meeting for July 28, 2000 to which the Minister was invited. This meeting took place at the Toco Composite School to a packed house. The print and electronic media, including a representative of the Associated Press, were in full attendance. The meeting was chaired by a former em-

Understanding Biodiversity Issues in Trinidad & Tobago

The following are useful web links on information pertaining to biodiversity conservation in Trinidad & Tobago:

Water Resources and Aquatic Biodiversity Conservation: A Role for Ecological Assessment of Rivers in Trinidad and Tobago
bvsde.paho.org/bvsacd/cef-2/MAKbiodiv.pdf

Integrating Biodiversity Conservation into the Tourism Sector in Trinidad and Tobago: A Case of Effective Local Community Participation
unep.org/bpsp/Tourism/Case%20Studies%20(pdf)/Trinidad%20&%20Tobago%20(Tourism).pdf

Progress of Trinidad and Tobago towards fulfillment of their Convention on Biological Diversity
cbd.int/countries/?country=tt

ployee of TIDCO who had been engaged by the developers as a community relations consultant. This person faced constant abuse from the audience for she was regarded as a traitor, she having worked with the Toco community before in TIDCO's sustainable community tourism programme.

The developers made a presentation, accompanied by state-of-the-art computer-generated graphics, to convince the community about the benefits of the project. They were assisted by TIDCO's Vice-President of Government Policy and Special Projects, who delivered an address supportive of the project. Handpicked members of the community supportive of the project made presentations amidst a barrage of heckling.

When it was S.A.D's turn to speak, they first presented to the gathering their environmental consultant who made a devastating presentation on the deficiencies of the EIS. Three members of S.A.D then delivered articulate and impressive statements of condemnation of the project. S.A.D. was prepared to support a viable ferry service that would be beneficial to the physical, social and cultural environment. However, they took strong objection to the ferry service being used as a "Trojan horse" to introduce into Toco heavy industrial projects designed to benefit outsiders but which were strongly opposed by the local people.

The Minister was visibly shaken by the very vocal opposition to the project from a wide cross section of the community. He had to admit that what passed for public consultation before was counterfeit and he declared that meeting to be the first genuine consultation with the local community on the port project. He invited S.A.D. to present their own Alternative Development Plan for the Toco area.

S.A.D's Alternative Development Plan

At a public meeting on September 30, 2000, S.A.D. presented its written Alternative Development Plan to the Minister of Works and Transport. In this plan it was acknowledged that the people of Toco appreciated the importance of the nation's major industrial and commercial centres. They did not, however, wish Toco to become an industrial port. The strong preference was for community participation in sustainable development that would maintain and enhance the natural, social and cultural environment, while offering opportunities to all the people of the community for growth and prosperity.

S.A.D's Alternative Development Plan contained the following elements:

- Traditional local tourism and recreational activity.
- Community-based ecotourism, including nature tourism and adventure tourism.
- Revitalisation and modernisation of agriculture and agricultural processing, including exploitation of developing niche markets for speciality products, both locally and internationally.
- Revitalisation and modernisation of the fishing industry
- Consolidation and expansion of Toco as a centre of sporting excellence.
- Cultural and social activities.

The Plan re-affirmed S.A.D's commitment to promoting the rich biodiversity of the Toco area through a holistic, environmentally sensitive approach to all development activity in the area so that Toco would remain the "green and clean" corner of Trinidad.

Aftermath

The port project was officially cancelled by Cabinet decision in October 200 and the Land Acquisition Orders rescinded in November 2000. In its annual national awards, the Daily Express of Trinidad and Tobago named S.A.D as the community group or organisation which made the most significant contribution to community development, for its work in mobilising the people of Toco against development deemed not to be in their interest.

The lesson of the case

The case of the Toco Port and Ferry Service is a classic case of the conflict between environment and development. It is also a case of the conflict between outside investment interests versus local interests. Under normal circumstances, the power of development and outside capital usually prevails over local interests, be they environmental or otherwise. In this case the local interests prevailed because they were genuine, well organised, well connected, well informed and articulate. It was a case of people power at its most potent.

The case also points a way for the successful conservation of biological resources in the face of tourism and other threats. The most important biological resources are invariably located in the rural hinterland where the most proximate human beings are in the adjacent rural settlements.

This case shows that the conservation of these resources could be achieved if the local communities are appropriately empowered. There exists a great deal of scope for national NGOs to work with local communities everywhere to catalyse them into a state of readiness for the application of the best practice principle of meaningful local consultation in policy formulation and developmental planning.

Other examples of best practices linking tourism development and BCP

As indicated earlier, it is difficult to find examples in Trinidad and Tobago where anyone has deliberately sought, as a matter of policy, to apply a best practice element to biodiversity conservation in the tourism sector. The case described above occurred because people rather than policy makers drove the process. There are, however two other cases where government officials took the lead in applying a best practice strategy, the same strategy in both cases. This strategy does not explicitly appear in the NBSAP.

Colorful coral reefs are popular tourist destinations
Photos supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Simply stated it is to: Apply the principle of sustainable livelihoods to the users of biological resources.

One case in Trinidad revolves around the protection of turtles and the other in Tobago around the protection of a coral reef.

The turtles of Matura Beach

The annual slaughter of the leatherback turtles at Matura Beach by subsistence hunters during the nesting season became too much for the understaffed Wildlife Section of the Forestry Division to handle. They decided, therefore, to enlist the support of members of the local community who would be willing to patrol the beach and protect the turtles. They could not afford to pay them salaries so they had to devise a means of rewarding the patrollers financially. By drawing on the strategy cited above, the Wildlife authorities had to link the turtle protection with a sustainable livelihood. It occurred to them that if they organised the local community and provided them with appropriate training, they could combine their patrolling with dollar-earning tour guiding.

They therefore catalysed the formation of the group called Nature Seekers Incorporated which has received international recognition for its work. This group has a vested interest in making the beach safe for turtle nesting since their livelihood depends on it. Today, the turtles of Matura Beach nest without disturbance and the group is going from strength to strength.

Buccoo Reef

Tours of Buccoo Reef have been taking place since its discovery in the 1930s. More than 40% of Tobago's hoteliers offer organised tours of the reef and an estimated 60% of all visitors participate in a reef tour at Buccoo reef at least once during their stay. The main type of visitor usage of the reef is via glass-bottom boat tours for snorkelling, reef viewing and walking. This usage over the years has resulted in severe degradation of the reef.

A comprehensive study of the reef was commissioned by the THA in 1989 and conducted by the IMA between 1989-1992 and updated in 1994. The study, which included detailed biological investigation, water quality baseline survey, a legislative review, a socio-economic survey and public education and awareness surveys, was used as a basis for the preparation of a management plan.

One of the key elements of this plan is to persuade the glass-bottom boat operators to be more vigilant about tourist damage to the reef formations. It has now been brought home to them that if the reef became degraded beyond a certain point, visitor interest would wane and their business would suffer. They finally grasped the sustainable livelihood point. Today, there is much more responsibility displayed by the boatmen and the reef is on the road to recovery.

Questions for Consideration

1) What types of habitats existed within Toco Bay, Buccoo Reef and neighbouring Matura National Park? What are some of the key species that exist in this ecosystem?

2) What were the pros and cons of developing a new ferry route between Trinidad and Tobago? With a partner, draw a time line that highlights al the main decisions and events that led up to this project.

3) Of the issues that need to be addressed in the management of the area, which ones pose the greatest risk to biodiversity in the region?

4) What possible impact could the destruction of the Toco Bay ecosystems have on the tourism industry in Barbados?

5) Identify a coastal ecosystem in your country that is being threatened by development. Give a brief description of the area, the threats and the stakeholders involved. What do you believe needs to happen to improve the situation? What conservation measures would you suggest?

B.8. Activity 3: Biodiversity and You: Recreation and Biodiversity CAN Go Together!

Objective:

In this activity students will analyze an outdoor recreational activity or sport, investigate any problems that their activity might cause for wildlife and develop a code of ethics for the activity that considers biodiversity conservation.

Procedure:

1. Review the case studies in this section and choose one of the recreational activities described – OR chose a recreational activity that you like to do, know something about or would like to try one day. For example, boating, bird-watching, bicycling, hiking, wildlife photography, sport hunting, sport fishing, shell collecting, SCUBA diving and snorkelling. Can you think of others?

2. Investigate the problems that the recreational activity causes for threatened and endangered species. For example, determine what problems boat traffic causes for endangered marine or freshwater species such as whales, manatees, otters, and corals. Mountain biking when carried out off established trails harms many species of plants and animals, disturbs wildlife, and can destroy soil, hillsides and terrain.

3. Develop a code of ethics for your chosen recreational activity that prevents injury or harassment of wildlife and/or plants. Ensure that the Code includes specific behaviours that participants could follow to model best conservation practices.

4. Send your proposed Code of Ethics to an organization involved with the activity, such as a SCUBA diving or naturalist club, and ask for the group's comments.

Cruise ship docked in coastal area
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Andrew Ross (Seascape Caribbean)

Part 2 / Section C

Coral Reef Ecosystems

USAID
FROM THE AMERICAN PEOPLE

February 2009

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Victoria, British Columbia, Canada

Table of Contents

C.1. What is a Coral Reef Ecosystem?

Coral reefs exist in the warm, clear, shallow waters of tropical oceans worldwide but also in the cold waters of the deep seas. For the purpose of this section, the marine, warm water coral reefs will be discussed.

Types of Corals

There are two main types of corals: **hard corals** composed of stony calcium carbonate, and **soft corals** composed of a protein and calcium carbonate material. Solid corals, or *Scleractinians*, including brain, star, staghorn, elkhorn, and pillar corals have rigid exoskeletons that protect their soft interiors. Soft corals, or *Gorgonians*, including sea fans, sea whips, and sea rods, sway with the ocean currents and lack a stony exoskeleton.

Tropical coral reefs occupy less than one percent of the Earth's marine environment, but are home to more than a quarter of all known marine fish species and tens of thousands of other species found nowhere else on earth[1]. The total area of the world's tropical coral reefs is around 284,300km^2. [2] Of the total amount of coral reefs in the world, 7.64% of it is located within the Caribbean Sea Large Marine Ecosystem[3].

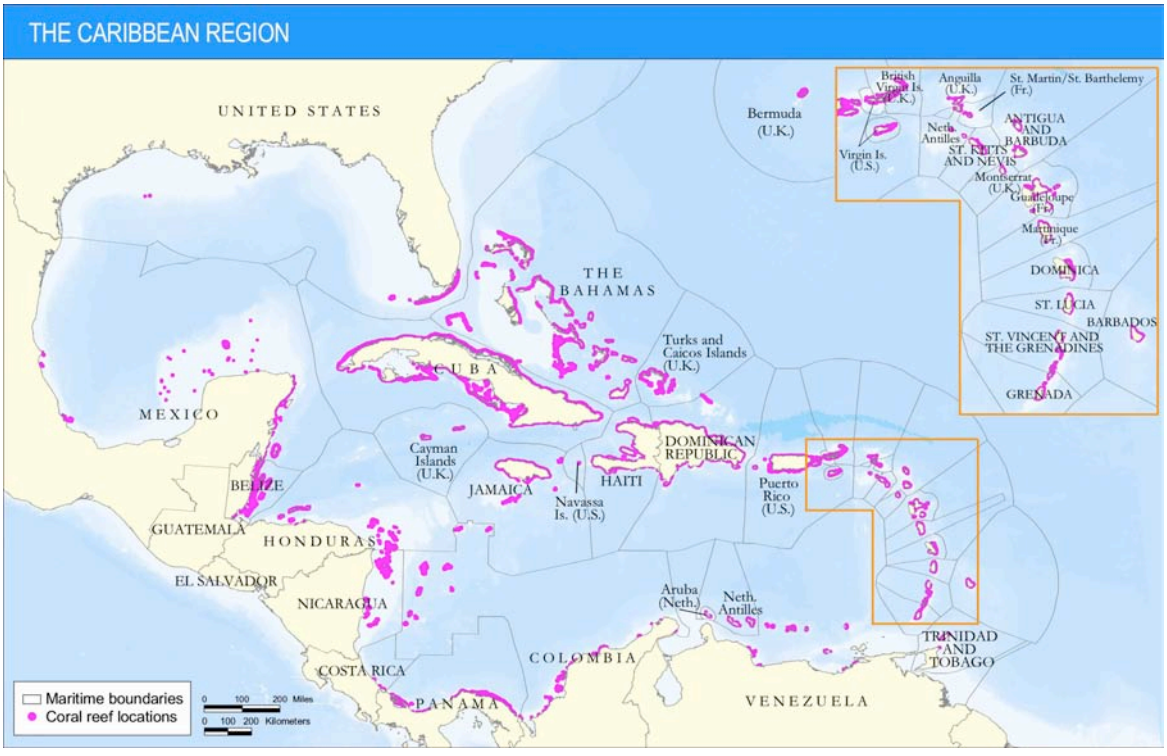
Factors Necessary for the Formation of Coral Reefs

Geographically, tropical coral reefs lie between the latitudes of 30 degrees north and south where sea temperatures are warmest. Tropical coral reefs require water temperatures between 18°C and 30°C. Tropical corals are found within three main regions of the world: the Indo-Pacific, the Western North Atlantic, and the Red Sea. The Western North Atlantic region contains the second most coral reefs (after the Indo-Pacific) and includes the coral reefs within the Caribbean.

C.2. Formation of Coral Reefs

Coral reefs are formed by the work of tiny organisms known as **coral polyps.** A coral polyp consists of a fleshy sack with a ring of tentacles that sits in a limestone skeletal case, secreted by the polyp. Thousands of coral polyps develop together and create a structure of limestone (calcium carbonate or $CaCO_3$). The prime reef builders are the stony or hard corals (Anthozoa species). The bulk of any reef colony is composed of nonliving matter. It is only the upper layer that is living cora[4]l. While corals are the chief architects of reef structure, they are not the only builders. Coralline algae cement various corals together with compounds of calcium, and other organisms such as tube worms and molluscs donate their hard skeletons[5]. Tropical coral reefs can grow upwards at rates of 1centimetre to 100 centimetres per year. This is in contrast to deep sea corals which grow a mere 5 to 25 millimetres each year. For both coral types, over time they form extensive reefs.

Reef-building corals have evolved an essential symbiotic relationship with a type of brown algae called **zooxanthellae** (*Symbiodinium microadriaticum*). A **symbiotic relationship** exists where two or more organisms co-exist together in a mutually advantageous relationship, with both deriving benefits from each other. Millions of these single-celled algae are living as symbionts within their tissues of corals. Zooxanthellae produce sugars and oxygen through photosynthesis which helps the coral in the process of producing limestone or calcium carbonate. With this assistance by zooxanthellae, corals grow up to three times faster. It is also the zooxanthellae, which give the corals their characteristic greenish color. In the case of a change in environmental conditions, such as increased temperatures or changes in salinity, the coral polyps may expel the algae. Without



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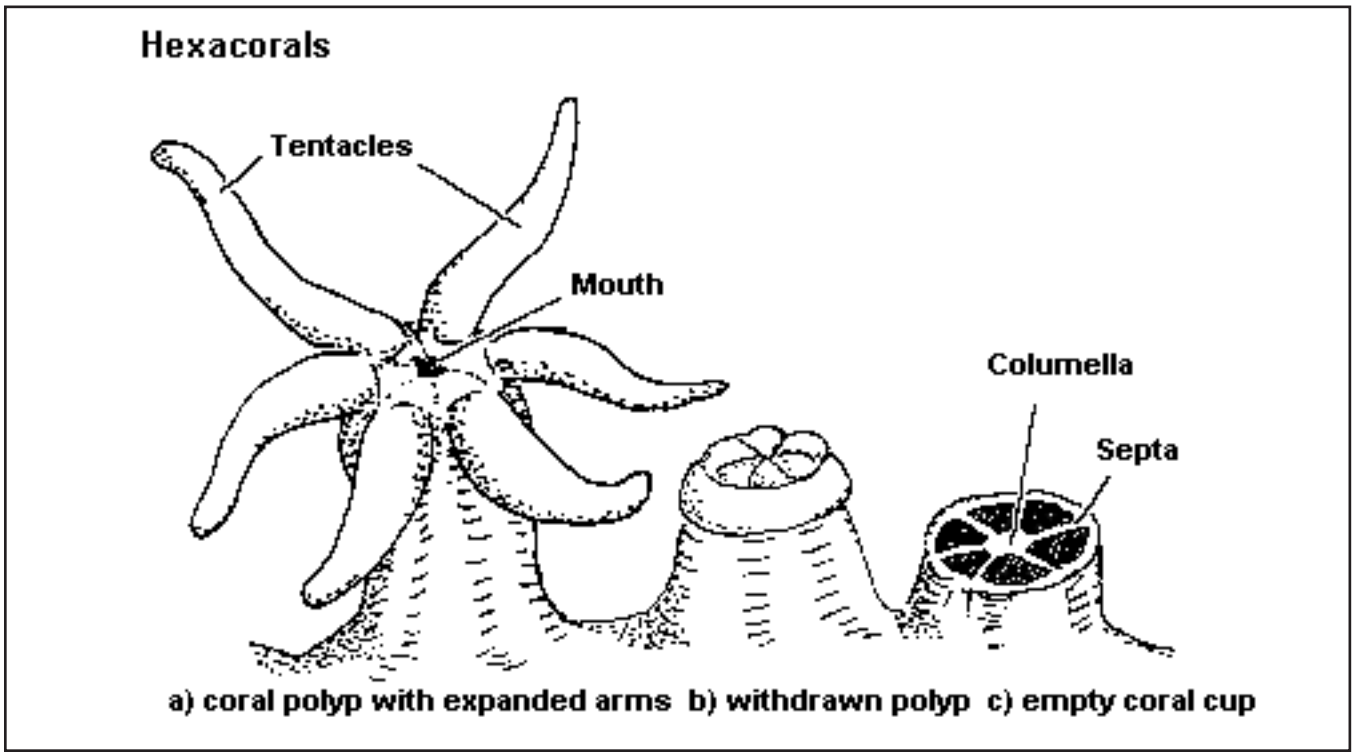


Zubi, T. (2008). Coral reef ecology. Retrieved from: starfish.ch/reef/reef.html

Coral reefs rank among the largest and oldest living communities of plants and animals on Earth, with the most established coral reefs beginning to grow 5000-10,000 years ago[6].

Photo supplied by: Andrew Ross (Seascape Caribbean)

algae, the coral becomes completely white in colour and is considered bleached. If the coral retains some algae it may survive, but if bleaching occurs the coral is considered dead.

Tropical corals require access to sunlight to survive. The algae living in their cells require light for photosynthesis. Because of this, the water where they grow needs to be shallow and clear. High levels of sediment in the water can smother the coral polyps. Corals also require salt water, and the lowering of salinity in their marine habitat can kill them. Essentially, coral development occurs away from river mouths and other sources of fresh water.

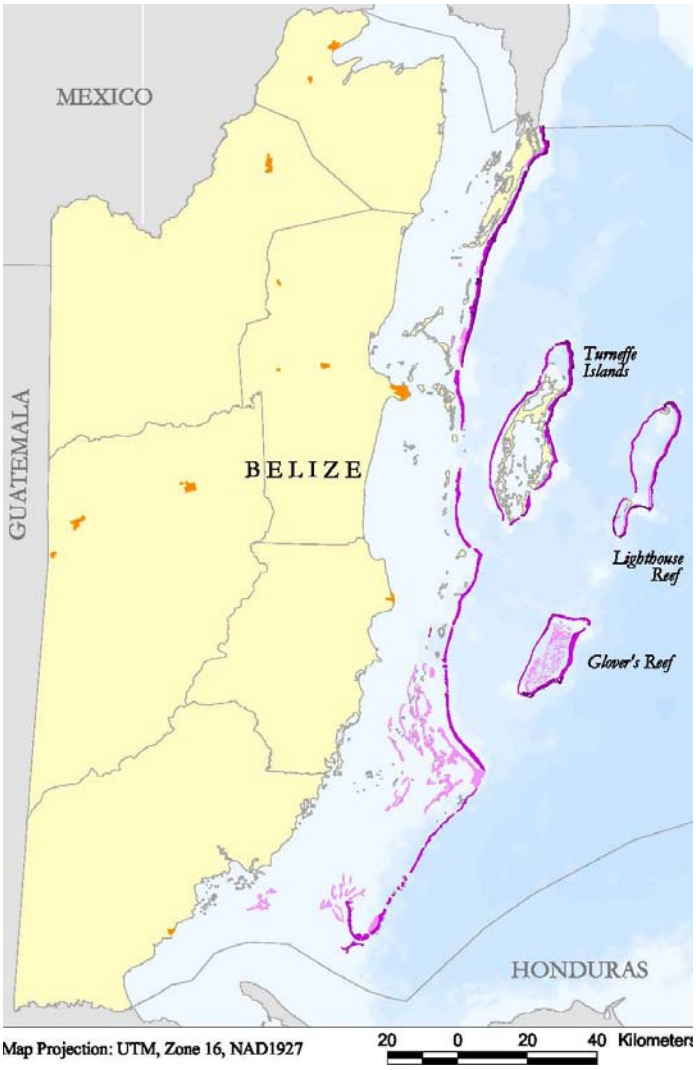
C.3. Types of Coral Reefs

There are four different types of coral reefs: **fringing reefs, platform reefs, barrier reefs**, and **atolls**. Reefs that grow in shallow waters are classified as fringing reefs. These reefs border the coast of tropical islands or continents closely or are separated from the coast by a narrow stretch of water. Fringing reefs are generally narrow platforms a short distance from shore and don't contain a substantial lagoon. Fringing coral reef communities are found in places on the shores of most of the islands in the Eastern Caribbean. Platform reefs develop in sheltered seas, but quite far offshore. They are flat-topped with small and shallow lagoons.

Barrier reefs are reefs that are grow parallel to the coast but are separated from land by a lagoon. As the reef continues to grow and moves further offshore, it eventually reaches the edge of the **continental shelf** (the region of relatively shallow water surrounding every continent). Barrier reefs can originate offshore if

Coral Reefs in Belize

Belize boasts the second largest continuous reef system in the Western Hemisphere, second only to Australia's Great Barrier Reef. The reef of Belize stretches 250 kms along the entire length of the country and it encloses an approximately 6000 sq. km lagoon.



Data Sources: Coral reef data from Belize Biodiverstiy Mapping Service (Belize Ecosystem Map, 2004) and CZMAI, 1997 (for Glover's Reef); Bathymetry from WRI, 2004; Administrative Districts for Belize from CCAD (www.ccad.ws).

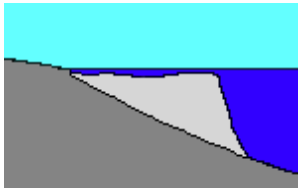
Reefs at Risk in Belize
A collaboration between the World Resources Institute, Belize Coastal Zone Management Authority and Institute, and many other partner organisations in Belize. Datasets available on the Belize Coastal Data CD (email datacen@coastalzonebelize.org for more information).

the depth of the seabed is shallow enough to give corals sufficient light to develop. The two largest barrier reefs are the Great Barrier Reef in Australia, which stretches over 2300 kilometres off the coast of Queensland in northeast Australia, and the Mesoamerican reef in the Caribbean, which stretches nearly 250 kilometres from the northern tip of Mexico's Yucatan Peninsula to the Bay Islands in northern Honduras.

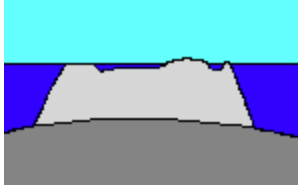
Atolls are rings of reef, often encircling an island of sand and coral rubble. They typically have a shallow, sandy, sheltered lagoon in the centre and access to the open sea is through a number of channels. These channels provide fresh, colder water to the inside lagoons. Coral atolls begin as fringing reefs around active oceanic volcanoes. After volcanic eruptions cease, an island remains. Over long geologic periods, fringing coral continues to grow and develop into a circular coral reef, which is known as an atoll.

Barrier Reef

Atoll



Fringing Reef



Platform Reef

Zubi, T. (2008). Coral reef ecology. Retrieved from: starfish.ch/reef/reef.html

C.4. Species Biodiversity

Coral reefs are one of the most biodiversity-rich ecosystems in the world. The Caribbean boasts the highest coral reef diversity in the Atlantic Ocean due to its geographic isolation from other oceanic regions[7]. Staghorn coral (*Acropora cervicornis*) and elkhorn coral (*Acropora palmata*) are among the dominant species living on modern Caribbean reefs. They are particularly fast growing and able to cope both with damage caused by hurricanes and by rapid changes in sea level.

Caribbean reefs also house lettuce coral (*Agaricia lamarki*), star coral (*Montastrea faveolata*), brain coral (*Colpophyllia natans*), scleractinian coral (*Montastrea annularis*), greater star coral (*Montastrea cavernosa*) and shet coral (*Agaricia lamarcki*).

Coral reefs are patchy habitats but they provide excellent breeding grounds for a vast number of species. Longspine sea urchins (*Diadema antillarum*), sea fans (*Gorgonia*), moray eels (*Gymnothorax moringa*), crustaceans, and conch and other molluscs are found among the corals. Reef fishes are generally sedentary due to the high concentration of phytoplankton and other food sources within the reef [8]. Some of the common reef fish species found within the Caribbean include rainbow parrotfish (*Scarus guacamaia*), angelfish (*Pomacanthidae*), yellowtail damselfish (*Chrysiptera parasema*), lizardfish (*Synodus intermedius*), needlefish (*Belonidae*), clown fish (*Amphiprion clarkia*), trumpetfish (*Aulostomus maculatus*), butterfly fish (*Chaetodontidae*), triggerfish (*Balistidae*), wrasses (*Labridae*), parrotfishes (*Scaridae*), basses/groupers (*Serranidae*), and groupers (*Epinephelus*).

Smaller fish species tend to stay within close proximity to the reefs where food and shelter are readily available, whereas larger fish tend to travel further offshore. Larger fish such as jacks (*Carangidae*) and snappers (*Lutjanidae*), as well as the Caribbean reef shark (*Carcharhinus perezii*), come into coral reefs to prey on smaller fish species.

C.5. Importance of Coral Reefs

Coral reefs are often referred to as the "rainforests of the oceans." This name is attached to this ecosystem as a result of its role in providing habitat and food for an extensive number of species. Coral reefs host an extraordinary variety of marine plants and animals (perhaps up to 2 million) including one quarter of all marine fish species. Up to 4,000 individual species can co-exist on a single reef at a density 100 times greater than the average for the open ocean[9]. These species include the coral species themselves as well as algae, fish, dugongs, marine turtles, sea snakes, worms, crustaceans, molluscs, and starfish. Coral reef ecosystems have important ecological and economic functions for all coastal regions.

C.5.a. Food Source and Habitat

The soft polyps of coral provide an important food source for many other sea creatures, while reef caves and crevices are essential as cover for the protection and shelter for many different species of fish. Reefs also serve as important spawning and nursery grounds for lobsters, shrimp, and various fish species.

C.5.b. Water Filtration

Coral reefs also clean and filter surrounding waters. Filter-feeding sponges, bivalve molluscs, crustaceans, worms, and echinoderms all contribute to cleaning the waters surrounding the reef. This ecological role is essential to maintaining water conditions necessary for the survival of the reef's and ocean's species.

Parrot Fish
Science Daily. (2007). Parrotfish Critical To Coral Reefs: Permanent Damage Likely Unless Urgent Action Taken, Scientists Warn. Retreived from: sciencedaily.com/releases/2007/10/071031112907.htm

Brain coral (Colpophyllia natans)
Conservation Science Institute. (2007). Ocean change initiative. Retrieved from: conservationinstitute.org/coral.htm

C.5.c. Fisheries

Coral reefs are vital to the Caribbean's and the world's fishery industry. Coral reefs act as nurseries for approximately one quarter of the ocean's fish. As a result of this extensive amount of fish, fishing is an essential industry to the people within the Caribbean. The Caribbean's fisheries are an essential source of food and a source of revenue for local communities as well as national and international fishing fleets. Reefs also provide the main source of protein, in the form of fish, shellfish, and molluscs, for more than 1 billion people in the tropics[10].

C.5.d. Tourism

Coral reefs are an important focus of tourism in tropical areas. Scuba diving and snorkelling are two activities for tourists who visit and explore coral reefs. Within areas where coral reefs are protected, these two activities provide extensive income to local companies operating dive and snorkel shops. Cesar, Burke and Pet-Soedeit estimated that coral reefs provide nearly US$ 9.6 billion in annual net benefits from tourism globally[11]. Well-managed coral reef–based tourism can also provide significant alternative or additional sources of income to poorer coastal communities in developing countries. Within the Caribbean, the skeletons of corals and algae containing calcium carbonate provide sediments that create beach sand. The clear, white sand is one of the essential draws for tourists to the Caribbean.

C.5.e. Coastal Protection

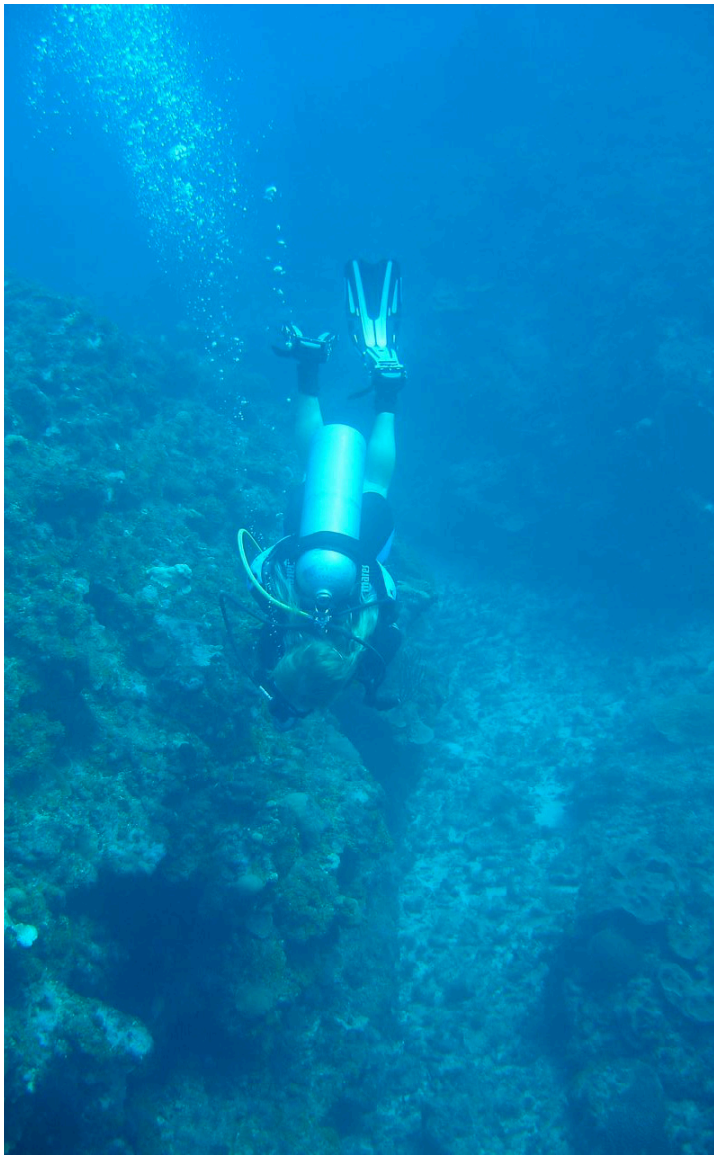
Coral reefs form a natural and self-repairing barrier that protects the coasts by absorbing violent wave impacts of ocean storms and hurricanes. In helping to prevent coastal erosion, flooding, and damage of shore property, the reefs save the countries within the Caribbean a significant amount of money each year. Having reefs protecting the shores reduces insurance and reconstruction costs, reduces the need for costly coastal defences to be built, and reduces the costs of human displacement and death.

C.5.f. Source of Scientific Advances

Because coral reefs harbour thousands of species, much can be learned about the living world by studying these species. Research on reef organisms has provided insight into human reproductive cycles and potential cures for cancer as well as the large-scale cycling of carbon, which may control climate change. Coral reefs, like tropical forests, can also contribute to future medical advances. Scientific discoveries of the species within tropic reefs have contributed to advances in medicine and, if reefs are kept healthy and fully-functioning, more advances may be made in the future.

C.5.g. Intrinsic Value

Reefs are among the most spectacular displays of nature's creativity. For many coastal communities around the world, coral reefs are essential features of cultural traditions. Reefs provide an endless source of personal inspiration and wonder. For those who have experienced coral reefs through books and pictures or those who have adorned a snorkel and mask and floated above a coral reef and witnessed first-hand the beauty and complexity of coral reefs, a world without this beautiful ecosystem would be a much poorer place.



Divers off reef Antonio, Jamaica
Photo supplied by: Andrew Ross (Seascape Caribbean)

C.6. Types of Human & Natural Impacts

C.6.a. Pollution

Nutrient pollution is the primary suspect in most damage to Caribbean reefs[12]. Urban and industrial waste, sewage, agrochemicals, and oil pollution are poisoning reefs. In particular, nutrients from municipal wastes and agricultural runoff reduce oxygen in shallow coastal waters in a process called eutrophication, which is lethal to marine life.

Low oxygen levels support the growth of benthic algae, which cover the corals and reduce their growth. In time, the algae die

Coastline of Brazil showing protection of coral reefs (highlighted in red and orange)
Ramsar Convention on Wetlands. (2009). Ramsar Convention on Wetlands. Retrieved fromramsar.org/pictures/ brazil-coral-map.jpg

and decay, consuming more oxygen in the process of decomposition, and the corals themselves die, leaving the entire ecosystem devoid of life.

Of particular concern in the Eastern Caribbean is the flushing of untreated sewage and municipal wastes into coastal waters. According to a 1997 report by the Organization of Eastern Caribbean States (OECS), inadequate provision for the management and safe disposal of sewage has contributed to the pollution of ground and surface waters and of the coastal zone. Wastewater discharges from urban populations and tourist developments are in many cases reaching the sea without treatment, or at best having been subject to preliminary treatment alone[13].

C.6.b. Over-fishing

Over-exploitation and declining catches are occurring within the Caribbean as a result of increasing demands for reef fish resources[14]. Reef fishes are one of the main inshore fisheries within the Caribbean. As reef fish are overharvested, there is a direct consequence to the balance of the food chain within the ecosystem. The direct effects of over-fishing include declines in abundance, size, and reproductive output of species. Changes in sex ratio, behaviour, and distribution also occur. Over-fishing also results in effects to the ecosystem. Changes in **predator-prey dynamics** (where predators no longer have their prey of choice and have to diversify their diet with other species), trophic structure, habitat, and algal blooms all occur as a result of over-fishing.

C.6.c. Tourism

Careless boating, diving, snorkelling, and fishing can have severe impacts on an ecosystem as sensitive as coral reefs. People touching reefs, stirring up sediment, collecting coral, and dropping anchors on reefs all pose threats the health of the Caribbean's coral reefs. Some tourist resorts and infrastructure have been built directly on reefs, and some tourist resorts empty their sewage or other wastes directly into water surrounding coral reefs. Tourism is the greatest industry in the Caribbean and increasing numbers of visitors have contributed to rapid and poorly planned coastal development, with associated problems of sedimentation and pollution that always follow such development.

C.6.d. Sedimentation

The removal of sand from beaches and coastal areas for use in the construction industry is widespread in the Caribbean. This produces severe and irreparable beach erosion in many places and increases the amounts of particulate material in the water [15]. As well, there is considerable soil erosion from upland areas as a result of **deforestation**. Increased amounts of sedimentation results in high turbidity in coastal waters and, in turn, adversely affects sensitive and productive benthic communities such as coral reefs[16]. This sedimentation ends up in the ocean, where it can smother corals by depriving them of the sunlight they need to survive. The destruction of mangrove forests, which normally trap large amounts of sediment, is exacerbating the problem in the Caribbean.

C.6.e. Mining Reef Resources

Live coral is sometimes removed from reefs for use in bricks, road-fill, or cement for new infrastructure. Corals are also sold as souvenirs to tourists and to exporters for sale abroad. In addition, coral reef fish populations and their coral habitat are targets for a world-wide trade in exotic fish. Unfortunately, the true ecological cost of humans having pretty fish tanks in their living rooms is borne by the coral reef ecosystems of the world.

C.6.f. Climate Change

Perhaps one of the greatest threats to coral reefs is the threat of global climate change. **Global warming** is resulting in rising sea levels, which will alter coral reef habitat. Coral reefs have

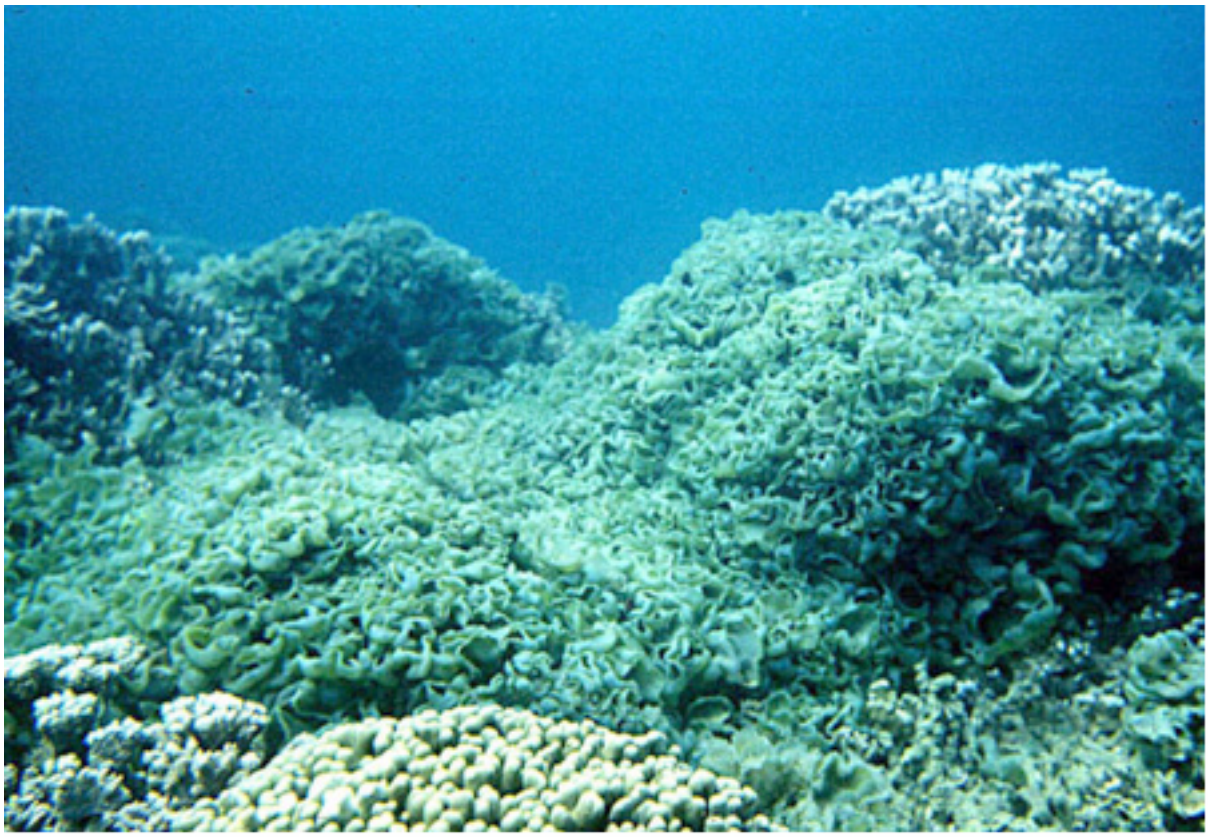
a specific range of tolerance, which includes a certain access to sunlight. Rising water levels may alter this.

According to Lewsey et al., changes in rainfall, increased coastal erosion, and a possible increase in the number and severity of hurricanes and ocean tropical storms are anticipated impacts of climate change[17]. Across the Caribbean, coral cover is reduced by 17%, on average, in the year following a hurricane impact[18]. As a result, an increased number and severity of hurricanes will be detrimental to Caribbean coral reefs. Increased erosion, which is predicted, will impact the clarity and water quality on which reefs depend.

Corals require an optimal water temperature to survive and, if exceeded, coral species will become extinct. One consequence of climate change is the increase in global water temperature. Global warming has already led to increased levels of coral bleaching, and this is predicted to increase in frequency and severity in the coming decades[19].

Coral bleaching, the whitening of corals due to loss of symbiotic algae, is a response that can be triggered by a variety of stressors including solar radiation, salinity shock, sedimentation, disease, and temperature increases[20]. In the Caribbean, rising temperatures is the main contributor to coral bleaching. According to McWilliams et al., a rise in regional sea surface temperature of 0.1˚C results in a 35% increase in the geographic extent and a 42% increase in the intensity of coral bleaching[21]. Maximum bleaching extent and intensity are predicted to occur at sea level temperature rises of less than +1˚C, which coincides with the most conservative projections for warming in the Caribbean by the end of the 21st century[22]. This translates to serious threats to the continued existence and survival of coral reefs.

In late 2005, the Caribbean region experienced one of the most devastating coral bleaching events on record. Warnings of the onset of the bleaching event were first reported by the National Oceanic and Atmospheric Agency (NOAA) in late August in the Florida Keys. By September and October, the bleaching had spread through much of eastern Caribbean. Surveys revealed that 85 – 95 percent of coral colonies were bleached in some areas. Corals can recover from short-term bleaching, but prolonged bleaching (over a week) can cause irreversible damage and subsequent death.



Reef covered in algae

National Aeronautics and Space Administration: Goddard Earth Sciences Data and Information Services Center. (n.d.). Ocean color: bad bloom rising. Retrieved from: disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/bad_bloom.shtml

C.7. Protecting Coral Reefs

Coral reefs are closely linked to both mangroves and seagrasses, and many reef animals move between these ecosystems during their lives. Coral reef–dependant species are linked to a specific type of coral and to its supporting plants and animals. Remove or change one essential component and the disruption may result in a chain reaction. For example, if reef parrotfish (*Scaridae*) and sea urchins (*Echinoidea*) are over-harvested, algal growth soon covers the reefs, killing the coral polyps. Parrotfish and urchins feed on excess algae and coral and, without them, the algae would multiply out of control, causing ecological unbalance and perhaps ecosystem collapse. Stakeholders of this ecosystem must take this interconnectivity into account when planning management and protective measures.

Local and national governments, non-governmental organizations (NGOs), local inhabitants, and scientists are increasing awareness about coral reef ecosystems through education and outreach. A strong outreach and education effort is essential to coral reef protection, and effective outreach requires dependable access to and efficient sharing of information with all stakeholders[23]. Improved communication between scientists, resource managers, and the public and well as greater education and integrated resource management are beginning to occur within the Caribbean. People in the Caribbean are starting to appreciate that it is important to reduce human-caused stresses, and to use and manage reef resources more sustainably.

Conservation groups such as CANARI and World Wildlife Fund are making efforts to prevent or minimize impacts of human use of coastal areas. In some cases, active restoration is occurring in order to repair damaged areas. Efforts are being made to reduce impacts of pollution and coal disease. Efforts are also being made to improve management of coral reef fisheries, which is an important component in the protection and restoration coral reef ecosystems. Steps taken include increased enforcement of exitsing regulations, and research to improve the understanding of fisheries' impacts on coral reef ecosystems. Scientists are working to increase local managers' ability to respond to coral bleaching events in order to minimize their impact and reduce the loss of healthy coral reefs in the face of climate change.

Protected areas in coral reef ecosystems can provide important shelter from some of the threats that reefs face and can provide researchers with key sites for coral reef ecosystem research and monitoring. The Eastern Caribbean contains a number of well protected areas as well, notably those off Saba, Bonaire, and Saint Lucia, which have been especially well managed, leading to the recovery of healthy reef ecosystems in localized areas. These provide a model for coral reef management throughout the region.

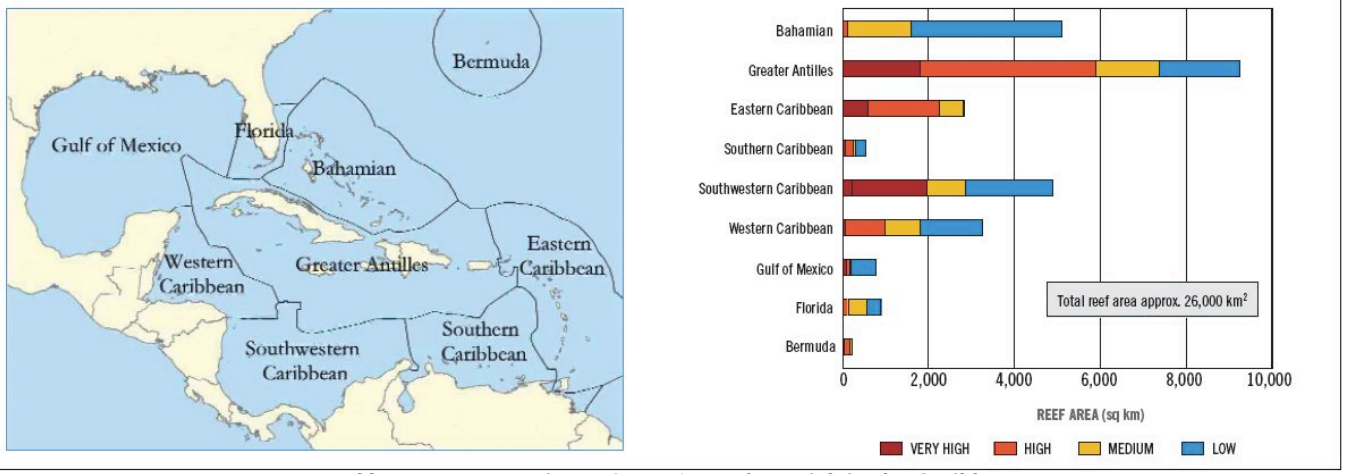
While there are significant pressures on the coral reef ecosystems of the Caribbean, there is a growing awareness about the necessity to protect them. Protection of coral reefs is essential, given that tourism and fisheries, important contributors to the economies of the Caribbean islands, depend on coral reef ecosystems.

Saint Lucia's experience:

In 2005, unusually warm waters in the region caused a high amount of coral bleaching in Saint Lucia. The unusually warm waters also resulted in low numbers of white sea urchins and low catches of pelagic fish (such as dolphinfish and wahoo) at a time of the year when these creatures were expected to be abundant.

Today, a lot of the corals that became bleached in 2005 have died. This does not augur well for Saint Lucia's water-based tourism activities, such as diving and snorkelling. The loss of corals also results in less reef fish, which affects the livelihoods of fishermen.

REEF AREA BY SUB-REGION CLASSIFIED BY THE REEFS AT RISK THREAT INDEX



World Resources Institute. (2004). Reefs at risk in the Caribbean.
Retrieved from: earthtrends.wri.org/features/view_feature.php?fid=55&theme=1

FIFTY FACTS ABOUT WIDER CARIBBEAN CORAL REEFS

DID YOU KNOW?

- The Caribbean region has an estimated 26,000 km^2 of coral reef surface, possessing an estimated 7% of the world's shallow coral reefs.
- In the Greater Antilles, coral reefs cover over 8,600 km^2.
- The Eastern Caribbean has a coral reef area of 2,600 km^2.
- The Wider Caribbean region has over 285 Marine Protected Areas (MPAs), containing 20% of the region's coral reefs.
- Time series data show declines in live coral cover from 1993 to 2001 in almost 2/3 of the sites investigated.
- Human activities threaten 2/3 of the Caribbean's coral reefs, placing 1/3 at high risk.
- About 9,000 km^2 of coral reef is threatened by increasing sedimentation and pollution related to land use activities.
- Coastal development including construction, urban run-off, tourist development and sewage discharge threatens 1/3 of the reefs of the Caribbean.
- A sewage pollution problem exists in almost 1/4 of the coral reefs surveyed since 1998.
- Treated sewage accounts for less than 20% of total sewage generated in the Caribbean.
- Only 1/4 of hotel and resort wastewater treatment plants are in good operating condition.
- In 1996, 3/4 of treatment plants operated by hotels and resorts did not comply with effluent discharge criteria.
- In the Caribbean, daily water consumption per tourist is an estimated 300 liters/day, which is about 3 times the per capita demand for domestic consumers.
- Coastal development resulting from population growth and intensive tourism, along with overfishing threatens over 80% of Caribbean reefs.
- Thirty six percent of coral reefs in the region lie within 2 km of inhabited land.
- The population living within 10 km of the Caribbean coast grew from 36 to 41 million during 1990-2000.
- Increases in coastal zone population density leave reef resources susceptible to exploitation to provide livelihoods and sustenance to coastal inhabitants.
- Overfishing is the most pervasive direct human threat to reefs and threatens 60% of them.
- Overfishing poses greatest threat to the Eastern Caribbean reefs followed by coastal development, sedimentation and pollution.
- The ecological balance of reefs is altered by overfishing due to increased algal growth and decreased coral cover.
- Caribbean coral reefs have evolved from a coral dominated to an algal dominated state over the past decades.
- Marine based sources of pollution such as wastewater discharge from cruise ships and other vessels, and leaks and spills from oil infrastructure threaten 15% of the region's reefs.
- In the last 20 years, cruise ship tourism has quadrupled worldwide, with 58% of the world's cruise ship passengers occupying the Caribbean cruise industry.

- Generally, cruise ships and cargo ships contribute 77% and 20% of all ship type waste respectively.
- Typical cruise ships generate daily averages of 2,228 gallons and 278.5 gallons of oily bilge water and garbage respectively.
- A cruise liner's anchor can ruin up to 200 km^2 of ocean floor by direct physical damage.
- In the next 5-10 yrs. further coral degradation will occur in many threatened areas.
- The Earth's average temperature has risen by .6-.8^o Celcius in the last 100 yrs., leaving corals more susceptible to bleaching.
- Over 500 significant coral bleaching incidents have been reported in the Wider Caribbean Region since 1980.
- It is predicted that by 2020, bleaching of reefs will be an annual event.
- Atmospheric temperature in the Caribbean would have risen by 2-4 ^{o} Celsius by 2070.
- Sea surface temperature levels are currently close to the upper thresholds for coral survival, placing stress on long-term coral survival.
- Currently, threats from predicted sea level rise of 3-10 cm/decade are unknown for damaged reefs and those under anthropogenic stress.
- Coral diseases have caused widespread changes in the Caribbean's coral reefs over the past 30 years.
- Coral diseases coupled with bleaching, pose a serious threat to the Caribbean's reefs.
- Tourism and recreation contribute the largest shares of the total economic value of Caribbean coral reefs, which is estimated between US$100,000 to $600,000.
- Annually, tourism contributes an estimated US$105 billion to the Caribbean economy.
- In at least 8 Caribbean countries, tourism accounts for over 30% of the GDP.
- International tourist revenues in the Caribbean totaled US$25.5 billion in 2000.
- In 2000, approximately 1.2 million divers visited the Caribbean, accounting for an estimated US$4.1 billion in gross expenditures.
- In 2000, net annual benefits of Caribbean dive tourism were an estimated US$2.1 billion.
- Close to half of all diving tourism in the Caribbean occurs in MPAs.
- Coral reef ecosystems provide shoreline protection, as reefs dissipate wave and storm energy.
- An estimated 21% of the Caribbean's coastlines are protected by coral reefs.
- Annual benefits of shoreline protection by healthy reefs are an estimated US$740 million to $2.2 billion per year.
- In the Eastern Caribbean, 70% of monitored beaches were eroded from 1985-1995.
- By 2050, 10-20% of current protection services could be lost on over 15,000 km of shoreline.
- The net value of lost benefits from reef shoreline protection could range from US$140-$420 million/yr. over the next 50 years.
- Continued reef degradation could reduce net annual revenues derived from coral reef fisheries by US$95million-$140 million/yr. by 2015.
- Net benefits derived from tourism, fisheries and shoreline protection could be reduced due to coral degradation by an estimated US$350-$870 million/yr.

Main References:
(i) Burke, L. and Maidens, J. (2004). *Reefs at Risk.* Washington, D.C. (USA): World Resources Institute.
http://www.wri.org/biodiv/pubs_description.cfm?pid=3944
(ii)*Tourism Expansion: increasing threats, or conservation opportunities?* at
http://www.grid.unep.ch/product/publication/download/ew_tourism.en.pdf

C.9. Case Study:
Tobago Cays Marine Park (TCMP), Southern Grenadines[24]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Tobago+Cays+Marine+Park+&sll=50.176898,-91.582031&sspn=50.412279,137.8125&ie=UTF8&ll=13.076803,-61.586609&spn=1.187838,2.15332&t=h&z=9&iwloc=A

Case Study:
oecs.org/ESDU/documents/opaal/Tobago_Cays_Marine_Park_ St%20Vincent.pdf

Background

The Tobago Cays Marine Park (TCMP) is a complex of well-developed coral reefs and seagrass beds located between St. Vincent and Grenada, in the Southern Grenadines (12 °28' N, 61° 22' W). The TCMP is a biologically rich ecosystem that attracts visitors from around the world. It has been described as the *jewel of the Caribbean*.

TCMP surrounds six main islands, including the five uninhabited islands of the Tobago Cays (Petit Bateau, Petit Rameau, Jamesby, Baradal, and Petit Tabac) and the populated island of Mayreau. The TCMP is managed under the legal authority of the 1997 Marine Parks Act of St. Vincent and the Grenadines.

Formal and informal reports and studies have suggested that there has been a slow degradation and deterioration of the coral reef and marine environment in the Tobago Cays. A number of natural and human-caused factors contributed to this degradation. The TCMP has been converted to an official marine protected area with strong management guidelines and plans, as well as sufficient monitoring and enforecment.

Coral reefs surrounding Tobago Cays Marine Park
Alvarez, A. (2008). Alycia Alvarez photography: travelling to Tobago. Retrieved from: alyciasavage.com/2008/07/

Environmental Characteristics

Surrounding the Tobago Cays are several shallow fringing reefs and a major horseshoe barrier reef. The main coral reef ecosystems of the TCMP are called Horseshoe Fore Reef, Petit Bateau, Petit Tabac, Baradal, and Mayreau Gardens.

Horseshoe Reef

Horseshoe Reef is the largest reef in St. Vincent and the Grenadines. In 1975 a study of the reef identified 30 species of corals. The reef is so large that it is divided into geographical sections with dominant coral species in each section. The sections are known as the back reef, the reef crest, and the fore reef. Surgeonfish (*Acanthurids*), parrotfish (*Scarids*), and clownfish (*Pomacentrids*) are found here. Other major families of reef fish include snapper (*Lutjanudae*), grouper (*Serranidae*), pufferfish (*Tetradontidae* and *Diodontidae*) and grunt (*Pomadasyidae*).

Petit Bateau

Petit Bateau is surrounded by patches of shallow fringing reefs. The reefs show a mixture of alive and dead coral, with new colonies establishing themselves atop dead branches. Fish fauna consist primarily of juveniles of parrotfish (*Scaridae*), damselfish (*Pomacentridae*), grunt (*Pomadasyidae*), and surgeonfish (*Acanthuridae*).

Petit Tabac

Petit Tabac is located to the west of Horseshoe Reef and does not receive protection from sea surge. Hurricanes and storms constantly hit this reef, resulting in substantial coral rubble. The reef is very shallow, with very small isolated colonies of soft corals and sponges. Sea fans (*Gorgonia flabellum*) and sea plumes (*Pseudopterogorgia sp.*) can be found on this reef. Several species of small and juvenile fish fauna have taken advantage of the protection offered within the coral rubble. Barracudas (*Sphyraena barracuda*), filefish (*Cantherhines macrocerus*), and eels (*Gymnothorax funebris*) can be found here.

Baradal

Baradal contains a mix of seagrasses (*Thalassia*) and scattered corals (Porites) at varying densities depending upon the depth of the ocean. Hawksbill turtles (*Eretmochelys imbricate*), leather-back turtles (*Dermochelys coriacea*), and green turtles (*Chelonia mydas*) graze on the seagrass.

Mayreau Gardens

Mayreau Gardens is a series of seven dive sites ranging from a steep sloping wall, reaching depths of up to 70 feet in deep areas to 25 feet in shallow areas. Shallow areas are made up of white sand with seagrass and patches of coral. A wide variety of habitats and biodiversity are supported within the area due to the presence of an environmental gradient, from well-illuminated turbulent waters in shallow areas to darker calmer conditions at the base of the reef.

Ecosystem User Groups

Fishers

Fishing has been restricted in the TCMP. However, illegal spear fishing was still reported to be taking place.

Yachters

Both local and foreign companies provide yacht chartering services for use in the Grenadines. In 2002, 85 vessels provided charter opportunities to passengers in this region.

Divers

Scuba diving in the Tobago Cays was provided by four local dive shops that average approximately 1,000 dives each year.

Cruise Ships Operators

Cruise ships regularly visited the TCMP. In the 2006/2007 cruise season an estimated 15,890 cruise ship passengers visited the Tobago Cays.

Charter Boat Operators

A number of boat operators provided day-trip excursions such as picnics and swims to visitors. Some single-boat charter operators may have taken up to 400 people a day out on excursions.

Water Taxi Operators

It was estimated that somewhere between 45 and 60 water taxis operated in the TCMP, transporting residents and tourists around the cays.

Vendors

Vendors operated in the TCMP selling T-shirts, handicrafts, ice, bread, fresh fish, fruits, and vegetables. Vendors were restricted to the north beach of Petit Bateau. Some speed boats traveled from yacht to yacht selling bread and fruits,T-shirts, conch shells, and lobster.

Tourists

Toursits participated in activies such as diving, snorkelling, swimming, sailing, hiking, fishing, and wind surfing. They accessed the reef by snorkelling, private boat, or catamaran.

Residents

The total number of residents on Union Island, Palm Island, and Mayreau was 2,189; however, local residents generally did not tend to visit or participate in any activities within the TCMP.

Mangagement Issues/Environmental Threats

There were a number of interrelated human-caused and natural factors that contributed to the degradation of the coral reefs in the TCMP.

Coral Bleaching and Disease

There had been a substantial loss in the health and vibrancy of the coral reefs on the TCMP. Lack of toilet and proper sewage facilities (for boats and cruiseships) had resulted in sewage and waste being dumped into the ocean. This, along with an number of other factors (such as climate change), had resulted in sublte changes in the chemistry of the ocean which resulted in eutrophication and an overgrowth in algae, thus impacting the reefs. Diseases such as black band and white band disease were also affecting multiple areas of Mayreau Gardens and the Horseshoe back reef.

Reef Breakage

As the TCMP became increasing popular as a tourist destination, the impact of increased human and boat traffic was significantly impacting the ecosystem. Reefs and seagrass beds were being broken and damaged from swimmers and snorklers walking on them and boaters dropping anchors on them. Feeding and nesting turtle populations were often disturbed by snorklers and divers chasing after or feeding them. Turtles were also becoming more and more comfortable with humans which leaves them more vulnerable to predation.

An increase in hurricanes and storms, due to climate change and global warming, had also resulted in coral reefs being damaged and disturbed.

Decrease in Fish and Other Species

Despite fishing being prohibited in the TCMP, a rapid decrese in fish species was still occuring. Fishers did not even consider the TCMP a viable fishing location, due to the decrease in fish populations. Populations of parrotfish, groupers, snappers and, turtles continued to decline. The scarcity of adult fish and dominance of juvenille fish in the TCMP suggested that overfishing near the TCMP may have beed a factor. Illegal harvesting of conchs, lobsters, turtles, and turtle eggs also continued to be a problem.

(Part 2/Section C) Coral Reef Ecosystems

Tobago Cays coral reef
Paradise Islands Organization. (2008). Tobago Cays Marine Park. Retrieved from: .paradise-islands.org/grenadines/tobago-cays-marine-park.htm

Questions for Consideration

1) Why is the Tobago Cays Marine Park (TCMP) an important ecosystem?

2) Who are the primary beneficiaries (i.e. the main user groups) of the economic activities which occur in and around the TCMP?

3) What types of degradation are occuring in the TCMP?

4) What impact would the continued degradation of the TCMP have on the organisms which inhabit the coral reefs?

5) What impact would the continued degradation of the TCMP have on the various groups of individuals who depend on the area for a livelihood?

6) Write an open letter to the Government Ministry/Department with responsibility for the TCMP expressing your concerns about the degradation of the TCMP, and suggesting measures which should be implemented in order to ensure the sustainability of the TCMP.

7) Imagine that you were given the responsibility to spearhead a programme of education aimed at sensitizing individuals about issues relating to the TCMP:

- Which group of individuals would you target and why?
- Identify and explain the issues that you would highlight.
- What strategies would you use in the education/sensitization process?

C.10. Activity 1: Mock Marine Management Plan

Objectives:

Students will be able to:

- Explain the interdependence of plants, animals and humans in the coral reef ecosystem
- Identify the social, economic and, cultural interests of stakeholder groups
- Use concepts of conservation to develop criteria for managing a coral reef ecosystem

Methods:

Students identify specific criteria they believe should be included in a mock management plan for a protected area.

Materials:

Tobago Cays Marine Park – Southern Grenadines Case Study

Time:

1 period (approx. 1 hour)

Background:

See Tobago Cays Marine Park – Southern Grenadines Case Study.

The purpose of this activity is to encourage students to consider the environmental and human factors that are influencing the health of the ecosystems in the TCMP, to explore typical conservation management goals and to suggest criteria, rules, activities, or components of a management plan of the TCMP.

So what is a management plan? A management plan is essentially a document that outlines the goals, policies and operational activities that are to take place in a specific circumstance. In the case of a marine park or protected area, a management plan might outline activities that can take place within the park, rules or regulations for the park, specific zones or area uses in the park (i.e. swimming zone, protection zone etc.), how resources are to be used in the park, enforcement activities, monitoring plans, and public education strategies.

The park management plan for TCMP identifies the following guiding principles and objectives that are designed to influence all management decisions:

Guiding Principles

- Any development in the TCMP must be sustainable and address the needs of both present and future generations
- The concept of conservation must be incorporated into the plan
- User groups/stakeholders should be treated equally and benefit equally from the management plan
- User groups/stakeholders should be actively involved in the management of the TCMP
- Elements of the management plan (i.e. solutions and practices) should be flexible and adaptable
- Natural resources should be managed using an integrated approach

TCMP Objectives

The objective of the TCMP management plan is to:

- Enhance conservation and the management of biological diversity.
- Sustain economic benefits from the use of existing natural resources.

Procedure:

1) Review TCMP Case Study with students.

2) Review the components of a management plan with students. Review the guiding principles and objectives of the TCMP management plan (*see Background*). Teachers may wish to post guiding principles and objectives for students to reference during the activity.

3) Have students brainstorm which polices, practices, rules and regulations and activities they think should be included in the TCMP management plan. Engage students in discussion about why they think their suggestions are important or relevant to the conservation of the park.

Students should consider the user groups/stakeholders of the TCMP, the environmental characteristics of the coral reefs of the TCMP, and the environmental degradation and impacts that are affecting the area. Encourage students to identify:

- A list of activities that should and should not take place in the TCMP (some examples may include: swimming; diving; snorkeling; boating; not touching the coral; not dumping sewage waste; scientific research, etc.)
- Some rules and regulations in regards to park use (some examples might include entry fees; times of use; total number of visitors; specific anchorage areas, etc.)
- Some practices that should take place to conserve or protect biodiversity in the ecosystem (some examples might include increasing scientific research; re-introducing declining species; designating no-use areas, etc.)
- Specific elements they think should be monitored (some examples might include testing water for sewage; monitoring algae blooms; spread of disease, etc.)

C.10. Activity 1: Mock Marine Management Plan

- Specific enforcement strategies (some examples might include patrolling coral reefs; fining people who break rules, etc.)

- Specific environmental education strategies (some examples might include posting signs; giving presentations to cruise ship tourists; training boat operators etc.)

As students make suggestions, have them reference their suggestions against the TCMP guiding principles and objectives. Would their ideas fit within these goals?

4) After brainstorming potential elements of the management plan, engage students in a brief discussion about the challenges of creating a management plan. Some suggested questions include:

- Why are management plans important?
- What factors need to be taken into consideration when developing a plan?
- What are some of the challenges that might be faced in creating a management plan?

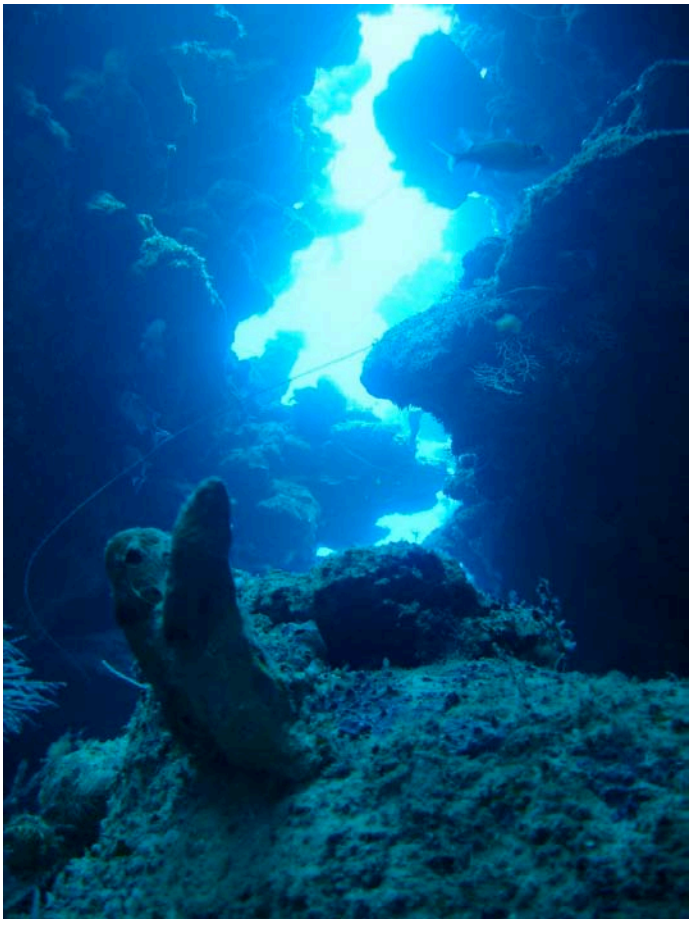
Extensions:

1) Have students work individually or in a group to develop and write out a sample management plan for TCMP.

2) Have students take the role of specific stakeholder/user groups and reflect on how they might feel about various elements of the management plan.

3) Have students focus on a specific species of plant or animal in the TCMP and have them develop a management plan for best protecting or conserving that specific species.

4) Engage the students in a role play by dividing them into groups to represent the various stakeholders. Each group of students would research the interests and concerns of their assigned stakeholder group. Then have a round-table discussion to develop the management plan.



Looking up through a coral reef cavern
Photo supplied by: Andrew Ross (Seascape Caribbean)

Diver studies coral
Photo supplied by: Andrew Ross (Seascape Caribbean)

C.11. Activity 2: Coral Reef Ecosystem Poster Presentation

Objectives:

Through peer-to-peer knowledge transfer, students will be able teach others about the value and importance of coral reef ecosystems as it pertains to the value and vulnerability of the region's coral reefs. This activity should introduce students to the elements and tools of public environmental education.

Methods:

Students practice researching, presentating, and developing **key messages** in environmental public education campaigns.

Materials:

- Student Worksheets
- Research resources such as library and/or Internet
- Pen and paper per student
- Poster paper and drawing materials per student

Time:

Discussion – 1 class period
Research – 1 class period
Poster Design – 1 class period
Presentation and discussion – 1 class period

Background:

Importance of coral reefs

The plants, animals and habitats within coral reef ecosystems are extremely interdependent on one another. The degradation of areas within a coral reef or extinction of a single species poses significant threats to other plants, animals and habitats connected with coral reef. It is important that we understand the interconnectedness of the various elements of coral reef ecosystems so that we can better protect and conserve them.

Importance of environmental education

Stewardship of the environment is dependent on the public being well-educated about the importance of ecosystem health to our social, economic, and cultural existence, both now and for future generations. The more we understand the interconnectedness of the natural environment and our impacts on it, the better we will be able to protect it.

Educating the general public about biodiversity and environmental conservation can be a challenging task. Environmental conservation concepts can be abstract and difficult to explain and understand. Successful public environmental education campaigns tend to focus on one to three specific key messages about a particular environmental topic. A key message is a single important thought or idea that is most relevant to the topic at hand. It is a simple concrete idea that people need to hear in order to effectively understand the issue. Key messages can be delivered to the public using a variety of methods and mediums such as verbal interviews, written explanations, images, video, and pod-casts.

The purpose of this activity is provide students with two opportunities:

- An opportunity to further research and understand the interconnectedness of specific species living in or near coral reefs
- An opportunity to try communicating to others a specific environmental message about why the element of the coral reef ecosystem that they researched is important and why it needs preserving

Procedure:

1) Review materials pertaining to the existence and value of coral reef ecosystems with students.

2) Have an open discussion with students about what elements make up an effective public education campaign.

3) Split students into groups and have them pick a species or aspect of a coral reef ecosystem found within the Caribbean Sea and encourage them to study how it is interdependent or interconnected to other species, habitats, or elements of a coral reef ecosystem.

4) Provide students with time and access to resources to perform the necessary research. Have students fill out the attached student worksheet to help guide their research. Review the student worksheet as a class and develop a list of assessment criteria that students agree on that describe an excellent poster. Post the assessment list in the classroom so students can refer to it.

5) Next, have students determine what key messages they think the general public needs to know about to best understand the interrelationships they have studied. Have students decide upon a single action they want the public to do to help conserve the coral reef ecosystem or the aspect they have studied.

6) Students should then design a poster (as if it was part of a public environmental education campaign) and using a mix of words, images, colors and designs attempt to convey one or two key messages that they have identified and an action that they wish the public to take.

7) Once students have completed their posters, have them hang posters up for other students to observe. Allow students time to look at each poster carefully.

8) Discuss with students the importance and challenges of developing environmental education campaigns. Suggested discussion questions include:

- What did you enjoy most/least about the activity?
- What was the greatest challenge in completing this activity?
- Review student posters. What key messages stand out? Why?
- What design techniques worked best? Why?
- Do you feel public environmental education campaigns are important/effective/needed? Why or why not?

C.11. Activity 2: Coral Reef Ecosystem Poster Presentation

Student Name: Date:

What aspect/element of the coral reef ecosystem have you chosen?

Describe the characteristics of the aspect/element of the coral reef (i.e. species type, food, habitats, type of activity, type of pollution).

Describe how the aspect/element is interconnected or interdependent on other aspects/elements of the coral reef ecosystem?

Why is this aspect/element and/or relationship important to coral reefs?

List 3 key messages the public need to know about this aspect/element?
1.
2.
3.

List 1 activity the public can do to protect this aspect/element and/or the coral reef ecosystem itself?

List 3-5 images that best depict the aspect/element of the coral reef ecosystem that you have researched.
1.
2.
3.
4.
5.

Brainstorm 5-10 words or phrases that best describe the aspect/element of the coral reef ecosystem that you have researched
1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

**Use the information you have recorded on this sheet to inspire your public environmental education poster on the topic.

C.12. Case Study: Community-Based Natural Resource Management in the Bay Islands, Honduras[25]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Bay+Islands,+Honduras&sll=37.0625,-95.677068&sspn=32.527387,68.90625&ie=UTF8&ll=16.343861,-86.531067&spn=1.230792,2.15332&t=h&z=9&iwloc=addr

Case Study:
srdis.ciesin.org/cases/honduras-006.html

Background

This case study is located in the Bay Islands, Honduras. The Bay Islands are located about 56 kilometres off of the north coast of Honduras. The Bay Islands constitute the northern most and sole insular department of the country of Honduras. Of the eight islands and over 60 cays comprising the archipelago, Roatan is by far the largest and most populated. Among the three principal islands, Roatan comprised 57% of the total land area (12,740 ha. of 22,516 ha.), and two thirds of the human population (16,000 of 24,000). Guanaja's population was 6,000 on a land area of 5,616 hectares. Utila supported a population of 2,000 on 4,160 ha of land.

The principal renewable resource in question is the coral reef ecosystem surrounding the islands. However, human activities both on the islands (e.g. deforestation, infrastructural development, and waste disposal) and in the water (dredging, construction, lobster, shrimp and conch fishing, SCUBA diving) created impacts on reef health.

A variety of cultural, political, environmental, and economic features were relevant to this case. The Bay Islands have a colourful history evidenced by the highly diverse human population. Although currently a part of Honduras, significant populations of Afro-Antilleans, Afro-Carib ("Garifuna"), Mosquito Indians, Anglo-Antilleans, and Anglo-Europeans live in the Islands. Many islanders speak Caribbean English and Spanish equally well.

Race relations were not always amicable, and ethnically homogenous enclaves were common. Relatively wealthy Americans and Europeans and Spanish-speaking Hondurans were the most recent arrivals to the islands. English-speaking Bay Islanders were commonly thought to be separatists by the national government.

Honduras is a poor country — only Haiti is poorer in the Western Hemisphere — with a corrupt and ineffectual government. Environmental issues were not high on the national government's agenda. A system of national parks was a relatively new addition to the Honduran landscape.

All economic activity in the islands depended upon the reef and the sea for its survival. Fish was a principal source of protein for Bay Islanders, and lobstering and shrimping were the traditional and dominant form of employment for islander men. Tourism, based upon SCUBA diving, was the most recent boom.

A case study of the institutional innovation to this situation, the Bay Islands Conservation Association (BICA), was conducted. It attempted to reveal the features of the BICA and the institutional

Sand Mining
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

and natural resource environment of the Bay Islands that contributed to its ability to manage the islands' natural resources from the perspective of its membership.

The initial situation

Prior to the formation of BICA, the aquatic and terrestrial natural resources of the Bay Islands were either unmanaged as open-access resources or exploited as private property. External effects of individual behavior, the common property management of shared resources, the public nature of an individual behavior, the common property management of shared resources, the public nature of a cultural heritage and economy closely linked to the natural resource base — none of these were addressed by any governmental or nongovernmental institution.

Management of the coral reefs, surrounding waters, and steep forested lands of the Bay Islands as open access resources became a visible problem in about the late 1980s. At that time, tourists began to know the islands as a new "in place" for SCUBA diving, , expatriate North Americans and Europeans began to see the islands as "the next Belize," and imported plastic products or products packaged in plastic became popular. Tourism development enticed mainland Hondurans to migrate to the islands in search of work. Expatriates and a few wealthier islanders purchased and developed lands for tourism businesses. Mangroves were cut, harbours were dredged from pristine beaches, coral was used construction materials, and hillsides were stripped of their foliage. No infrastructure for sewers, electricity, or the provision of fresh water existed for much of the islands. Sedimentation, eutrophication and diminishing fish stocks, shellfish stocks, terrestrial species, and fresh water supply resulted.

The marine and terrestrial ecosystems of the Bay Islands showed high levels of degradation. The principal reasons for difficulties in maintaining marine biodiversity were the destruction of habitat, the extraction of dead coral and sand for construction, and over-fishing or over-hunting of commercial species. The primary causes of terrestrial environmental degradation were establishing pastures on unsuitable land and developing housing estates. The decrease in fish species, deforestation, control of garbage and human waste, water issues, tourism development, and increasing strain on the fragile resource bases were the principal areas of concern for the long-term development of the Bay Islands.

The spoils of this development largely fell to the Islands' elite and the expatriate community. In sum, mainland Hondurans had probably benefited from their immigration relative to the difficult life of peasants on the mainland, but their living conditions were still not good by developed country standards. It could be easily argued that the majority of islanders had not benefited in sum from the formalization of the islands' economy through tourism.

It was no longer easy simply to live off of the land and the sea. Purchased goods were expensive. The land was all owned by outsiders and land tenure relationships had changed to reflect the preferences of the new stewards of the Bay Islands natural resources. The islanders' relative poverty and lack of education was unavoidably evident to them through interaction with tourists and satellite TV.

Solid waste from tourism pollutes ocean and rivers
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

After several years of unbridled development, it became apparent that the tourism would not continue to generate wealth if the natural environment upon which the boom was based was destroyed due to a lack of management. Everyone, except those with the financial wherewithall to permanently leave the Islands and, perhaps, those who would be able, in time, to return to a simple life of living off of the land and sea, would continue to suffer had the situation continued.

The change process

In 1990 the Bay Islands Conservation Association/Asociacion Para La Conservacion Ecologica de Las Islas de La Bahia was founded over concerns about the islands' fragile natural resources. The association's long-term mission was to create an environment which would provide economic opportunities for Bay Islanders and at the same time maintain the unique flora and fauna of the Bay Islands. BICA implemented a variety of programs and engaged in a number of activities in order to make progress toward its long-term mission.

A core group of expatriates and elites involved in the tourism industry formed the organization. Among the strongest personalities involved in the formation of BICA was the representative to the national senate from the islands. He was principally responsible for facilitating the granting of legal NGO status to BICA and in securing official management responsibility of the organization for the islands' reef ecosystems. He also owned the oldest, most famous, and among the most expensive resorts on Roatan. His wife served as the president of BICA from its formation until 1996. The leadership and most active members of BICA were largely acting in their economic self-interest through their participation in the organization.

The outcome

In 1990, there were approximately 68 BICA members located in the islands, the mainland, and abroad. By late 1995, the mailing list maintained in Roatan had grown to more than 350 individuals and organizations. Members received an annual newsletter detailing BICA activities and requesting another year's membership.

BICA's main office was located in the center of the main settlement of Coxen Hole, Roatan. BICA-Roatan was run by a seven-member board of directors. The Roatan office employed two paid (through local donations) secretarial staff and a Peace Corps Volunteer (PCV), who was paid by the US government. Neither the director nor the sub-director were financially compensated.

BICA's other two branches were located on the islands of Guanaja and Utila. BICA-Guanaja was formed of the Guanaja Ladies Club (GLC). Historically, the GLC was a social club of Bonacca Town's more prominent women. BICA-Guanaja consisted of expatriates involved in the tourism industry, GLC members, and several other prominent citizens. Guanajans had been in active in BICA. They decided to establish an office and distinct presence on Guanaja. BICA-Utila maintained an office in the chapter president's living room. It had recently elected a new board of directors, and reopened its renovated and expanded visitor center. The Utila branch had a paid director/president ($150/month) and no secretarial staff.

Among the important activities of all NGOs were fundraising and determining the appropriate use of collected funds. BICA sought financial support from local people and businesses, nonlocal people, the national government, and international organizations including NGOs and financial institutions. BICA's internal sources of funding included memberships, donations to specific projects, and sales. BICA's external sources of funding or expertise included the USAID, Fundacion Vida (national level Honduran NGO), the United Nations, TACA Airlines, the Caribbean Conservation Corporation (international NGO), the National (US) Marine Sanctuary Program, the Canadian Agency for International Development (CAID), the International Union for the Conservation of Nature (IUCN), the Quebec Union for the Conservation of Nature (UQCN), the government of Switzerland, and the Honduran Tourism Institute (IHT). BICA's operating budget, exclusive of in-kind transfers, was $21,869 in 1991, $53,695 in 1992, $48,381 in 1993 and $67,742 in 1994. (Figures are expressed in 1995 US dollars.) These funds were allocated among the organization's solid waste program, marine reserve management, environmental education program, buoy project, turtle project, green iguana project, and administration.

Questions for Consideration

Hold a class discussion around the following questions:

1. What are some of the limiting factors of the region for supporting life? (water, soil, fertility, forest cover, biodiversity, human populations?)

2. What were the specific human factors that contributed to the problems discussed in the case study? How could these have been avoided?

3. Historically, who benefited the most from the Bay Islands' tourism industry and why? What had to change in order that more residents benefited?

4. Has the carrying capacity of the area been exceeded? Explain.

C.13. Activity 3: Diagram the Case!

Objective:

Students will draw a graphic depicting the interrelated sequence of events and key players that led to the environmental issues and results described in the Bay Islands case study.

Materials:

- Flip chart paper
- Markers and/or coloured pencils
- Copies of Community-Based Natural Resource Management in Bay Islands, Honduras

Time:

1-2 class periods.

Procedure:

1. Distribute the case study to the class, and review any vocabulary words that may be new to the students. Locate the area of the case study on a regional map, and ask students if any of them have been to the area described.

2. When students have had the opportunity to read the case study, have students list the many groups and stakeholders involved in the case study on the board – there are a lot of participants! Then divide the class into discussion groups of about 3-4 students each.

3. Give each group a large sheet of paper and some markers, and ask them to develop a diagram depicting the ecosystem discussed (the Bay Islands and some of its plant and animal inhabitants), and the key players (local resident groups, the BICA and its branches, government and other stakeholders, tourists, other NGO's, and outside funders). Next, students should work to draw a timeline at the bottom or side of their diagram that highlights the dates and events that led to the Bay Islands management plan.

4. Ask each group to present their diagram to the class, and discuss how social, economic, and biological events are interrelated as the causes of the environmental issues depicted. What were some reasons for success? What would you do differently if you were in a management position in the Bay Islands?

5. Back in their discussion groups, have students generate some strategies for solving the problems of biodiversity loss. Proper and sustainable land use is a key to solving the problems. Have students write their strategies up on sheets of paper and display them in the school or community beside their diagrams of the case study issues.

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Rick Searle (EKOS Communications, Inc.)

Part 2 / Section D

Mangrove Swamp Ecosystems

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

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(Part 2/Section D) Mangrove Swamp Ecosystems

D.1. What is a Mangrove Swamp Ecosystem?

Mangroves swamps or wetlands are coastal wetland ecosystems found in tropical and subtropical regions of the world. They are characterized by **halophytic** (salt-tolerant) trees, shrubs, and other vegetation growing in saline waters from the intertidal zone up to the high-tide mark. These wetlands often grow in estuaries, sheltered coastlines, and river deltas, where fresh water meets salt water. Mangrove swamps are subject to the twice-daily ebb and flow of tides, fortnightly spring and neap tides, and seasonal weather fluctuations. Until recently, this ecosystem has been neglected because of its appearance as a mass of impenetrable woody vegetation, At least 35 percent of the world's mangrove forests have been lost in the past twenty years. Losses in mangrove forests exceed those for both tropical rainforests and coral reefs, two other well-known threatened ecosystems[1].

The **mangrove swamp ecosystem** (**mangal** ecosystem or **mangals**) gains its name from the large number of mangrove trees that dominate this ecosystem. There are about 39.3 million acres of mangrove forests in the warm coastlines of tropical oceans all over the world. The largest percentage of this ecosystem is found in Southeast Asia and the smallest percentage is found within the Caribbean[2].

D.2. Characteristics of a Mangrove Swamp

Individual plants in mangrove wetlands have different degrees of tolerance for exposure and submergence of their roots to seawater. Mangrove tree species show distinct **zonation**, where more salt-tolerant species are found closer to the water and less salt-tolerant species are found away from the water.

All plants in mangrove swamps have specialized adaptations to overcome the problems of anoxia (decreased levels of oxygen), high salinity, and frequent tidal inundation. Mangrove trees have shallow roots that spread widely, and support roots that grow directly into the mud to anchor the tree. The shallow roots may send up root projections, called **pneumatophores**, to the surface, which help to supply the plant with oxygen. These breathing roots allow mangroves to survive in anaerobic sediments, whereas buttresses and above-ground roots enable them to grow in unstable mud flats. Once established, these support roots provide a habitat for many species, including oysters, algae, barnacles, sponges, and bryozoans.

The mangrove support roots also help to impede water flow, thereby enhancing sediment deposit within the roots and slowing down the flow of rivers and stream water.

Some mangroves have prop roots protruding from the trunk and branches, which hold the tree's trunk and leaves above the water line and filter out the salt in the brackish water. Salt crystals that are taken up by the mangrove's roots are then stored in the tree's foliage. Upon reaching saturation, the mangrove rids itself of the salt by shedding its leaves. Mangrove foliage also houses water storage tissue to allow the plants to conserve water, which allows the trees to cope with periods of high salinity. Mangrove seeds are salt resistant and buoyant, which allows them to disperse and establish themselves in new areas far from their parent tree.

The earliest species of mangroves originated from Southeast Asia, where there are more mangrove species than anywhere else in the world. It is believed that mangrove seeds were brought westward to India, East Africa, and finally to Central and South America by ocean currents 23 to 66 million years ago. As a result, there are far fewer species of mangroves in the Americas than anywhere else in the world.

D.3. Types of Mangroves

Although a significant number of plant species can be found in mangrove habitat worldwide, of the recognized 110 species, only approximately 54 species constitute true mangroves, or species that occur almost entirely in mangrove habitats and rarely anywhere else[3]. There are four species of mangrove trees found

A mangrove Swamp
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

within the islands of the Eastern Caribbean: red, black, white, and buttonwood mangroves.

Red mangrove (*Rhizophera mangle*), the most common of the species and the first to grow in muddy areas, is easily recognized by its distinctive arching roots, which resemble a dense tangle. Red mangroves prefer the least elevated areas of swamps and require brackish to saline water for at least some part of the year in order to survive[4]. Although this species' bark is grey, it is the colour of the tree's interior which gives the species its name.

The red mangrove is the least salt-tolerant, so it grows closest to or in fresh or brackish water where there is more dilution. The black mangrove is the most salt tolerant, as it grows in hypersaline conditions to the back of the mangrove zone. (After water has evaporated from the back of the mangrove zone, it causes hypersaline conditions in the soil – salt content is much higher there than in the coastal waters.)

Black mangrove (*Avicennia germinans*) shows marked preference for higher, drier habitats and is not usually found within habitat that is completely inundated with water[5]. Black mangroves are characterized by prop roots that extend from the lateral branches but do not produce the tangle of roots seen in the red mangroves. Black mangroves are the source of mangrove honey. The bark of this species is dark and scaly.

White mangrove (*Laguncularia racemosa*) has no outstanding root structures and tends to have less stringent habitat requirements than either red or black mangroves. The bark of this species is white.

Buttonwood mangrove (*Conocarpus erectus*) can appear in bush or tree forms and prefers less saline environments. As a result, this species is found the furthest distance from the coast. Its bark is grey. Of the four species of mangrove within the Caribbean, it is generally the smallest in height[6].

A distinct zonation of these species is evident in mangrove swamps. Red mangrove is grows nearest water. Behind them, white mangrove and black mangrove predominate, along with a few other plant species such as the swamp fern (Acrostichum aureum). Further back, under less saline and drier conditions, the button mangrove and coastal scrubland forests are found.

The *hypersaline* conditions are actually quite helpful, since when freshwater reaches mangroves, the salt in the wetland is dissolved in this freshwater which then goes on to flow to the sea. Mangroves therefore protect coral reefs from an influx of freshwater from the land by regulating salt content in the water that passes through them.

Red Mangrove (Rhizophora mangle)

Black mangrove (Avicennia germinans)

White mangrove (Laguncularia racemosa)

Photo source: Carrington, S. (2002). Swamp communities: Caribbean island terrestrial habitats. Retrieved from: cavehill.uwi.edu/FPAS/bcs/courses/Ecology/ECOL2453/ecol2453_sc/Swamp_communities.html

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D.4. Biodiversity in the Mangrove Swamp

One of the most biologically diverse ecosystems, mangrove swamps is known as the "rainforest by the sea". The mangrove wetlands within the Caribbean are particularly diverse as they host the world's richest mangrove-associated invertebrate fauna and provide habitat for a number of globally-endangered animal species[7].

Since these swamps are constantly being replenished with nutrients transported by fresh water runoff from the land and flushed by the tidal movement, they host extremely large populations of bacteria and other decomposers and filter feeders[8]. This ecosystem sustains billions of worms, protozoa, barnacles (*Balanus*), oysters (*Crassostrea*), sponges, and other invertebrates, some of which live attached to the mangrove roots. These organisms, along with those living in the soft sediment that accumulates around the base of the mangroves, in turn feed fish and shrimp, which support wading birds and other larger predators.

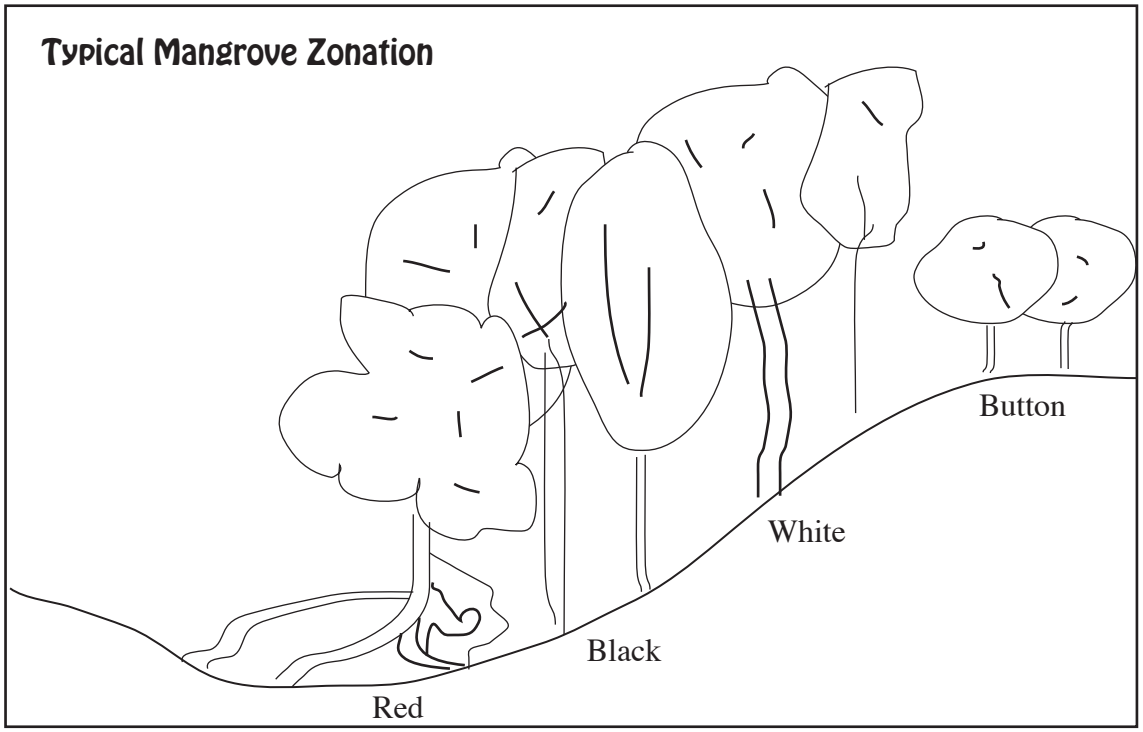
The swamps provide a rich habitat for over 2,000 species of fish, shellfish, invertebrates, and plants, and are the breeding grounds for fish, shrimp, prawns, crabs, shellfish, and snails.

Living above the waterline on the prop roots of the red mangrove are animals such as the mangrove periwinkle (*Littorina angulifera*), the isopod (*Ligia*), and the mangrove crab (*Aratus pisonii*). Invertebrates such as the mangrove oyster (*Crassostrea rhizophorae*), the flat tree oyster (*Isognomon alatus)*, barnacles (*Chthamalus and Balanus*), and mussels (*Brachidontes*) live on the roots below the waterline. Lower in the root region a number of encrusting attached organisms can be found, including several species of sponges, bryozoans, hydrozoans, and the fan worm (*Sabellastarte*).

Swimming crabs (*Portunidae*) and various bivalves live on the soft mud bottom below the mangroves, and fiddler crabs (*Uca*), mangrove tree crabs (*Goniopsus cruentata*), mangrove crabs (Ucides cordatus), and mud skippers (*Oxudercinae*), are found in the mud flats among mangrove roots[9].

Many fish species that inhabit coral reefs as adults live as juveniles in mangrove swamps. Mangroves are in essence nursery habitats for these species, and their presence increases fish populations on the nearby reefs. Mangrove forests are also nesting sites for many shore birds and home to fishing cats, lizards, sea turtles, and many more animals. For many species of fruit bats, such as the dawn bat, mangrove blossoms and fruit form a significant portion of their diet.

The mangrove forest canopy is prime habitat for a number of species of birds including Yellow warbler (*Dendroica petechia*), Scarlet ibis (*Eudocimus ruber*), Cattle egret (*Bubulcus ibis*), Green heron (*Butorides virescens*), Bananaquit (*Coereba flaveola*), Adelaides warbler (*Dendroica adelaidae*), Caribbean elaenia (*Elaenia martinica*), Green throated carib (*Eulampis holosericeus*), Saint Lucia oriole (*Icterus laudabilis*), Lesser Antillean bullfinch (*Loxigilla noctis*), Antillean crested hummingbird (*Orthorhyncus cristatus*), Carib grackle (*Quiscalus lugubris*), Lesser



Antillean saltator (*Saltator albicoloris*), Common egret (*Casmerodius albus*), and Brown pelican (*Pelecanus occidentalis*).

D.5. Importance of Mangrove Swamps

Mangrove swamps fulfill certain important economic and environmental functions for countries across the world. These functions include provision of wood and non-wood forest products; coastal protection against the effects of waves, wind, and water currents; conservation of biological diversity, including a number of endangered mammals, reptiles, amphibians and birds; protection of coral reefs and sea-grass beds against siltation; and provision of habitat, spawning grounds, and nutrients for a multitude of fish and shellfish[10].

D.5.a. Timber and Non-Timber Products

Mangrove wood is resistant to rot and insects, which makes it extremely valuable as a commodity. Numerous coastal and indigenous communities worldwide rely on this wood for construction materials and fuel. Fishermen, farmers, and other rural populations depend on mangrove forests as a wood source for timber, posts, fuel, and charcoal, and as a source for non-wood forest products such as food, thatch, fodder, alcohol, sugar, medicine, and honey. By the 1980s in the Eastern Caribbean, harvesting mangroves as a source for charcoal had become a major source of subsistence income and an important cottage industry[11]. Historically, mangroves were also exploited as a source of tannin which was used to cure and dye leather and fabricate fishing nets, though the increasing use of nylon fishing nets and chrome as the agent for curing leather has reduced this need[12]. Within the Caribbean and South America, the nectar of mangrove flowers, particularly the Avicennia species, is exploited in the apiculture industry, and beehives are transported to mangrove areas during flowering to produce honey and wax.

Harvesting a mangrove swamp for wood
Food and Agriculture Organization (FAO). (1959). An international review of forestry and forest products. Rome: Food and Agriculture Organization of the United Nations. Retrieved from: fao.org/docrep/x5393e/x5393e04.htm#mangrove%20silviculture

D.5.b. Coastal Protection

Mangroves help protect the coastal and coral reef ecosystems from surge storms (particularly during hurricanes), waves, and tsunamis. Their massive root system is efficient at dissipating wave energy, so the natural force and energy of these natural disasters are dispersed before ever reaching the shore[13]. In areas where mangrove trees have been cleared, coastal damage from hurricanes is much more severe.

D.5.c. Natural Filtration

The dense root systems of mangrove forests also act as a natural water filter by slowing down tidal water enough for the water's runoff sediment to be deposited on swamp vegetation as the tide enters the mangrove swamp. This results in much less sediment flowing out into coral reefs, seagrass beds, and the open ocean, and thus improves water clarity and turbidity for coastal and marine species. Mangrove swamps' role in entrapping upland runoff sediments is essential in the prevention and reduction of coastal erosion and the stabilization of the coastline.

D.5.d. Basis of Marine Food Chain

Mangrove trees play an essential role in both the marine **food chain** and the detrital food cycle by transferring organic matter and energy from the land to marine ecosystems. A food chain is the complex feeding relationships that exist in nature. The **detrital food cycle** is a food chain that begins with **detritus**, which is organic debris formed by the decomposition of plants and animals and followed by decomposers, including bacteria and fungi. As mangrove leaves drop into tidal waters, they are colonized within a few hours by marine bacteria that convert difficult to digest carbon compounds into nitrogen-rich detritus material. The resulting microorganism-covered leaves become essential food for the smallest animals within the mangrove ecosystem, such as worms, snails, shrimp, molluscs, mussels, barnacles, clams, oysters, and the larger commercially-important striped mullet. These detritus eaters are then prey for carnivores like crabs and fish, which are subsequent prey for birds and game fish.

D.5.e. Fisheries

The role of mangroves in the marine food chain is essential. According to Kapetsky (1985), the average yield of fish and shellfish in mangrove areas is about 90 kilograms per hectare, with maximum yield of up to 225 kilograms per hectare[14]. Declines in local fish catches often occur when mangrove forests are wiped out. Assessments of the links between mangrove forests and the fishery sector suggested that for each hectare of forest cleared, nearby coastal fisheries lose 480 kilograms of fish per year[15].

From 1980 to 1990, there has been a ten percent decline in mangrove area within the Caribbean. Paralleling this decline, the total marine fish catch also declined ten percent in the Caribbean during the same period[16]. Between 1982 and 1991, penaeid shrimp catches in the insular Caribbean declined by 51 percent, and the collection of mangrove oysters (*Crassostrea rhizophorae*) declined by 20 percent[17]. Without mangrove habitat, species such as these cannot survive. The dense root systems of mangroves

Mangrove ecosystem cleared for new resort development
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

form habitat for fish, crabs, shrimps, and molluscs. They also serve as nurseries for juvenile fish and lobsters.

D.5.f. Tourism

Given the diversity of life inhabiting mangrove systems, and their proximity in many cases to other tourist attractions such as coral reefs and sandy beaches, many countries have started to tap into the tourism potential of their mangrove forests. This is especially true in the Caribbean, where tourism is one of the mainstays of the islands' economies. Bonaire National Marine Park in the Netherlands Antilles has marketed snorkelling expeditions in and around mangroves to witness a marvellous variety of young fish, jellyfish, and urchins against a background of interwoven mangrove roots[18]. While coral reefs are a more common draw for tourists, mangrove forests offer great potential for revenue generation.

D.6. Emerging Trends/Major Threats

D.6.a. Lack of Public Concern

Unfortunately, some of the general public within regions which have significant mangrove ecosystems generally regard mangrove swamps as a health threat which should be eradicated. These swamps are seen as barren wastelands full of bacteria and breeding grounds for mosquitoes. These sites are then targeted for landfills, solid waste disposal, and deforestation. Only in the last two decades has any attention been paid to this ecosystem. Those working towards the protection of mangroves are still facing a lack of public awareness and concern[19]. Increasingly though, recognition of the economic value of mangal for fisheries, coastal stabilization, and ecotourism is causing the conservation of mangrove swamp ecosystems to be given more concern[20].

D.6.b. Reclamation

Within the world, the major causes of clearings and losses of mangrove swaps are competition for land for urban development, tourism, and agriculture or shrimp-pond construction. Develop-

The Ramsar Convention

The Ramsar Convention, or more properly, the Convention on Wetlands, signed in Ramsar, Iran, in 1971, is one example of conservation work being done at the international level. The mission of the convention is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world. At present, more than 158 countries have signed the Convention, including many in the Caribbean region. *(See table below.)*

Country	# of Ramsar Sites	Surface Area (hec)
Antigua and Barbuda	1	3,600
Bahamas	1	32,600
Barbados	1	33
Belize	2	23,592
Costa Rica	6	510,050
Cuba	6	1,188,411
Dominican Republic	1	20,000
Guatemala	7	628,592
Honduras	6	233,320
Jamaica	3	37,765
Nicaragua	8	405,691
Panama	4	159,903
Saint Lucia	2	85
Trinidad and Tobago	3	15,919
Venezuela 5	5	263,636

Caribbean Ramsar sites include: Codrington Lagoon (Barbuda); Inagua National Park (Bahamas); Graeme Hall Swamp (Barbados); Sarstoon Temash National Park (Belize); Turberas de Taamanca (Costa Rica); Lago Enriquillo (Dominican Republic); Parque Nacional Jeanette Kawas (Honduras); Portland Bight Wetlands and Cayes (Jamaica); Mankoté Mangrove (Saint Lucia) and Caroni Swamp (Trinidad)

More details on the Ramsar Convention and sites can be found at **ramsar.org.**

ment of land for urban and tourism development has been the main regional cause of loss of mangrove swamps within the Caribbean over the last 25 years[21]. **Reclamation** of mangrove swamps continues to make room for tourist-related infrastructure, such as marinas, hotels, and harbours, golf courses, road construction, and solid waste disposal.

D.6.c. Pollution

Mangroves are susceptible to pollution, particularly oil and other petroleum compounds. Oil pollution — resulting from offshore oil exploration and production, pipelines, tanker accidents, and intentional clearing of ship's ballast tanks in the Caribbean region — causes mortalities of mangrove trees, roots, and associated fauna[22]. Continued dependency on imported oil for energy needs of most Caribbean states and the use of the Caribbean as a travel route suggest that petroleum will continue to be a significant pollutant impacting Caribbean mangal[23].

D.6.d. Sewage, Urban Runoff, Pesticides and Solid Waste Dumping

Mangroves act as sinks, which concentrate pollutants such as sewage, toxic minerals, urban runoff, pesticides, and herbicides. These pollutants have persistent effects on mangrove growth and production. If concentrations reach threshold levels, they will cause entire mangrove areas to be killed. In recent years, the biggest regional threats to mangroves in the Caribbean are the ever-increasing development of the tourism industry, pollution from runoff of fertilizers and pesticides, and improper disposal of wastes. Within the islands of the Eastern Caribbean solid waste dumping still occurs where sewage is pumped untreated into the water ecosystems. A higher sewage load is associated with increased concentration of Vibrio species, which causes seafood poisoning in shellfish found in mangrove swamps[24].

D.6.e. Climate Change

Climate change leads to higher atmospheric temperatures, soil warming, altered weather patterns, and rising sea levels[25]. All these effects could profoundly influence mangrove growth and survival. Mangrove forests require stable sea levels for long-term survival. They are therefore extremely sensitive to current rising sea levels caused by global warming and climate change. Accelerated rising sea-levels also threaten mangrove habitats with inundation, erosion, and saltwater intrusion. Changes in precipitation, increased coastal erosion, and a possible increase in the number and severity of hurricanes and ocean tropical storms are also anticipated impacts of climate change[26]. Rising sea levels, as a result of climate change, is associated with the melting of glaciers and the polar ice caps. This influx of fresh water into the oceans causes alterations in the ocean's salinity, which could negatively impact mangrove swamps[27]. Increased erosion, which is predicted, may exceed mangroves ability to filter out sediments and maintain clear and

sediment-free estuary water, thus having impacts on the habitats of mangrove and coral reef dwelling species.

D.6.f. Over-harvesting

Today, mangrove wetlands are one of the most threatened ecosystems in the world[28]. Mangroves are often exploited as a source for wood for local populations in the world. Mangrove wood makes a superior form of charcoal and many trees are being cut down to sustain local charcoal industries. Mangrove trees are used for firewood, construction wood, wood chip and pulp production, charcoal production, and animal fodder. While harvesting has taken place for centuries, in some parts of the world it is no longer sustainable, threatening the future of the forests. In the Caribbean, harvesting is not one of the largest stresses, but extraction does continue to occur[29].

D.6.g. River Changes

Dams and irrigation decrease the amount of water reaching mangrove swamps, thus changing the salinity level of water in the swamps. If salinity becomes too high or drops too low, the mangroves cannot survive. In addition, increased erosion due to land deforestation can increase the amount of sediment in rivers, which can overcome the mangrove forest's filtering ability[30]. Eventually, this will lead to the mangrove forests being smothered.

D.7. Protecting Mangrove Swamps

Mangrove forests, which once covered more than 200,000 square kilometres of coastline in the world, have been diminished by

TABLE 9

Mangrove species composition in North and Central American countries

Species	Anguilla	Antigua and Barbuda	Aruba	Bahamas	Barbados	Belize	Bermuda	British Virgin Islands	Cayman Islands	Costa Rica	Cuba	Dominica	Dominican Republic	El Salvador	Grenada	Guadeloupe	Guatemala	Haiti	Honduras	Jamaica	Martinique	Mexico	Montserrat	Netherlands Antilles	Nicaragua	Panama	Puerto Rico	Saint Kitts and Nevis	Saint Lucia	Saint Vincent and the Grenadines	Trinidad and Tobago	Turks and Caicos Islands	United States	US Virgin Islands
Acrostichum aureum	√	√			√[a]			√		√		√			√	√				√	√	√	√	√	√	√		√	√	√			√	√
Avicennia bicolor										√				√					√						√	√								
Avicennia germinans	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Avicennia schaueriana	√	√						√				√			√	√					√		√	√				√	√	√	√	√	√	√
Conocarpus erectus	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Laguncularia racemosa	√	√		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Nypa fruticans																										√[b]								
Pelliciera rhizophorae										√															√	√								
Rhizophora harrisonii										√												√[a]			√	√					√			
Rhizophora mangle	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Rhizophora racemosa										√															√	√					√			
Total no. of species	6	6	2	4	4	4	3	6	4	9	4	6	4	5	6	6	3	4	5	5	6	6	6	6	9	10	4	6	6	6	7	5	6	6

Food and Agriculture Organization (FAO). (2007). The world's mangroves: 1980-2005. FAO Forestry Paper 153. Rome: Food and Agriculture Organization of the United Nations.

35-86 percent, and are critically endangered or approaching extinction in 26 out of the 120 countries in which they are found[31]. Further, mangrove forests are disappearing at a rate of ont to two percent per year, a pace that surpasses the destruction of adjacent coral reef and tropical rainforest ecosystems. These losses, combined with increasing **fragmentation** of mangroves, reduces their viability and the quality of the services they provide.

Mangrove ecosystems are linked through exchanges of water to both upstream terrestrial ecosystems and downstream marine communities[32]. Disturbance and productivity within upland communities strongly affects the dynamics of downstream mangal, seagrass beds, and coral reefs, while coral reefs and seagrass beds protect mangrove forests from wave impacts[33]. Coral reef, tropical rainforest, coastal, and ocean ecosystems ultimately both have an impact on and are impacted by mangrove swamps, because they are all connected. In managing and conserving this ecosystem, this interrelationship must be taken into account.

Mangroves are increasingly appreciated for the many roles they play. Caribbean governments are beginning to realize the benefits of healthy mangroves, both for their ecological value and for the economic advantages provided by sustainable tourism and national fisheries. Some governments have initiated activities to conserve and protect them; however, in some countries in the region, the public still does not consider mangroves a resource to be actively protected[34].

Adequate legislation for the conservation and protection of mangrove swamps is not very common in the Caribbean, and only very few countries have specific laws for the conservation of these ecosystems (Costa Rica and the United States are examples)[35].

A positive step forward in the protection of these ecosystems is the growth in integrated management agreements (between stakeholders such as farmers, tourism operators, charcoal producers, and protected area managers) within areas that house mangrove swamps. In some areas of the Caribbean, active restoration of mangrove forests is even occurring[36].

Most countries have now banned the clearing of mangrove areas for aquaculture, and require environmental impact assessments prior to large-scale conversion of these areas to other uses. Anguilla, Aruba, Montserrat, Saint Lucia, and the Turks and Caicos Islands have maintained their mangrove areas relatively constant over the past 25 years. As a result of increased awareness in the region, the annual rate of mangrove area loss has decreased in the last five years in 24 countries within the Caribbean[37]. Government-issued permits are also beginning to be required to cut mangrove trees within the Eastern Caribbean, although enforcement is virtually non-existent[38].

Education and outreach are necessary in gaining protection because it is through these means that support is garnered from all stakeholders of the ecosystem. Designated conservation areas may also save some of the forests. Since 1986, Saint Lucia has moved to protect a number of mangroves around the island, declaring them marine reserves. Having protected-area designation may help communities encourage and develop a thriving sustainable ecotourism industry based on mangrove swamps.

While there are growing pressures on mangrove swamp ecosystems within the Caribbean, there is also a growing awareness and recognition that these ecosystems are a natural area that deserve and require protection and conservation. Many organizations are working within the region to preserve mangrove swamps.

D.8. Case Study: Managing the Mankoté Mangrove, Saint Lucia[39]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Vieux+Fort+Saint+Lucia&sll=13.871913,-60.900993&sspn=0.077828,0.134583&ie=UTF8&ll=13.731214,-60.947342&spn=0.077875,0.134583&t=h&z=13&msa=0&msid=112231967872874630261.000001135276b56805c25

Case Study:
cbd.int/doc/case-studies/inc/cs-inc-lc-01-en.pdf

Background

The Government of Saint Lucia recognized the need to conserve mangrove ecosystems. In 1986, most of the island's mangroves were declared marine reserves under the Fisheries Act of 1984. Mankoté (on the southeast side of the island) is a basin mangrove, which covers 40 hectares within the Mankoté Marine Reserve. It is the largest of the island's mangroves and represents 20% of the total area of the islands' mangrove forests. Mankoté is an important biodiversity-rich ecosystem that plays a critical role in providing wildlife habitat and in controlling coastal erosion.

The Mankoté mangrove was also an important source of fuelwood for Saint Lucia. It provided approximately 30% of the charcoal sold in the adjacent town of Vieux Fort, an urban commercial district which hosts the major international airport, a number of hotels, major docking facilities, and an industrial complex.

Prior to 1986, the Mankoté mangrove was in decline due to excessive cutting for fuelwood (for charcoal and cooking fuel), fishing, spraying of pesticides, and waste dumping. To conserve the mangrove and protect the ecosystem from further degradation, the government, researchers, a local non-profit organization and mangrove timber harvesters came together to establish a management agreement for the use of the mangrove. This agreement set out specific guidelines for how the mangrove trees could be harvested, who could harvest them, how tree-cutting would be monitored, and what other activities could take place in the area. This experimental approach to managing the marine reserve has reversed the degradation of the Mankoté mangrove.

Environmental Characteristics

The Mankoté mangrove is 40 hectares in size and is the largest mangrove in Saint Lucia. The mangrove species identified in Mankoté include the red (Rhizophora mangle), black (Avicennia germinans and Avicennia schaueriana), white (Laguncularia racemosa), and buttonwood (Conocarpus erecta) (Conservation & Sustainable livelihoods).

The Mankoté mangrove is vital to maintaining coastal ecosystem stability. This is an important area for fish breeding, avifauna habitat, silt trapping, water-quality maintenance, and nutrient exporting.

Many species of plant and animal depend on the Mankoté mangrove ecosystem. Local species of birds such as the Cattle egret (Bubulcus ibis), Green Heron (Butorides virescens), and Caribbean elaenia (Elaenia martinica) depend on the mangrove. Migratory birds such as the Belted kingfisher (Ceryle alcyon), Peregrine falcon (Falco peregrinus,) and Osprey (Pandion haliaetus) also visit Mankoté. Marine species such as Crevalle Jack (Caranx hippos, and Euryhaline oyster (Crassostrea rhizphorae) rely on the mangrove for food and shelter.

Ecosystem User Groups

Department of Fisheries (DOF): Due to the fact that Mankoté is a declared marine reserve under the Fisheries Act, it falls under the jurisdiction of the DOF for active management. Additionally, it is a Ramsar site, and is considered a forest, so it is managed by the Department of Forestry as well.

Aupicon Charcoal and Agricultural Producers Group (ACAPG): This is an informal cooperative of about 15 individuals who harvested mangrove wood to produce charcoal. This cooperative did not exist prior the establishment of a management agreement for Mankoté. As part of the management agreement, individuals who wished to harvest wood from the mangrove had to become members of the ACAPG and agree to the rules of tree cutting and monitoring.

Caribbean Natural Resources Institute (CANARI): A non-governmental organization which has been involved in the management and monitoring of activities regarding Mankoté since 1981. CANARI was largely responsible for organizing the charcoal harvesters into an informal cooperative.

Hunters and Fishers: Mankoté is a prime location for seasonal activities such as fishing, bird hunting, and crab hunting.

Recreation and Tourism: Local residents and tourists visit Mankoté for therapeutic bathing, birdwatching, and ecotours.

Business Operators: Entrepreneurs are continuously targeting the private property surrounding Mankoté for development. In the past, proposals have been submitted for the development of large-scale resorts and golf courses in and adjacent to the mangrove forest.

Scientists and students: Mankoté is an easily accessible mangrove forest that contains a vast amount of information for scientists and students to study.

Management Issues

Resource Extraction

Mangrove timber harvesters were dependent on the continued sustainability of the Mankoté mangrove as a resource. Although timber harvesters put pressure on Mankoté, they practiced a number of sound management measures. For example, each timber harvester used one cutting area per season and rotated cutting areas, returning to cut over the area after at least two years. They cut mangrove trees selectively in strips of 10-20 meters, zigzagging their cuts to access clusters of suitable stems. All harvesters were aware of each other's cutting area in any given season. Harvesters allowed time for the trees to regenerate before re-cutting and left uncut species of mangroves as cover to impede the evaporation of the swamp. Harvesters also worked together as part of the cooperative to record, monitor, and report how much wood was being cut and how well the mangrove was regenerating.

Potential Development

Entrepreneurs continued to view the private property around Mankoté mangrove as a prime location for development. Pressures from industry, construction and increased tourism in the area had the potential to significantly impact the health of the mangrove ecosystem.

Cultural Pressures

There are many threats to this ecosystem in Saint Lucia today. The general public generally regarded mangroves as a health threat, which should be eradicated. Mangroves are often perceived as breeding grounds for mosquitoes. Because of a lack of understanding about the environmental and economic significance of mangroves sites such as Mankoté, they were often targeted for landfills, solid waste disposal, and deforestation. While declaring Mankoté a marine reserve has helped to protect the ecosystem, not all members of the general public understand why this is important.

Summary

Mankoté is an example of the joint effort of key user groups working together to protect an important ecosystem from degradation while continuing to allow resource extraction.

While efforts have been made to protect the mangrove from further degradation, Mankoté's future is still uncertain, as development interests in the area remain a threat. Researchers are continuing to study and monitor the effects and impacts of the selective mangrove harvesting that is taking place. Other potential environmental threats — such as rising sea levels due to climate change, and solid waste disposal from nearby residents and industries — also need to be examined to ensure the future sustainability of this ecosystem.

Questions for Consideration

1) Why is the Mankoté mangrove an important ecosystem?

2) What types of human activities were impacting the sustainability of the Mankoté mangrove prior to 1986?

3) What are some of the current threats that might impact the sustainability of this ecosystem?

4) What possible impact would the destruction of the Mankoté mangrove have on the community of Vieux Fort on Saint Lucia?

5) What conservation measures do you suggest should be implemented to increase the sustainability of the Mankoté mangrove?

6) Can you identify a mangrove swamp in your county that is being threatened by human activity? Give a brief description of the area and the threat, and list some possible ways to protect the mangroves.

7) Is Mankoté mangrove a Ramsar site? What are the other Ramsar sites in the region? Is there one close to you?

8) After reviewing this case study, teachers are encouraged to take their students on a field trip to a mangrove in their country and have the students assess the mangrove's current condition and challenges using the questions above. For example, the students could look for signs of human activity within or near the mangrove and to identify possible or actual threats to the mangrove.

Photo supplied by: Rick Searle (EKOS Communications, Inc.)

D.9. Activity 1: Stakeholder Debates

Objective:
Students will be able to identify a variety of stakeholder groups, their interest, their impacts, and their concerns about the conservation of mangrove swamps.

Methods:
Students practice their debating skills.

Materials:
Managing the Mankoté Mangrove; Saint Lucia Case Study

Time:
1-2 periods (approx 1.5 hours)

Background:
Managing the Mankote Mangrove; Saint Lucia Case Study

Debate Structure
A debate is essentially a calm, logical, structured argument between two parties. A variety of topics can be debated. Topics in a debate are usually presented as a statement. As with an argument, there are two sides or view points to the statement topic. The party that agrees with the topic is called the affirmative and the party that disagrees with the topic is called the negative. When teams or groups of students are debating each other it is important that every member work together to present their teams case for why they believe the topic statement to be true or false. A useful technique to ensure team members stay on track is for each debate to start their case with "The statement_____ is true/false because…"

For the purpose of this activity, the structure of the debate should be kept simple. Debating teams should be kept small (2-3 students). The affirmative team presents their case first. The first speaker should state the team's position and present one reason for this position. The first person on the negative team will present their team's position, give an explanation for why they disagree with the other team's statement, and present one reason for their position. The second person from the affirmative team should give one reason for why they disagree with the other team's most recent statement, and present a second reason for their team's position. The second person from the negative team should give one reason for why they disagree with the other team's most recent statement, and present a second reason for their team's position. The third person from the affirmative team should give one reason for why they disagree with the other team's most recent statement, and summarize the reasons their team has presented. The third person from the negative team should give one reason for why they disagree with the other teams most recent statement, and summarize the reasons their team has presented.

Mangrove in Costa Rica
Eco Preservation Society Blog. (2008). Costa Rica's mysterious mangroves: a treasured and exotic habitat. Retrieved from: ecopreservationsociety.wordpress.com/2008/02/13/costa-rica-mysterious-mangroves-a-treasured-and-exotice-habitat/

Procedures:
1) Review *Managing the Mankoté Mangrove; Saint Lucia Case Study.*

2) Explain debating structure to students.

3) Divide students into small groups of 2-3 students. Explain to students that they will be debating topics from the perspective of stakeholder/user groups as they pertain to the Case Study. Students will need to come up with their positions on the topic as if they were a member of a specific user group of the Mankoté Mangrove.

4) Assign two groups (one will be the affirmative, the other will be the negative) to the following statements and stakeholder groups:

"The private property around Mankoté Mangrove should be converted into a private golf course."
(Affirmative = Business operator / Negative = Scientist)

"Charcoal harvesting should be banned from the Mankoté Mangrove."
(Affirmative = Department of Fisheries / Negative = Aupicon Charcoal and Agricultural Producers Group)

"Mangroves should be eradicated."
(Affirmative = Local Residents / Negative = Students)

"Conservation of Mankoté Mangrove is only important to charcoal harvesters."
(Affirmative= Aupicon Charcoal and Agricultural Producers Group / Negative = CANARI)

"Fish are the most important species in the mangrove."
(Affirmative = Fishers / Negative = Hunters)

(*Note: Teachers and/or students may wish to come up with other potential debate topic statements.)

5) Give students 10 minutes to come up with their position on the topic. Students will need to come up with 2-3 reasons (one for each member of the team) for why they agree or disagree with the statement. Reasons don't need to be lengthy, but can be simple one sentence statements.

6) Have students stand-up and debate the topics, taking turns presenting their topic statements, positions and reasons. Each student should be given a maximum of 1-2 minutes to present his or her position and rebuttal.

7) Once all topic statements have been debated, debrief with students about challenges of the exercise and what they learned about the stakeholder/user groups of the Mankoté Mangrove. Some suggested discussion questions include:

- What did you enjoy about this activity?
- What were some of the challenges of this activity?
- What did you learn about the stakeholder groups of the Mankoté Mangrove from this activity?

D.10. Activity 2: Making Mangroves Matter[40]

Objective:

Students will be able to generate a list of activities that impact mangrove swamp ecosystems, as well as explore possible actions they could take in regards to the conservation of mangrove swamps.

Methods:

Students identify and evaluate activities that directly and indirectly impact mangrove swamps and consider possible solutions to reducing these impacts. Then using creative methods such as skits, songs, commercials, etc., students present this information to fellow classmates.

Materials:

- Recipe Cards (or rectangular cut out pieces of paper)
- Pen per group of students

Time:

1-2 periods (approx. 1.5 hours)

Background:

The purpose of this activity is to get students to:
a) Think about natural and human activities that directly and indirectly impact biodiversity in the mangrove swamp ecosystem;

b) Consider ways these impacts can be prevented or mitigated; and to

c) Consider conservation activities that could take place to protect mangrove swamps for degradation.

Procedure:

1) Review mangrove swamp ecosystem biodiversity curriculum.

2) Ask students to brainstorm a list of human activities that impact the health of mangrove swamp ecosystems. As students suggest activities, post their responses for them to review. Divide the list into two categories, direct impacts and indirect impacts. Direct impacts include those activities that take place within the ecosystem that influence it. An example of this would be charcoal producers cutting mangroves for fuel wood. An indirect impact would be an activity that takes place outside the ecosystem that has the potential to influence it. For example, driving cars burn fossil fuels that emit greenhouse gases into the atmosphere. Greenhouse gases contributed to climate change, resulting in changes sea levels, which impacts the health of the mangrove. Activities that directly impact the ecosystem may be easier for students to identify. You may wish to provide helpful hints to encourage students to identify activities that indirectly impact the environment as well.

3) Once a list of activities has been developed discuss with students the differences between the two categories of activities.

4) Next, on the top of individual recipe cards write out each of the identified activities, one activity for each card.

5) Divide students into small groups (2-4 people per group).

6) Hand out one recipe card, with the identified activity listed on it, to each group.

7) Have students spend a few moments discussing the activity on their recipe card. Have students answer the following questions and write down their answers on their recipe card.

- How does this activity impact the mangrove swamp ecosystem?
- Who is involved in this activity?
- Can this impact be prevented or mitigated (lessened)? How?
- What conservation activities might need to take place to reduce the impact of this activity on the mangrove swamp ecosystem?

8) Once students have finished discussing their activity and its impacts and have written down their answers on the recipe card, have students work together as a group to come up with some dramatic or artistic way of presenting this information to other students. Students may wish to create a drawing, develop a brief skit, sing a short song, write a poem or commercial etc. The objective of the presentation is for students to identify the activity, its impacts, and things that can be done to protect or conserve the environment. Students should aim to keep their presentations brief 3-5 minutes max.

9) Have student groups present their creative presentations to the class.

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Biodiversity of the Caribbean

ECS

A Learning Resource Prepared For:
ORGANISATION OF EASTERN CARIBBEAN STATES

(Protecting the Eastern Caribbean Region's Biodiversity Project)

Photo supplied by: Jennifer Goad

Part 2 / Section E

Tropical Forest Ecosystems

USAID
FROM THE AMERICAN PEOPLE

February 2009

Prepared by Ekos Communications, Inc.
Victoria, British Columbia, Canada

Table of Contents

(Part 2/Section E) Tropical Forest Ecosystems

E.1. Introduction

Life is difficult in the Caribbean, if you are a tree. A number of conditions transpire to make it so. The islands are small and most are heavily populated. To meet the needs of the region's growing population, forests are cleared to make way for settlements and agriculture, but loss of forest ecosystems produces unintended consequences that often come at a cost to human welfare as well as to biodiversity. On top of disturbances caused by humans, forests must also cope with hurricanes, heavy rains, landslides, and the like.

The forests need to be protected and conserved; where they are not, deforestation typically leads to such impacts as soil erosion, loss of habitat for wildlife, or alterations in the **water balance** (flow of water in and out of a watershed). These can combine to make human habitation of an area very difficult, and sometimes impossible.

Among the Caribbean islands, the remaining forests cling to a perilous and tenuous existence because of past mismanagement and increasingly high demands for benefits derived from these forests. The situation leaves very little room for error in decisions affecting forest preservation and use.

E.2. The Forests of the Caribbean

At present, the region's forests cover approximately six million hectares or 26% of its land[1] and vary widely in composition. According to the terrestrial ecoregions of the world, they can be generally classed as tropical and subtropical moist broadleaf forests, tropical and subtropical dry broadleaf forests, or tropical and subtropical coniferous forests.

Tropical and subtropical moist forests occur throughout the Caribbean. They are classified according to the altitude they are found (lowland to montane) and the amount of precipitation they receive (wet to rainforest). Originally this forest type covered approximately 85% of Jamaica, 60% of Hispaniola Island (Dominican Republic and Haiti), 85% of the Leeward Islands, 70 – 95% of the Windward Islands, and 90% of Trinidad and Tobago[2]. Throughout the range of this forest type, the average annual rainfall varies between 750 milimetres to an astonishing 10,000 milimetres! This mind-boggling amount of rain has been recorded in the interior highlands of Dominica, one of the Windward Islands. These islands feature some of the most biologically rich and diverse moist forests within the Caribbean because their rugged terrain not only intercepts moisture-laden Atlantic air masses, it inhibits human development.

Tropical and subtropical dry forests also exist throughout the entire Caribbean but not nearly to the same extent. They once covered 15% of Jamaica, 20% of Hispaniola Island, 5% of Trinidad and Tobago, and very small portions of the Leeward and Windward Islands[3]. These forests are typically found between the coasts and the mountains, where the average annual rainfall rarely exceeds 1250 milimetres.

An *ecoregion* is a "relatively large unit of land containing distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land use change." [4] Not only do ecoregions provide a useful tool for classifying communities of species and their environment, but they also can be applied to the preservation and conservation of biodiversity.

Tropical and subtropical coniferous forests are the most restricted of forest types within the region, occurring primarily in Cuba and Hispaniola Island. On the latter island, this type of forest occupies about 15% of the land, either on the lower slopes of mountains (850 – 2200 metres elevation) or on relatively flat areas higher up (2100 – 3175 metres elevation). As such, they constitute the only forest type to exist above 2500 metres.

Not surprisingly, each forest type requires specific management strategies, and these must be crafted with care. Because of the small size and steep slopes of the Caribbean islands, many forest types may only be found in a small area, which presents an added challenge for forest management.

E.2.a Dry Limestone Forests

Dry limestone forests form a large part of many of the Caribbean island ecosystems. These dry forests are found in the rain shadow of mountains and along coastlines where soils are often poor, and typically receive less than 1000 milimetres of rain annually. The tree canopy is usually low (8 – 12 metres or 20 - 35 feet), and the trees themselves are spindly and slow-growing due to the lack of rainfall. During the dry season, which normally lasts from December to July, some trees will drop their leaves to better survive long periods without rain. Other plants have water storage structures, such as thick trunks and waxy coatings on their leaves, trunks, and branches, which help keep moisture in. The forest canopy is largely evergreen, dominated by Gymnanthes lucida (*Euphorbiaceae*) in areas of limestone soil, while the emergent layer is more deciduous. Thick growths of climbers, vines, and strangler figs are sometimes found where more soil is present.

These forests and scrublands are important habitats for many unique bird and plant species. Wander through these forests and you'll come across a variety of species adapted to the dry terrain, including iguanas, butterflies, and hummingbirds. Thorny tree species such as acacias and logwood are common., Tall, upright cactus and thatch palms — as well as agaves, which are attractive to orioles and hummingbirds — grow in clear, unsheltered areas. White-crowned pigeons, Caribbean doves, parakeets, hummingbirds, vireos, and warblers are found year-round. In Jamaica, the endangered Jamaican iguana is restricted to dry forests in the Hellshire Hills outside Kingston. An endemic tree frog and the Jamaican boa (*Epicrates subflavus*) are also restricted to these dry forests.

The machineel tree (*Hippomane manicella*) is widespread throughout the Caribbean. It thrives in dry regions close to the shore. The sap of this tree is highly irritating to the skin, and so toxic that native populations used it to coat the tips of their poison arrows. Iguanas happily eat its fruits but they are poisonous to people. Even rainwater that passes over the tree's leaves can irritate the skin.

E.3. Tropical Rainforests

The term rainforest is a very imprecise. Most attempts to define it have relied upon the amount of rainfall. Unfortunately, there is no consensus as to what that amount should be. The lowest limit for the average annual rainfall is 1000 milimetres; the highest is 4000 milimetres. What is not in dispute is where rainforests are found: between the Tropic of Cancer and the Tropic of Capricorn. In other words, near the Equator. Also not in question is that rainforests clearly belong to the tropical moist broadleaf forest type within the Caribbean region.

A tropical rainforest has more kinds of trees than any other forest type in the world. In fact, 70% of the plants in rainforests are trees.

E.3.a. Cloud Forests

Tropical montane cloud (or mist) forests are a rare type of mountain forest found in tropical areas where local climatic conditions cause cloud and mist to be regularly in contact with the forest vegetation. They are a subtype of the tropical and subtropical moist forests.

Examples of Caribbean Cloud Forests

- **Nevis Peak (St. Kitts)**
- **Blue & John Crow Mountains National Park (Jamaica)**
- **Santa Elena & Monteverde Cloud Forests (Costa Rica)**

For videos links about Cloud Forests visit:
video.google.com/videosearch?client=safari&rls=en-us&q=Cloud+Forests+Costa+Rica&ie=UTF-8&oe=UTF-8&um=1&sa=X&oi=video_result_group&resnum=4&ct=title#

E.4. Structure of a Forest

Generally, forests can be thought of as having five distinct layers: **overstory (emergent), canopy, understory, shrub layer,** and **forest floor**. Each layer has its own unique assemblage of plant and animal species. The overstory refers to the crowns of the emergent trees which tower above the canopy of the other trees. These trees can attain heights of 30 metres or more. The roof of the forest or canopy is formed by the branches and foliage of the closely-packed trees. The understory consists of more widely-spaced and smaller tree species as well as regenerating canopy and overstory species. It is shielded from harsh, intense sunlight, drying winds, and heavy rainfall. Still younger, juvenile trees and shrubs make up the next layer while the forest floor is covered with litter from the canopy above, along with flowers, ferns, fungi, and mosses.

Tree ferns in the cloud forest of the Blue and John Crow Mountains National Park of Jamaica
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

Among the Leeward and Windward Islands, where the rainforest is relatively undisturbed, the overstory or emergent layer consists largely of the gommier (*Dacryodes excelsa*). On the latter islands, the gommier tree is frequently found in association with bois rouge (*Amanoa caribaea*) and bois côte (*Tapura antillana*) which form the canopy. Understory species may include bois de ferre (*Licania termatensis*) and the swizzle stick tree (*Quararibea turbinate*).

Flying over the seemingly closed canopy of the rainforest or standing below it, it seems that the limbs of the individual trees interlock and touch, but that is not the case. Instead, the limbs remain separated from each other by a metre or so. Scientists think that perhaps this is an adaptation to stop or slow the spread of infestations from caterpillars or diseases.

While this phenomenon is intriguing, the canopy presents other equally impressive wonders. Consider the billions of leaves overhead. Each acts somewhat like a micro-solar panel, gathering in the sun's energy to power the photosynthesis process, in which carbon dioxide and water are converted into oxygen and simple sugars. The former is given off into the atmosphere while the latter are used for the tree's growth. Because there are so many leaves, the rate of photosynthesis is very high, resulting in an abundance of fruits, seeds, and flowers which, in turn, attract and support a large diversity of animals.

E.5. Deforestation

The Caribbean is one of the world's "biodiversity hotspots", retaining just over 10% of its original forest cover[5]. High rates of **deforestation** within the region has raised alarm among conservationists around the world.

Originally, the tropical and subtropical moist broadleaf forests covered 85% of Jamaica. By 1983, this had been reduced to just over 6%[6]. In the Dominican Republic and Haiti, this forest type has shrunk from around 60% to less than 15% at present. Among the Leeward and Windward Islands as well as in Trinidad and Tobago, tropical forests are shrinking.

Tropical and subtropical dry broadleaf forests have been hit even worse. In Jamaica, they are practically non-existent, despite having once covered 15% of the island. On Hisponiola Island, this forest type has been reduced from over 20% to less than 8% of the land. Among the Leeward and Windward Islands as well as in Trinidad and Tobago, the dry forests have been practically wiped out. Only tiny fragments remain.

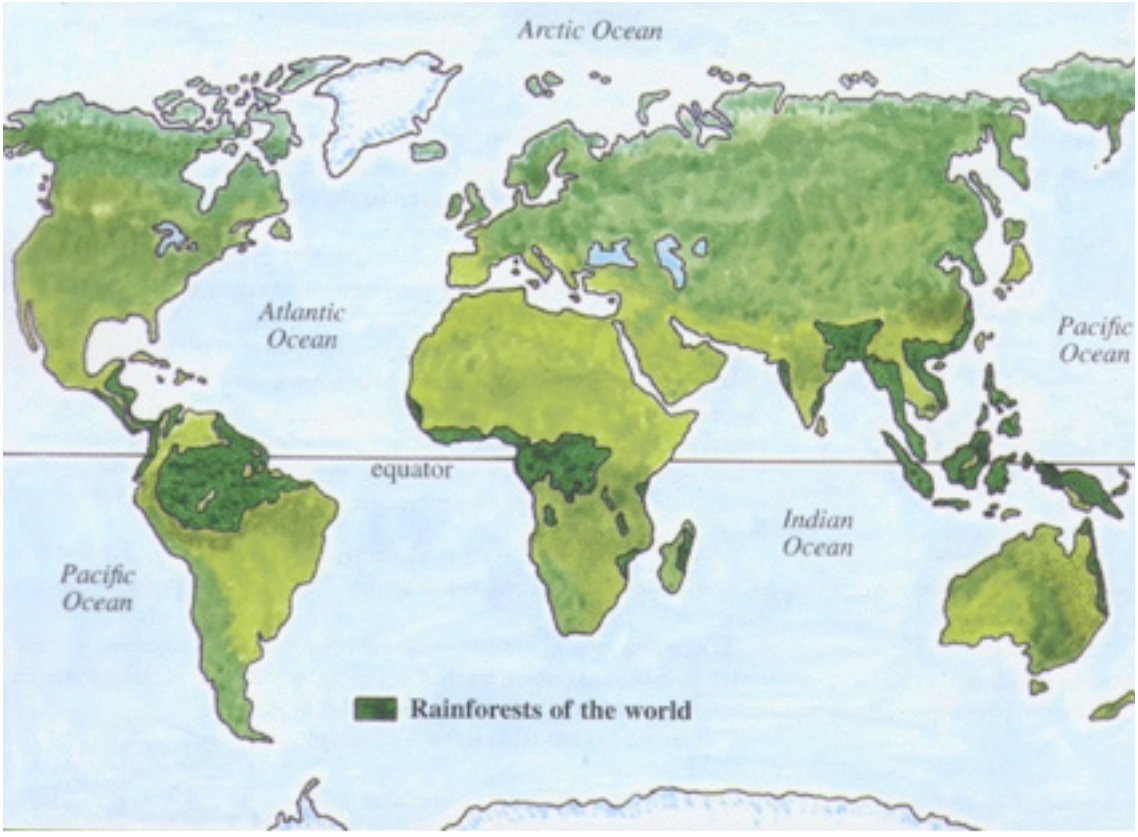
Meanwhile, the tropical and subtropical coniferous forests of the Dominican Republic and Haiti also continue to rapidly disappear.

Tropical Rainforests of the World

Rainforest cover by biogeographical realm

Realm	% share of world rainforest cover	Millions square miles	Million hectares
Ethiopian/ Afrotropical	30	.72	187.5
Australasian	9	.22	56.3
Oriental or Indomalayan	16	.39	100.0
Neotropical	45	1.08	281.2
Total		**2.41**	**625.0**

Butler, R. A. (2009). Tropical rainforests: world rainforests. Retrieved from: rainforests.mongabay.com/0101.htm



Learning About Rainforests. (n.d.). Where are the rainforests. Retrieved from: srl.caltech.edu/personnel/krubal/rainforest/Edit560s6/www/where.html

The deforestation noted above results from natural and human causes. Earthquakes, volcanic activity, tsunamis, and hurricanes have all had an impact on the region's forests at one time or another; however, hurricanes are widely believed to have the greatest impact. Since 1886, the Caribbean islands have borne the brunt of approximately 1060 tropical storms, many of which attained hurricane strength, with wind speeds in excess of 118 kilometres per hour[7]. When a hurricane passes over an island, there is generally severe damage to terrestrial ecosystems as well as to human settlements. When Hurricane David struck Dominica in 1979 with wind speeds up to 92 kilometres per hour, approximately three million trees were killed[8]. These effects are produced principally by fierce winds that come successively from opposite directions, by flying debris, or by storm surges of flood waters in coastal areas. The accompanying intense rainfall saturates the ground, softening it, causing the roots to have less of a firm hold, while simultaneously making the canopy heavier and the trees top-heavy[9]. Combined wind and rain strip trees of foliage or blow them down.

As destructive as they are, natural processes typically inflict relatively short-term damage on species and ecosystems. Within 14 months after the passing of Hurricane Gilbert over Jamaica in 1988, many tree species had produced new leafy crowns that hid their broken branches. Only seven weeks after a lashing by Hurricane Hugo in 1989, the trees of Puerto Rico had pretty much replaced all of their stripped branches with new leaves[10]. Hurricanes can even stimulate new growth within ecosystems, such as mangroves, coastal estuaries, lagoons, and even forests. Natural forces, no matter how destructive, rarely convert forest land to non-forest land over the long-term; hence, their deforestation effects are very short-lived. This is not the case with human impacts.

Large-scale disruption of Caribbean forests began with the arrival of Europeans in the late 1400s and has rapidly escalated in recent times. Initially, the forests were harvested selectively for fine woods for export, as well as for firewood. But the population was small, and the demand for wood was quite low. Inland forests, because they were not near the growing coastal communities, remained largely untouched. The plantation period brought slave labour, allowing forest lands to be extensively cleared, which resulted in soil erosion and changes in water quality and quantity. As early as 1721, deforestation was enough of a concern in Antigua that forest conservation legislation was drafted[11]. Fortunately for the forest ecosystems and the species that depend on them, an economic collapse followed and the plantations were abandoned. With the passage of time, the forests began to reclaim many of the cleared areas, except where the land had been too severely degraded. Even today, scrubs are all that have managed to replace the forests that once stood on some tracts of land.

It is worth noting that, in general, forests in humid life zones recover much more quickly than those in very dry or wet life zones[12]. At these two extremes, vegetation such as trees are more challenged to become established and to survive. This explains why islands with dry climates, such as Antigua, Barbuda, and Barbados, have a lower potential for forest regeneration of cutover areas than humid climate islands such as Dominica, St. Kitts or Saint Lucia.

Following the economic collapse of the colonial plantations and the abolishment of slavery, people began to live inland among the mountains. To support themselves, many turned to agriculture, which required the clearing of patches within the forest. By the early 1900s, the growing human population both in the mountains

Lignum vitae: The Tree of Life

D'Asign Source Botanicals. (2006). Plant list: tropical.
Retrieved from: dasignsourcebotanicals.com/plant_list.cfm?id=tropical

A well-known tree that is characteristic of this dry forest ecosystem is the lignum vitae (*Guiacum officinale*), or tree of life. This slow-growing tree, with its lovely blue flowers and incredibly hard wood, was first noted by Christopher Columbus in Jamaica. It is thought that the name was adopted because of its medicinal qualities – the sap was used to treat syphilis and other diseases. Other common names are palo santo, holy wood, greenheart, and ironwood. The lignum vitae is the national flower of Jamaica and the national tree of the Bahamas. The wood of lignum vitae sinks in water, and is the most dense of any known wood. (On the Janka Scale of Hardness, which measures the relative density of various types of wood, lignum vitae ranks highest, with a Janka hardness of 4500. (Compare this with hickory at 1820, red oak at 1290, and yellow pine at 690.) The wood is self-lubricating and harder than brass, making it very popular for use in ball bearings and propellers. For centuries, lignum vitae was used for propeller-shaft bearings in nearly all ships worldwide, and in some submarines. These bearings rarely required replacement, despite the severity of typical marine weather conditions. Due to this demand, the tree was heavily over-harvested from Jamaica and other Caribbean islands. It is still listed as a potentially endangered species by CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora).

Some of the ecological services provided by tropical forests:

- ***Climate regulation:*** forests take up and hold some of the excess carbon dioxide (CO_2) that human activity puts into the air. A whopping 400 tonnes of this **greenhouse gas** can be absorbed by one hectare of mature rainforest each year!
- ***Water regulation and purification:*** Forests act like large sponges, holding water that would otherwise run rapidly down slopes and into rivers and cause erosion, landslides or floods. Water slowly cycled through a forest is naturally-cleansed.
- ***Soil formation:*** Through the action of living vegetation on bedrock, soil is formed. Organic materials such as leaves, branches, and bark from trees and shrubs enrich the soil as they decompose. The root systems anchor the soil and prevent it from being washed away by heavy rains.
- ***Biological pest control:*** Forests are home to countless natural predators such as birds, wasps, and spiders, which prey on pest species that plague crops and plantations.
- ***Provision of timber products:*** Trees may be harvested so their wood can be used for construction of homes and other buildings or used in manufacturing items such as fine furniture.
- ***Provision of medicinal compounds:*** Tropical forests are vast storehouses of raw materials for modern medicines. The total number of plant-derived products in modern medicines amounts to several thousand, with many more yet to be discovered.
- ***Recreational/tourism purposes:*** Nature-based tourism is one of the fastest growing sectors in the region, with the opportunity to experience tropical forests a prime attraction.

and on the coasts made far greater demands on the forests for firewood and for export. The forests were rapidly depleted and many islands became net importers of wood, when once they had been net exporters. For example, in the 1930s, Saint Lucia's wood exports were worth 2.5 times more than its wood imports, but by the late 1970s, the flow had reversed. In fact, its imports were more than 259 times the value of its exports[13].

Commencing in the late 1940s, deforestation rapidly accelerated as an ever-growing human population now began to apply modern machines to land-clearing for settlements, agriculture, mining, timber harvesting, and other developments. Throughout the Caribbean, the rate of deforestation is very high. By the mid-1990s, Jamaica claimed the dubious honour of having the highest rates of deforestation[14]. In 1997, the Food and Agriculture Organization of the United Nations estimated deforestation rates for the region to be anywhere between 0.8 per cent to 7.2 per cent.

Deforestation comes at a terrible cost to the region's biodiversity and to human well-being. The destruction of forests destroys critical habitat for countless species of plants and animals. As explained in Unit 1, the myriad of species and ecosystems that share the planet with us have value in and of themselves, quite apart from any use we may or may not derive from them. The World Commission on the Environment and Development also noted that there were powerful ethical, aesthetic, scientific, and economic reasons to protect and conserve biodiversity. "Conservation of living natural resources – plants, animals, and microorganisms, and the non-living elements of the environment on which they depend – is crucial for development," it declared. "The challenge facing nations today is no longer deciding whether conservation is a good idea, but rather how it can be imple-

Wild Ginger Lily found in tropical forest
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Tropical forests provide vital resources for Caribbean communities
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

mented in the national interest and within the means available in each country."[15] In particular, the commissioners drew attention to the countless ecological services performed by natural ecosystems such as stabilization of climate, protection of watersheds and soil, and the provision of nursing and breeding grounds for fish and other food sources.

E.6. Conservation, Protection and Restoration of Tropical Forests

Although the Caribbean tropical rainforests continue to decline, there are some hopeful signs of positive change. The government of Trinidad and Tobago structured its first forest policy in 1942, and since then has revised it several times, most recently in 2003, to meet important environmental and social goals. In 2004, the government of the Dominican Republic embarked upon a plan to achieve sustainable forest management, which included actions to foster restoration of critical areas for conservation and productive purposes. Additionally, they sought to strengthen protection of remaining natural forests.

Between 2002 and 2004, the Central America Commission on Environment and Development launched the Central America Forestry Strategy as well as a Regional Biodiversity Strategy[16]. The first principle of this later strategy establishes the protection and conservation of biodiversity as fundamental to sustainable development and to the quality of life for people of the region.

Demonstrating some leadership within the region, the Organization of Eastern Caribbean States (OECS) developed the **St. George's Declaration of Principles for Environmental Sustainability** in 1999. The declaration was updated in 2006. In its preamble, the declaration states that the OECS is "firmly convinced that the well-being of humanity depends upon preserving a healthy environment with all its ecological systems, a rich variety of plants and animals, fertile soils, pure water and clean air, and that the peoples of the Member States are entitled to a healthy and productive life in harmony with nature [17]."

The most concrete way of protecting and conserving tropical forests and their native biodiversity is through the establishment and management of protected areas. In 2004, Cuba proposed to add nine new protected areas to its system, which are regulated, controlled and monitored under the National System of Protected Areas.

Recognizing the critical role of protected areas in meeting the St. George's Declaration of Principles for Environmental Sustainability, the OECS commissioned work to draft policy and legislation to guide the development of a more effective protected area system across its Member States. The final report of this work carried out under the auspices of the OECS Protected Areas and Associated Livelihood Project was completed in September of 2008. The proposed act will seek to achieve the following purposes:

- Support the long-term growth and sustainable development of each country in business, tourism, recreation, education, and scientific research
- Provide for the sustainability of biodiversity, culture, livelihoods, heritage, watershed protection, and other ecosystem services
- Protect wilderness areas
- Facilitate the implementation of the requirements, goals, and aims of applicable international agreements
- Assist in the mitigation of natural and anthropogenic disasters, and prepare for and respond to the impacts of climate change

To ensure that these purposes are met, the act also calls for the creation of a Protected Areas Coordinating Body which will consist of representatives from public, private, and not-for-profit sectors.

The progress with the establishment of protected areas appears exceptionally good. Between 1950 and 2003, protected areas increased from 17.5 to a whopping 397 million hectares within

the Latin American and Caribbean region, reaching 19 per cent of its total area and 23 per cent of the world's protected area[18]. Of these, more than 640 protected areas are found within the Caribbean, with more than 100 being focused on the marine environment. Unfortunately, many of these protected areas are not actively managed and remain paper parks.

There are a total of twenty-three (23) reserves on St. Vincent and the Grenadines, which are described as existing on paper simply due to the inability of local authorities to follow through on enactment of legislation. However, this inertia on the path of the authorities makes the protection of the rainforest on St Vincent even more crucial. There are eight areas on St. Vincent and sixteen areas in the Grenadines designated as forest and wildlife reserves. On St. Vincent there are the Kingstown Reserve, Campden Park Reserve, Colonarie, Soufriere, Mt. Pleasant, Dalaway and Richmond Reserves and a new National Forest Boundary, all of which are waiting gazetting and enactment by law.

However, as the OECS has recently acknowledged, the protected area network is uneven. Additionally, there are many critical ecosystems still needing protection.

To be successful at preserving and conserving biodiversity, it is clear that the protected areas of the Caribbean must contribute to development, and they do so in a number of important ways, such as protecting water catchment areas, guaranteeing fresh water supplies, maintaining fish habitat, and providing for tourism. However, protected areas within the region suffer from chronic funding shortages that limit the ability of governments to adequately maintain them. Hence, there is a vital role for citizens to take up the stewardship responsibility and care for these protected areas.

Visit the forest reserves and protected areas on your island, and learn more about their ecosystems, the threats they face, and what you can do to bring about change.

Eco-tourism provides educational opportunities to help protect tropical forests
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

Questions:

1. What are some relationships between the economy of the Caribbean and the state of the region's forest ecosystems?

2. What human activities impact the current state of most Caribbean forests? With a partner, list some ideas for ensuring that the use of forest resources proceeds at a sustainable rate.

3. List the ways that ecosystem goods and services provided by forests impact you and your family's livelihood.

4. Create a list of ways you use the forest (e.g. products, recreation, food, firewood, paper products, etc). Survey family and school members to add to your list. Can you find ways to reduce your consumption of forest products?

Explore Jamaica's Forests

Visit the following links for useful information about tropical forests in Jamaica:

Jamaican dry forests
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0218_full.html

Jamaican moist forests
worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0131_full.html

Forest cover and deforestation in Jamaica:
An analysis of forest cover estimates over time
forestry.gov.jm/PDF_files/JA%20Forest%20Cover%20Change.pdf

Protecting Jamaica's Tropical Forests:
Innovative Tools for Conservation
nature.org/wherewework/caribbean/jamaica/files/jm_tropicalforests.pdf

Jamaican Biological Diversity
jamaicachm.org.jm/Biodiversity/intro.asp

The Pitons of Saint Lucia
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

E.7. Case Study: Central Forest Range National Park (CFRNP), St. Kitts[19]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Mount+Liamuiga+St.+Kitts&sll=34.957995,-95.800781&sspn=31.764875,68.90625&ie=UTF8&ll=17.344412,-62.741203&spn=0.145504,0.269165&t=h&z=12

Case Study:
oecs.org/esdu/opaal-docs.html

Background

The central ridge of the island of St. Christopher (St. Kitts) consists of three volcanic centres in a chain of hills, extending from Mount Liamuiga (3,792 ft/1,156 m) in the northwest, through Verchild's Mountain in the middle range (2,444 ft/745 m), to Olivees Mountain in the southeast (2,953 ft/900 m). The area is 5,382.71 hectares (13,300.91 acres) – almost one quarter of the entire landmass of St. Kitts – and is the last area of extensive forest cover in the island. Almost all the domestic water supply on the island emerges from this area. In order to protect the island's watershed and to conserve this biologically rich ecosystem, the local government has proposed the development of the Central Forest Range National Park (CFRNP). The proposed park would include all mountain forest areas 1,000 feet or 304.8 meters above sea level.

Environmental Characteristics

The proposed region of the CFRNP is rich in biodiversity. The last detailed study of the area identified 926 plant species, 45 of which are endemic to St. Kitts or the Lesser Antilles. This area of rainforest is home to wild orchids, candlewoods, flamboyant tree, tree ferns, and tropical vines. A variety of key tree species also inhabit this region, including the royal palm, mahoe, spiny-trunked sandbox ceiba, turpentine, papaya, mango, and breadfruit trees.

The green vervet monkey and the mongoose are examples of two introduced species that inhabit this forest range. The introduction of these species has resulted in a significant decline in the indigenous species of lizards, iguanas, and tortoises, as well as birds that nest on the ground. There are also many native species such as frogs, bats, and butterflies. This region has the earliest documented evidence of honeybees in the Caribbean.

The average annual temperature in this region is 27 degrees Celcius (80°F). Near sea level the annual rainfall is approximately 1,250 to 2,000 milimetres (50 to 80 in) a year. Rainfall increases with altitude and on the windward slopes of the mountains.

While human populations do not permanently reside above the 1,000 ft/304.8 m range of the mountains of St. Kitts, humans have had a significant influence in the region. In the past this area was home to multiple sugar-cane plantations and timber logging. The sugar industry has now collapsed in this area. However, an extensive network of overgrown trails have been cut into the forest by loggers and military that provide limited access for tourists and hunters seeking plants and animals.

Ecosystem User Groups

Due to the steep terrain of the CFRNP, human activity is currently quite limited in the region. Human activities that typically take place in rainforests, such as woodcutting, charcoal burning, hunting, marijuana cultivation, planting of food crops, pasturing of animals, housing, and the harvesting of materials for craft, do not currently take place in this region. The forest region below 1,000 ft/304.8 m sea level provides sufficient resources for these activities to take place.

Human activities that are currently taking place in the CFRNP are limited to water harvesting, root harvesting, recreation, and tourism.

Water Harvesting

The St. Kitts Water Services Department harvests water captured by the forest. There are six intakes and one reservoir in the forest itself and a number below it. The water supply for all St. Kitts comes from this area.

Root Harvesting

The Kokanga Root, which gives a mellow taste to rum, mauby, and sarsaparilla, is harvested from CFRNP. Harvesters use the trail system in their search for the root. Other roots may be harvested for medicinal purposes, but no studies have been done in this regard.

Tourism

The proposed CFRNP is physically beautiful, possessing natural features to support nature tourism. Some residents currently hike into the forest and a few tour companies take tourists into the mountains.

Management Issues

Potential Encroachment

While very few people are currently accessing the CFRNP, there is some concern that nearby farmers may begin to move their farms and pasture their animals within the CFRNP, especially if the land below 1,000 ft/304.8 m sea level becomes overused or strained from current farming practices.

Trail Management

The most popular hiking route in the CFRNP is the Mount Liamuiga Crater Trail in the northwest range. This trail is heavily used and is showing signs of overuse. There is an uncomfortable amount of litter along the trail, and there has been some erosion

due to overuse. The second most popular hiking route, the trail to Dos D'ane Pond at 975.36 m. on Verchild's Mountain, is also showing significant signs of erosion.

The old Military Trail from Wingfield to Phillips between the middle and southeast Ranges, which was quite popular with Kittitians (especially schoolchildren) in former days but has not been much used in recent years, is blocked and is in need of maintenance.

The Sofa Stone Trail to the top of Monkey Hill (353.26 m) needs to be reopened. Although this trail is not in the CFRNP, if it is reopened it will take some of the pressure off the trails in this region. An estimate of how much foot traffic each trail can handle must be determined and an effort made not to exceed it. Some particular authority must manage the CFRNP to supervise maintenance and to keep track of usage.

Forest Management

Since the 1970s, the Department of Agriculture has been managing the watershed and surrounding forests of the CFRNP. Forest rangers used to monitor activities in this area; however, due to cutbacks, the posts for forest rangers have not been filled for some years. There is currently no management plan for this region, although efforts are underway to develop such a plan.

Management Recommendations

When the Central Forest Range becomes a national park, the management arrangements must be clear. Park authorities should consider including watershed management in their responsibilities. Day-to-day management of the region should be placed in the hands of a non-governmental entity. A governing board of management should be established with representatives from various government agencies (such as for water, forests and tourism), the private sector (such as the tour operators), and non-government agencies (such as the National Trust and the Heritage Society).

It is recommended that a user-fee be collected from users of the resources, including hiking tourists, to contribute to the cost of park management. A service charge should be collected from the national water company, representing a resource rent for the water captured by the forest.

Although the very remoteness of the Central Forest Range above 1,000 ft/304.8 m has led to the disappearance of almost all human impacts there, legal protection is necessary to prevent any future new impacts.

Questions for Consideration

1) What types of habitats exist within the Central Forest Range National Park (CFRNP) ecosystem? What are some of the key species that exist in this ecosystem?

2) What types of human activities take place in and around the CFRNP? What impacts might these activities have on the organisms that inhabit the rainforest ecosystems of the CFRNP?

3) Why is the proposed CFRNP a significant ecosystem?

4) What is the significance of the CFRNP to the water supply system of St. Kitts?

5) What are the potential benefits of designating the CFRNP a protected area?

6) What rules should govern the everyday operations of the CFRNP?

7) Who (which stakeholders / user groups) should be involved in deciding the rules about which activities can and cannot take place in the CFRNP?

E.8. Activity 1: Letter to the Editor

Objectives:
Students will be able to describe the biological, cultural, and economic value of tropical rainforests and consider strategies for effective management of such areas.

Methods:
Students practice reviewing research, formulating an opinion, participating in strategic planning, and enhancing their writing skills.

Materials:
- Central Forest Range National Park Case Study
- Pen and paper per student

Time:
1-2 periods (approximately 1.5 hours)

Background:
Letters to the editor are typically short, concisely written opinion pieces submitted to newspaper or magazine editors by its readers. Editors cut content from the bottom up, so the main point to the topic should be outlined at the top of the letter, followed by justification for the main opinion. Letters usually include short sentences and should be no more than a couple of paragraphs long.

The purpose of this activity is for students to review a case study pertaining to tropical forest ecosystems, determine what the relevant management issues and solutions are for the ecosystem, concisely formulate their thoughts, and write a letter to the editor outlining their suggested ideas for better managing the ecosystem.

Procedure:
1) Review *Central Forest Range National Park (CFRNP) Case Study* with students. (This activity will work with any case study)

2) Review how to write a letter to the editor with students. Teachers may wish to review sample letters to the editor taken from local newspapers or magazines. Develop some criteria for what the letter format should contain and how it should be presented, and post them for students to refer to during the activity.

3) Challenge students to write a short letter to the editor (maximum 250 words) explaining why the CFRNP is an important ecosystem, what management issues are important and list some recommended solutions for better managing the ecosystem.

Extensions:
- Have students present or read their letters to the editor to the rest of the class. Ask students to pick 3-5 student letters that they would publish if they were an editor. What are the reasons students chose these letters to publish?

- Have students take on the role of a specific stakeholder group and write a letter to the editor from the perspective of a specific stakeholder.

- Have students write a letter to the editor from the perspective of a species of plant or animal that depends on the tropical forest ecosystem.

Fine furniture made from Blue Mahoe a native tree of Jamaica
Photo supplied by: Rick Searle (EKOS Communications, Inc.)

E.9. Activity 2: Exploring Tropical Forests

Objectives:

Students will be able to identify, describe, and explain the interdependence of a variety of plant and animal species that exist in a specific tropical forest. Students will also be able to identify human economic and cultural uses of that forest. Students will be able to compare the biodiversity and uses of tropical forests around the world.

Methods:

Students practice their research, writing, and presentation skills using a variety of available resources and media. This activity can be completed in groups or on an individual basis.

Materials:

- Student Worksheets
- Pen and paper per student
- Access to library and/or Internet resources with information about tropical rainforests
- Presentation resources (craft supplies, projectors, etc)

Time:

- Research – 1-2 periods (approx 1.5 hours)
- Presentation development – 1-2 periods (approx 1.5 hours)
- Presentation to class – 1-2 periods (approx 1.5 hours)
- Discussion period – one class period (approx 30 minutes)

Note: Students may need to work outside class on this activity to bring it to completion, or more time can be given during class periods to accommodate student needs.

Background:

Tropical forests can be found near the equator in Asia, Australia, Africa, South America, Central America, and on many Pacific Islands. Depending on their location on the globe, each tropical forest is home to unique ecosystems and a variety of different plants and animals.

Tropical rainforests generally share similar climatic conditions, experiencing on average minimal annual rainfalls between 1,750 millimetres and 2,000 millimetres. Average monthly temperatures typically exceed 18 °C. All tropical rainforests play important cultural and economic roles for human populations. For example, over ¼ of modern medicines are derived from plants found in tropical rainforests around the planet.

The purpose of this activity is to provide students with the opportunity to explore, research, compare and contrast, and share information about the tropical forests of the world.

Procedure:

1) Divide students into a minimum of 6 groups. Students should select a continent or geographic region (Asia, Australia, Africa, South America, Central America or Pacific Islands) and determine a forest from are that they wish to research. Teachers may wish to equally divide up geographical areas and assign them to students. Be sure to have at least one group study a specific Caribbean forest.

2) Provide students with instruction on how to use available resource materials, such as the library and Internet, to compile their research on their assigned tropical forest.

3) Have students use and fill out the attached Student Worksheets, to assist in directing their research. Students may wish to divide up the worksheets into sections within their group to speed completion of the activity.

4) Once research has been completed, instruct students on how to work together in their groups to develop a 5-10 minute presentation on their tropical forest. Each student should be prepared to speak for 1-2 minutes on a specific element of his or her tropical forest. Students should determine what the key elements and points of interest are about their tropical forest that they wish to present. Presentations can be oral only, or if resources and time exist, can be elaborated on to include display or multi-media materials.

5) Next, have each group of students present the information they have collected on their tropical forest to the rest of the class. Allow each group a maximum of 10 minutes to present their material.

6) Once each group has presented their tropical rainforest to the class, engage the students in a discussion about the similarities and differences between the tropical forests of the world.

Suggested discussion questions:

- How easy or difficult was it to find information about a tropical forest in your geographic area? Why do you think it was easy or difficult to find information?
- What were some of the main similarities or common elements about the tropical forests that were presented?
- What were some of the main differences about the tropical forests that were presented?
- Which human activities seem to have the greatest influence or impact on the health of ecosystems within tropical forests?
- What types of things can students do to help protect and conserve tropical forests?

Extensions:

Better yet, take the students on a field trip where they would be encouraged to explore a forest for themselves. Let them see how many species of animals they could find. They should also look for animals in the different levels of the food web. Students can identify threats to the forest and examine how the biodiversity can be impacted by the threats.

E.9. Activity 2: Exploring Tropical Forests

Names of Group Members: **Date:**

Tropical forest Name:

Tropical forest Geographic Location:

Continent
Country
Closest major state/county/city

Environmental Characteristics:

Elevation
Climate
Temperature
Description of terrain
Brief description of key forest characteristics

Main Tree and Plant Species: List 3-6 tree or plant species that exist in this tropical forest.

For 3 of the above species describe how other plant or animal species are dependent or interdependent the tree or plant species (i.e. for food or shelter).

Main Animal Species: List 3-6 animal species that exist in this tropical forest.

For 3 of the above species describe how other plant or animal species are dependent or interdependent on the animal species.

Main Human Activities: Identify 2-4 human economic or cultural activities that take place in the tropical forest.

Identify how these human activities are impacting the biodiversity of the tropical forest (positively or negatively).

Natural Impacts: Identify 1-2 natural occurrences that are impacting the tropical forest.

Rainforest Management: Identify any individuals, groups, or organizations that are responsible for monitoring or managing the tropical forest.

Conservation or Degradation: Summarize the overall sustainability of ecosystem health in the tropical forest. What factors are influencing the degradation of the forest? What factors are contributing to the conservation of the tropical forest. *(Try identifying specific stakeholders or user groups and people or organizations involved in degrading and conserving the forest).*

Why is Conserving Biodiversity in this Tropical Forest Important?

E.10. Case Study:
Land of Wood and Water, Deforestation in Jamaica[20]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Jamaica&sll=37.0625,-95.677068&sspn=32.527387,68.90625&ie=UTF8&t=h&z=8

Case Study:
forestry.gov.jm/PDF_files/JA%20Forest%20Cover%20Change.pdf
and
fao.org/DOCREP/ARTICLE/WFC/XII/0530-C3.HTM

Background

The name Jamaica is believed to be derived from the Taino word, Xaymaca, which means 'land of wood and water'. The island is 231 kilometres long with a maximum width of 79 kilometres. When Christopher Columbus landed on the island in 1494, most of it was densely covered with forests, except for scattered clearings occupied by the Tainos. This dense vegetative growth would have protected the soil and supported the continuous surface flow of the island's many rivers and streams.

There are four main types of forests in Jamaica, whose distribution is determined by the rainfall pattern: dry limestone forest on southern lowlands and hills; intermediate limestone forest in the central uplands; wet and very wet limestone forest in the Cockpit Country and John Crow Mountains; and rainforest on the lowlands and mountain areas.

After centuries of improper land use, the island has lost much of its natural vegetation and, as a consequence, is suffering major environmental problems such as flooding, soil erosion, destruction of wildlife and wildlife habitat, and decreased surface flows in streams and rivers.

At present, Jamaica's lowlands have been mostly cleared for agriculture, and overall more than 75% of the original forest has been lost. Hurricane Gilbert played havoc in Jamaica in 1988, with torrential rains and winds. Subsequent extreme flooding and numerous landslides left a toll of death, homelessness, and destruction of much of the country's infrastructure. But blame was not on nature alone. Increasing deforestation in Jamaica's mountains and the resulting soil erosion worsened the impact of the hurricane. Remaining forest is largely secondary in nature and only the mountain forests in the most remote, inaccessible, and steep parts of the island have survived undisturbed.

Many Causes of Deforestation

The country has a sad record of deforestation, much of it due to the fast-growing tourism industry and agriculture expansion — mainly coffee plantations, which are developed high up on mountain slopes. The tourism industry has replaced beaches and forests with newly built hotels and roads, and inappropriate agricultural practices have resulted in accelerated soil erosion that cause downstream sedimentation and flooding.

In recent years, deforestation has led to the deterioration of more than a third of Jamaica's watersheds, drying up streams and rivers and causing cities and towns to suffer from lack of water. The diversity of plant and animal life is also threatened by the destruction of forests, leading to the loss of traditional ways of life, the knowledge about local plants and their medical and other uses.

The impacts of this deforestation have been widespread, but have had major implications in Jamaica's watershed areas. The lack of forest cover has damaged water quantity and quality, increased soil erosion, and increased the siltation of rivers with impacts as far-reaching as the coast. Like a chain reaction, this has caused the degradation of the coral reefs and beaches that surround the island, through soil erosion and the resulting siltation and smothering of coral. These impacts, particularly the damage to coastal beaches, coral reefs, and water quality, have serious implications for Jamaica's tourism industry, a major income earner for the island. Of course, the livelihoods of many rural Jamaicans, including fishermen and farmers, have also been effected.

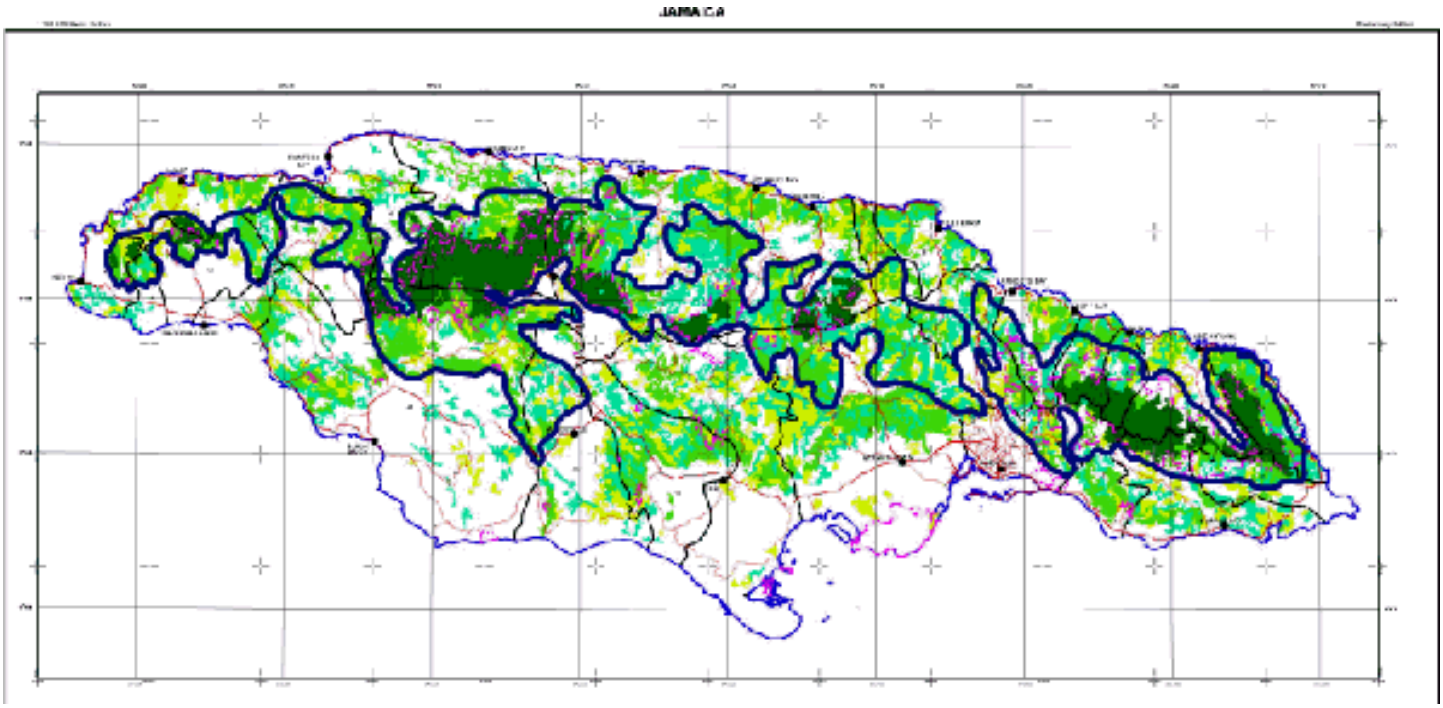
Bauxite mining, the island's second largest foreign exchange earner after tourism, is another major cause of deforestation in Jamaica. This activity destroys large areas of forest because bauxite is extracted by open-cast mining, which requires the complete removal of vegetation and topsoil. Bauxite mining is also an indirect cause of deforestation through the opening of access roads into forests. Once access roads are cut, loggers, coal burners, and yam-stick traders move in, removing the trees in and around the designated mining areas. Mining is thus responsible for extensive deforestation far beyond the mining areas themselves.

Jamaican Forestry Management issues

Agencies responsible for the management of the Jamaican Forest must resolve the demands for forest use and the need for forest conservation through implementation of appropriate sustainable policies and plans. A significant achievement in Jamaica has been the development of the National Forest Management and Conservation (NFMC) Plan by the Forestry Department. There now exists a clearly defined plan that all national stakeholders can use as a guide. The NFMC Plan (Forestry Department, March 2001) outlines the primary constraints to effective management which include public awareness, co-operation and compliance, commitment to enforcement, human resources, and enforcement capability.

The Spinal Forest Project

The Environmental Foundation of Jamaica (EFJ) (efj.org.jm) conceived the Spinal Forest Project in 2003, named for the goal



Proposed Spinal Forest Boundary
Gage, I., and Edwards, E. (2003). Creating a Jamaican spinal forest. Jamaica: FAO 2003 report. Retrieved from: fao.org/DOCREP/ARTICLE/WFC/XII/0530-C3.HTM

of developing a continuous spinal forest along the main mountain ridges that extend along the center of the island. The ridge rises up from the Great Morass in Negril, spanning east from Dolphin Head in Hanover to the John Crow Mountains in Portland and including important areas such as the Cockpit Country, Bull Head Mountain, the Dry Harbour Mountains, and the Blue Mountains. Many of the areas within the spinal forest are ecologically significant, particularly those rich in biodiversity (both plant and animal species), areas with significant water resource protection functions, and areas with ecotourism potential.

The restoration of forest on the island's spine is expected to have significant benefits at both local and international levels. The EFJ is working with local non-governmental Organisations (NGO's), private sector partners, and various government agencies such as the Forestry Department and the National Environment and Planning Agency (NEPA). This multi-stakeholder approach is essential to ensure all stakeholders are involved.

Main stakeholders

- Government: national, regional (parish) and local community levels
- National parks
- Non-governmental organizations, including environmental groups and local community groups
- Industry: bauxite companies, fisheries, logging, local factories, retail stores, etc.
- Charcoal producers
- Farmers: local agricultural cooperatives and range animal associations, and yam-stick harvesters
- Fisheries: local, regional, national, and international fishers and companies
- Tourism industry: resorts; attractions such as Dunn's River Falls; ecotourism operators who do tours in the river valleys and forested regions; diving and snorkeling companies; boating companies; car and bike rental agencies; etc.
- Private landowners
- Schools: primary and secondary
- Community colleges

The Spinal Forest Project has five major project components. They are:
1. Forest Conservation
2. Reforestation
3. Expansion of the Forestry Database
4. Public and Political Awareness Campaigns
5. Training and Research

Forest Conservation

Critically important areas and an established forest reserve were identified, and management and conservation strategies designed to maintain these areas. Several steps were employed:

- identifying and mapping landowners
- social intervention with land owners and surrounding communities
- land surveying
- conducting biophysical surveys to determine the species richness (biodiversity) in the areas
- marking of areas to be conserved
- deployment of wardens

- engagement of the community in supporting forest conservation and sustaining their own livelihoods

Development of forest enterprises is a key element of the project that impacts upon maintaining sustainable livelihoods, as it sets out to identify and develop ventures that will ensure the conservation of the forest by users. A major public and political awareness component accompanied these efforts to ensure public support.

Reforestation

Areas to be reforested were identified and **reforestation** plans developed. Areas included bauxite-mined lands, private lands, agricultural lands through agro-forestry interventions, scrublands, and plots in key areas that served as demonstration plots. Ensuring a consistent seedling supply is an important precursor to reforestation activities. A nursery was developed with the capabilities to produce 1 million seedlings required for planting 2000 hectares per year. A `Buy-A-Tree' programme was implemented to obtain local and international funding support. Funds are to be used for continued reforestation activities.

Expansion of the Forestry Database

The Spinal Forest project involved research on biological, physical and socio-ecological parameters. All data collected during the project was incorporated in a comprehensive forestry database.

Public and Political Awareness Campaign

The success of forest conservation and reforestation depends on a high level of public and political support. Land issues are often contentious and the solution to the competition for the forestry lands is multidimensional. A specific campaign to develop awareness and then active support was developed and implemented in conjunction with the reforestation and conservation activities. Participation of all stakeholders is very important to ensure all voices are heard and plans are developed collaboratively.

Training and Research

Training was an essential component of the Spinal Forest Project. The research is aimed at ensuring that there will be a corps of trained forestry managers, scientists, and wardens who form a strong human resource for continued forest development. The research also produced a body of information to guide future reforestation and conservation efforts, including the propagation of native and endemic tree species.

Project Impacts Expected

- Increased biodiversity (habitat for important flora and fauna)
- Improved watershed conditions
- Increased water availability
- Improved water quality
- Improved land productivity
- Reduction in siltation of rivers and reservoirs
- Reduced marine and coastal pollution
- Reduced flooding (Reduced loss of life, property, roads, crops, etc.)
- Increase in forest products including lumber and plants
- New forest ventures including nature trails, eco-tours, mountain lodges and parks
- Increased tourism earnings through targeting of the domestic and international nature tourism market
- Income through carbon sequestration grants

The Dunn's River Watershed Management Project: A Pilot Trial

The EFJ began the Spinal Forest project with a 2-year pilot project on the popular tourist area of Dunn's River. The Dunn's River Watershed Management Project (DRWM) goals were to:

1. Assist with the reforestation of the watershed by replanting an area of 230 hectares on the Dunn's River watershed.

2. Remove solid waste that was deposited on the watershed.

3. Educate the surrounding communities in proper environmental management.

The primary objective of the programme is the reforestation of the 230 hectares. Much of the reforestation occurred during two predominant planting seasons (April - May and September - November). Various factors including administrative issues, seedling mortality, and cattle consumption of seedlings provided obstacles in the projects' first year. Within a year or two, these factors were taken into account in the project. The education programme has targeted mainly schools and the wider community who depend on and live in the watershed. The project discovered that illegal dumping of garbage by contractors was the primary source of the solid waste cleared. A community aware of the negative impacts of dumping on the watershed was instrumental in minimizing continued dumping. This project has therefore provided some exposure to the myriad of issues that the larger Spinal Forest Project may face.

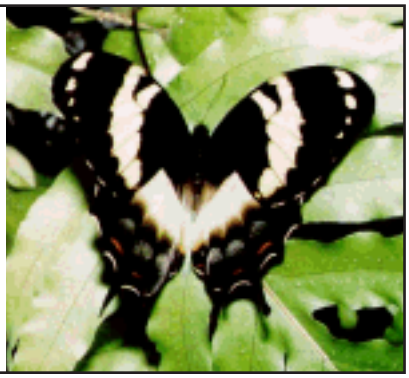
Results

- Demonstration forestry plots in visible areas as an information tool
- 200 hectares of direct reforestation
- Production of 2 million seedlings as part of the private planting venture
- Increased private forestry
- Improved nursery operations for supply of over 500,000 seedlings annually
- Liaison with bauxite companies for the reforestation of mined-out lands
- National and international awareness of the Spinal Forest Project
- Developed `Buy-A-Tree' Programme as a fundraising mechanism
- Incentives plan for forest enterprises

Soil Erosion - St. Andrew, Cinchona

Effects of Flood Damage from
Tropical Storm Lily (Sep 30 - Oct 1 2002)

The Giant Swallowtail butterfly that is only found in Jamaica is one species that is highly dependent on the presence of the forest in high altitude areas for its survival. Removal of its habitat impacts its distribution and abundance.



Giant Swallowtail

The Jamaican iguana is endemic to Jamaica and is reported as only inhabiting the Hellshire Hills area. Increased forest removal for coal, farming, etc has impacted the iguana population. Dogs and mongoose that now have increased access to iguana populations prey upon them and therefore significantly reduce their population.

Jamaican Iguana

Gage, I., and Edwards, E. (2003). Creating a Jamaican spinal forest. Jamaica: FAO 2003 report. Retrieved from: fao.org/DOCREP/ARTICLE/WFC/XII/0530-C3.HTM

Community members benefit not only from the natural resource of a restored or conserved forest. They also obtain income as stakeholders hired for assisting in implementation and management. Developing stands of forest for obtaining funds from carbon sequestration grants to combat climate change speaks to the larger international cooperation integral to the development process. New areas for conservation, improved forests, current scientific data, new research results to improve forestry, political and public awareness, and public buy-in will be beneficial not only to Jamaica but to the region as a whole.

Questions

1. What are the main causes of deforestation in Jamaica?
2. What are the impacts of deforestation? Why is it such a critical issue for the country?
3. The Spinal Forest Project is a long term project to reforest and conserve major portions of Jamaica's forested lands. Who are the main stakeholders in the study?
4. Do the five major project components adequately address all the stakeholders involved? Why / why not?
5. Do the project components support the list of projected impacts? Why / why not?
6. The Dunn's River project is a smaller pilot project that is part of the Spinal Forest Project. Discuss its results and level of success. What would you do differently to increase the anticipated impacts of the project as part of the larger Spinal Forest Project?
7. How would you go about getting stakeholders involved in a reforestation project?
8. What conservation measures would you suggest to protect biodiversity?
9. Can you suggest some projects that help locals make their living while supporting forest sustainability?

E.11. Activity 3: Take Action to Conserve Tropical Forests

Objective:

In this activity, students will investigate both local and imported products that come from tropical forests, and take action by writing letters to manufacturers requesting conservation information.

Materials:

Books and reference sites on forest products

Time:

2 class periods and research time

Procedure:

1. Many of the products we use originated in tropical forests. Food, fruit, palm oils, wood and paper products, and building materials are some examples. Working in small groups, have students investigate the products that come from Caribbean forests and other tropical forests world wide.

2. Each group could be given a type of product to research: i.e.

- food, fruits and nuts
- oils and chemicals
- wood
- paper
- animal products
- building materials, etc

(see *A.8. Activity 4: A Wealth from Trees,* in Section 1 for more examples)

3. Give students some time to research their forest products group, and develop a list of items. Share the lists with the class.

4. Have each group make a list of things they have eaten or products they have used in the last month that have come from tropical forests.

5. Now have each student choose a product, and write a letter to the manufacturer or distributor of the product. Website searches should help identify manufacturers addresses and contact information. Student letters should present their research and ask the manufacturers about their commitment to conservation of tropical forests. Have students ask manufacturers to describe specific programs or procedures they use to help conserve rainforests and harvest their products sustainably.

Large areas of tropical forest are often cleared for agriculture
Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

E.12. Case Study: Regenerating the Dominican Dry Forest[21]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Dominican+republic&sll=37.0625,-95.677068&sspn=32.527387,68.90625&ie=UTF8&t=h&z=7

Case Study:
srdis.ciesin.org/cases/dominicanrepublic-003.html

Campesinos in Charge of the Management & Regeneration of the Dominican Dry Forest: A Project of Dominican-German Co-operation

Background

Experience has shown that sustainable management of natural resources can succeed only with the support of the local population, who must be convinced of its methods, as well as receive direct and measurable benefits from it. Despite this, national governments, in co-operation with international technical and financial aid organizations, often attempt to execute programs such as conservation and management of soils, water, and vegetation through institutions which are neither prepared nor equipped to promote intensive participation of the target population. The result is that those who are expected to change management procedures never become fully involved in the activities designed to do this, nor do they always see the benefit such changes bring about. The key to success is early involvement and active participation of the target population at all levels.

History of the Dry Forest Project

For the first six years of its existence, the Dry Forest Project operated along similar lines — that is, with limited participation of the target population. Created in 1987 and located in the southwest of the Dominican Republic, the project was largely executed by a regional planning institute, INDESUR, in cooperation with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). During its initial phase, a forestry inventory was elaborated, groups of campesinos (local forest dwellers) became organized, and direct-marketing by these groups was promoted. All planning and decision-making processes, however, were made by a group of technicians comprised of members of INDESUR and the GTZ, usually including only a token representative of the campesino groups. Operating within a culture saturated by paternalism and machismo and a commercial climate dominated by middlemen (those buying, transporting and reselling forest products), large landowners, and the national forest authority (administrated by the military), the results obtained in favor of the campesino were rather meager.

The need for new direction as well as swifter and more concrete action from the ground-level up was obvious, but neither INDESUR nor the local NGOs previously involved with the project were prepared or willing to change tactics. Therefore, the GTZ project-team took the initiative and began to involve the campesino groups more intensively in a process of participative planning and decision-making, transferring the execution of the majority of activities into their hands. Clear objectives, which were economically meaningful to and understood by the campesinos, were established, and strategies for obtaining those objectives were discussed and mapped out slowly, step by step, over a period of time. The project team quickly changed its role from developing planning procedures and executing and evaluating activities to coaching, the campesinos as they gradually took over these activities.

Living Conditions in the Dry Forest

The communities promoted by the project were situated in an environment which, for the last four decades, had been exploited by people from other regions, leaving the local campesinos with very limited alternatives. Historically, they could either contribute labor for the timber industry or produce charcoal. As a result, 500,000 hectares of forest was gradually degraded into the secondary vegetation known as the dry forest. It consisted mainly of small thorny trees and shrubs, which were of little commercial value, as well as cactus. The entire region was in danger of desertification. The timber industry no longer exists. Agriculture in the dry forest was no longer viable without irrigation, and water had become increasingly scarce. As a result, the campesinos survived on charcoal-burning, goat-keeping, and day-laboring at the larger, irrigated farms in the valleys. Charcoal-burning was quite strenuous and unappealing labor which created very little personal income. It was considered a way of making a living only if there were no better alternatives.

The campesinos who lived in the dry forest were amongst the poorest members of Dominican society, almost marginalized, their living conditions unknown to the majority of the public. Ignorant of the proper procedures for the marketing of their products, they became completely dependent on traditional middlemen who organized groups of campesinos for charcoal burning. The campesinos received food in advance for their labor, but the majority of the profit from the sale of charcoal remained in the hands of the middlemen.

New Objectives for the Project & Campesinos

To implement the first step of sustainable management, the dry forest required the initial extraction of the dry wood, conserving for some years all the living trees in the area. This procedure entailed more labor input for every sack of charcoal produced. Somehow more income for the campesino families needed to be generated as a compensation for the extra labor and as an incentive to apply a new and unproven procedure. It was vital that the communities be involved in any discussions and decisions taken to achieve the overall establishment of the methods of sustainable

management. The following four objectives were a result of those initial discussions:

1. The campesinos of the nine communities collaborating with the project established a federation in order to defend their interests more effectively. Their associations at village level and this Federation of Producers in the Dry Forest (FEPROBOSUR) were to be organized as economically independent self-help groups.

2. Since the campesinos, due to lack of demand, could not produce more charcoal nor raise the price for their product on a highly competitive market, the only possible way to increase income was to sell directly to the distributors on the main market in Santo Domingo, bypassing the middlemen. The federation had to be in charge of the entire marketing process.

3. The campesinos came to understand that sustainable management was necessary in order to halt encroaching desertification and thereby to ensure a living for themselves and a future for their children in the dry forest. A very simple agreement on management practices comprised of only eight basic rules was established.

4. Living and working primarily on common- or state-owned land, the campesinos had no formal rights to use or to protect trees from cutting by people from other areas. To assure them the economic benefits of their efforts to practice sustainable management, title deeds had to be obtained for the village associations.

The New Procedures of Participation

During the process of change, it was made clear that the initiative of the campesinos was paramount; the project team would only assist. The team explained that it would not work for the campesinos, but with them in a collaborative relationship. There would be no gifts. Rather, the team would share time, expertise and guidance, as well as assistance in the formation of connections to official institutions, the mass media and NGOs. Financial inputs would be available only to support specific activities for the benefit of the self-help groups.

Unlike earlier attempts of other institutions to improve the situation of the campesinos in the dry forest, available potentials in and around the villages were focused upon rather than the many problems and deficiencies present.

Planning was carried out in close and constant cooperation with the campesinos at village level. Campesino representatives began to meet together in the newly acquired offices of the federation. Planning procedures were simple and the pace was set by the campesinos themselves. Many campesinos do not read or write, so most agreements were made orally with very little being documented on paper. It was agreed that there would be a continuous process of planning, executing, and evaluation of all the steps necessary to obtain the established objectives.

Priorities were established according to the needs identified by those living in the villages. Economic improvement was, by far, the highest priority. Therefore, the first activity planned and executed by the federation was the organization of the transport of charcoal to the capital. Immediately a conflict arose with the middlemen who were, for the first time, forced to negotiate with campesinos, whom they had never considered as partners, let alone as competitors. The campesinos now obtained a far better share of the total profit, converting the middlemen into the owners of lorries under contract. After this first important success, which seemed almost unbelievable to the campesinos, their enthusiasm began to grow along with their young organization.

Results

After five years of cooperation between the project team and FEPROBOSUR, the first objectives were close to being fully realized.

1. Government institutions and NGOs recognized FEPROBOSUR as an important representative of the campesinos of the Dominican southwest. The federation maintained its economic independence by charging a fee for every product of the dry forest which was transported to the capital. It had its own office and staff, plus communication and transportation facilities, which, although obtained through various donors, were maintained by the federation. The federation was comprised of more than 80 associations from 40 villages. One third of its approximately 2,700 members were women, organized into their own groups as well as participating within the mixed groups.

2. In 1997, FEPROBOSUR sold almost U.S.$1 million worth of products of the dry forest. Charcoal remained an important product for the campesinos, but others —such as railway sleepers for the national sugar industry, fence posts, and wood for use in construction and agriculture — accounted for higher income on new markets. Marketing was the most important activity of the federation and the main reason for its existence. The middlemen, although reduced to the less lucrative role of carriers, had accepted their position and worked well with the campesinos. Meanwhile, FEPROBOSUR had gained a regional monopoly on the wood trade as well as the respect of the national forest authority, with whom it had developed are relationship of close co-operation.

3. The dry forest has responded well to the simple management rules established and executed by the campesinos. Between 1992 and 1996, the availability of wood in the dry forest doubled. The increase in height, density, and shading would be obvious to the casual observer, but it had also been measured by periodic checks of marked observation plots and validated by comparing satellite photos. The project team and the federation worked on detailed management plans for every community.

4. In co-operation with the Dominican Land Reform Institute (IAD), provisional title deeds were presented to most village self-help groups. They amounted to 130,000 hectares, while titles for another 50, 000 ha. were being prepared. The IAD was willing not only to change these into permanent titles but also to provide the villages with infrastructure, such as water and roads, which settlements under Dominican land reform usually receive.

Conclusion

It has to be pointed out that none of these results were obtained easily. Campesinos did not all decide to co-operate at once, nor did the opponents of the project, such as middlemen and large landowners, give in simply for the sake of public welfare. Also, while most government institutions acknowledged the success of the project and its particular way of working with campesinos, they did not actively support FEPROBOSUR nor did they take advantage of the experience gained by applying these methods in other regions of the country. Nevertheless, due to the struggle that was necessary to obtain these results, the members of FEPROBOSUR, and especially of its managing board, gained experience, self-esteem, and pride in their accomplishments, while the lives of campesinos living in the dry forest improved measurably. Their success was the best guarantee for the sustainability of the project.

Questions

1) Why is the dry forest an important ecosystem?

2) Who are the primary beneficiaries (i.e. the main user groups) of the economic activities which occur in and around the Dry Forest, and what activities do they depend on?

3) This case study focuses on the campesinos who live in the Dry Forest and the challenges they face in surviving increasing tourism and development while preserving their culture, values and lifestyles.
Before the planning process was begun, what activities did the campesinos carry out for their survival and to generate income? What exploitive activities went on that damaged the areas' biodiversity as well as the campesinos' livelihood?

4) Charcoal production is a common yet inefficient method of producing fuel.
List some reasons why charcoal production is seen as an ecologically destructive practice, and how it might impact the areas' biodiversity.

5) State the changes that the projects' planning process brought to the area – both to the local communities and to the region. Why do you think it was successful?

6) What impact would the continued degradation of the Dry Forest have on the organisms which inhabit the forests?

7) What impact would the continued degradation of the region have on the various groups of individuals who depend on the area for a livelihood, particularly the campesinos?

8) Imagine that you were given the responsibility to spearhead a programme of education aimed at sensitizing individuals about issues relating to the Dry Forest region.

- Which group of individuals would you target and why?
- Identify and explain the issues that you would highlight?
- What strategies would you use in the education/sensitization process?

Photo supplied by: Ministry of Agriculture, Lands, Forestry and Fisheries (St. Lucia)

E.13. Case Study: Alexander Skutch Biological Corridor, Costa Rica[22]

Google Earth Map:
maps.google.com/maps?f=q&source=s_q&hl=en&geocode=&q=Costa+Rica&sll=37.0625,-95.677068&sspn=32.527387,68.90625&ie=UTF8&t=h&z=7

Case Study:
yorku.ca/lasnubes/howard%5B1%5D.pdf

Biodiversity conservation and rural sustainability: a case study of the Alexander Skutch Biological Corridor in Southern Costa Rica

Background

National parks and other protected areas are inadequate mechanisms to ensure the conservation of the world's biodiversity, particularly in tropical environments where most of the biological wealth of the planet is concentrated. Deforestation has not only taken a heavy toll on tropical forests and their respective biotas; forest fragmentation into terrestrial islands has also been a powerful force for the depletion of biological diversity. Creative alternatives are needed to ensure the long-term survival of biodiversity and to enhance the achievement of sustainable development at the local community level. Three such alternatives are the creation of biological corridors, green consumerism, and financial support for environmental services.

The Los Cusingos-Las Nubes Biological Corridor in southern Costa Rica illustrates each of these three approaches to biodiversity protection and rural sustainability. This corridor is the focus of a joint research and development project of the Tropical Science Center (TSC) of Costa Rica and the Faculty of Environmental Studies (FES) of York University in Toronto. This partnership also involves the regional farmers' cooperative (COOPEAGRI, R.L.) of southern Costa Rica and Timothy's World Coffee, a specialty coffee corporation headquartered in Toronto.

Environmental description of the corridor region

Las Nubes, designated as a private biological reserve, is a montane rainforest at approximately 1200 to 1500 metres above sea level on the Rio Pefias Blancas on the Pacific slope of the Talamanca mountain range in southern Costa Rica. To the northeast is Chirripo National Park, which continues into La Amistad, an international biosphere reserve that Costa Rica shares with Panama. Las Nubes thus forms part of one of the largest contiguous rainforest ecosystems in Central America.

The Rio Pefias Blancas is the main river flowing through Las Nubes, with its crystal-clear water cascading over rapids and waterfalls. Several deep gorges dissect Las Nubes, each presumably characterized by endemic species. Downstream is Los Cusingos, a lowland wet forest at approximately 700 metres in the middle portion of the river basin. This is the former homestead of the world-renowned ornithologist Dr. Alexander Skutch. The Tropical Science Center now owns and protects Los Cusingos as a neotropical bird sanctuary.

The Central American Commission on Environment and Development officially recognized this watershed as a portion of the Mesoamerican Biological Corridor that extends from Panama through Mexico. The Los Cusingos-Las Nubes Corridor is particularly significant in ecological terms because it connects forest fragments from the highest elevations to those nearer the Pacific coast, whereas most of the Mesoamerican Corridor connects fragments primarily at higher elevations. The significance of the highland-lowland connection is that the dryer lowlands forests are the most threatened ecosystems in Central America.

The forests of Costa Rica are rich in biological diversity
SoGoNow.com. (2007). Finding the real gold in Costa Rica. Retrieved from: sogonow.com/archives/2007/09/costa_rica.php

Development of the biological corridor

The corridor consists of forest patches of various sizes, ages, and species composition; agricultural fields (primarily coffee and sugarcane); pastures; and degraded lands. There are several critical elements of the plan for the development of the corridor, the protection of its biological resources, and the sustainable development of its rural communities:

(1) Transitioning from sun-grown coffee to more ecologically sound production as a means of stabilizing hydrological resources, enriching the soil, reducing soil erosion, and increasing biodiversity. The incentive for farmers to adopt a transition strategy is provided through a local co-operative of growers who sell certified sustainable coffee to Timothy's World Coffee, which is then marketed throughout Canada.

(2) Creation of a model shade and organic coffee farm, "El Grano Tico," for demonstration of certifiably sustainable production practices. This is jointly financed by COOPEAGRI and the Fisher Fund for Neotropical Research and Conservation. Volunteer students from York University, working in collaboration with local coffee farmers, built the first nursery for trees identified as the most appropriate species for shade coffee, economic productivity, and ecological sustainability.

(3) Restoration of riverine forest to act as a hydrological corridor as well as a biological corridor.

(4) Transitioning from degraded pasture lands to reforested land and agroforestry systems. The tree nurseries will ultimately provide the plants for reforestation of degraded pastures. However, considerable outreach and extension must be done to involve local cattle ranchers to participate in restoration efforts.

(5) Transitioning to improved pastures, including the use of improved pasture grasses and partial tree cover.

(6) Reforestation of degraded (non-pasture) lands, largely for regeneration of water resources and for erosion control. These lands consist of abandoned subsistence farms, sugar cane plantations, and coffee-eucalyptus plantations.

(7) Future land acquisition through direct purchase of forest lands and other critical ecosystems within the corridor. This is an attractive component of the strategic development plan jointly being implemented by TSC and FES. York University owns the Las Nubes Rainforest in the upper reaches of the watershed, and Tropical Science Center owns the Los Cusingos Sanctuary in the lower portion. A program to purchase additional land would strengthen the long-range sustainability of the biological borridor by removing certain lands from potential threat.

(8) Municipal provision of public lands to NGOs for forest protection and regeneration. One such example is the Parque Natural on the lower Rio Pefias Blancas that is leased to TSC and managed by a local community group, COCOFORES, for restoration and environmental education activities.

The Quetzal depends on healthy forest ecosystems in Costa Rica
Burns Business Strategies. (2007). San Jose, Costa Rica.
Retrieved from: burnsbridges.com/?cat=11

(9) Participation of local community groups in small business activities. A women's co-operative at Reserva San Luis in the Monteverde Biological Corridor, for example, is making bamboo furniture and paper products from bamboo wastes. A similar co-operative could be established in the Los Cusingos-Las Nubes Corridor for the manufacture of paper products from the wastes of coffee, banana, bamboo and sugar cane production. Organic fertilizers for coffee fields and home gardens could also be made from these waste products.

(10) The construction of a community environmental center (with library, laboratory and computer facilities) will serve as the focal point for joint research projects and for outreach and training activities.

Green consumerism

There have been numerous attempts to market ecologically certified products from the tropics, such as timber, coffee, cacao, tea and others[23]. The consensus, however, is that the pressures of commercial logging and deforestation for agriculture and pastures are of such a scale that marketing sustainable timber and agricultural products cannot prevent the loss of biodiversity on a large scale.

Nevertheless, the opportunity remains to capitalize on green products to protect local and regional biodiversity. In fact, regional landscape conservation — based on a mix of protected

Viewing monkeys in their natural habitat is a popular eco-tourism attraction in Costa Rica
Travelguidecr.com (2008). Costa Rica photos and videos. Retrieved from: travelguidecr.com/2008/02/costa-rica-monkeys.htm

areas, buffer zones, sustainable forestry and agriculture, and international marketing — may offer the best hope for protection of biodiversity in some tropical areas, including southern Costa Rica. Furthermore, the quality of the agro-ecological matrix in a tropical montane landscape is an important determinant of the maintenance of biodiversity, quite apart from the capacity of the landscape to produce certifiably green products.

Much of the coffee produced within the Los Cusingos-Las Nubes Corridor is technified sun-grown coffee that is produced with little to no shade cover, a high density of coffee plants, and significant inputs of agricultural chemicals (fertilizers, pesticides, herbicides, and fungicides). Other coffee farms have varying amounts of shade cover provided by a small number of tree species, and a few follow traditional shade-grown coffee production techniques.

A major objective of the research and development activities within the Los Cusingos-Las Nubes Corridor is to convert sun-grown coffee to more traditional forms of shade-grown organic production. The benefits from traditional production include erosion control, particularly on slope land susceptible to accelerated erosion; greater soil moisture retention; enriched soil fertility and improved soil structure through organic farming practices; and increased biodiversity, particularly of resident forest birds and neotropical migrants[24]. An increase in the diversity and abundance of surface-dwelling beetles in more traditional forms of production has also been observed[25]. The species of ground-foraging ants was significantly higher in a landscape matrix of forest fragments and shade grown coffee than in one with forest fragments and technified coffee farms[26].

In spite of the natural values of shade-grown, organic coffee, there has been a trend among many Latin American producers toward the technification of coffee production based on sun-tolerant varieties, largely because of higher yields[27]. However, the world coffee market is saturated to the extent that many small producers are abandoning their coffee farms for other means of gaining a livelihood. Even larger producers are now leaving coffee unharvested because the cost of production and marketing exceeds the potential profit.

Small producers are better positioned to survive the saturated market by producing high quality, shade-grown organic coffee for the boutique or specialty coffee market in Europe and North America. The small farmers in the corridor region of southern Costa Rica began to invest in the conservation practices associated with shade grown organic coffee, once they were guaranteed a fixed price for their product that will cover their investment and provide a wider profit margin.

The York University-Tropical Science Center project in the corridor therefore has two thrusts: one is to aid the local farmer to convert to ecologically sound coffee production that can be certified as sustainable; and the second is to secure a portion of the international market for the product.

A partnership between York University and Timothy's World Coffee provides the financial guarantee. The project supports the conversion from technified coffee to shade-grown organic, and farmers are guaranteed a price above current fair trade price for the sale of Las Nubes Sustainable Coffee throughout Canada. The remaining benefits are funneled into local community sustainability and financing additional research and program activities.

Such a program is not likely to solve the problems of the loss of tropical biodiversity except at the local level. However, ecological production and green consumerism, together with other forms of alternative conservation practice and financing, will contribute toward saving tropical biota at the regional level. Furthermore, the successful marketing of green products yields other societal benefits such as forest protection, hydrological stabilization, and pollution reduction.

Financial incentives for conservation

Government payments to private landowners for the natural environmental services provided by forested ecosystems are a significant incentive for conservation. These services include carbon storage, erosion control, soil fertility, maintenance of water quality and quantity, and protection of biodiversity.

Costa Rica has been a leader in developing such conservation grants. Administered by the environment ministry's National Fund for Forestry Financing (FONOFIFO), this is becoming an increasingly important mechanism for protecting forest land in Costa Rica. The Tropical Science Center, through its agreement to protect York University's Las Nubes Rainforest, receives an annual government payment from this program.

Another objective of the project is to enlist a larger number of landowners within the corridor to participate. Considerably less success is anticipated from this effort since the maintenance of land under forest cover is now more profitable than conversion to coffee and other agricultural crops or pastures.

A bold new approach initiated by Conservation International (CI), investment in conservation concessions, is similar to the mechanism for the payment for environmental services. According to CI, conservation concessions provide a powerful way to expand the green market from its present dependence of products to the broader notion of green services-the opportunity to purchase biodiversity preservation directly[28].

Rather than leasing forested land in the tropics to logging and mining companies, governments and landowners lease land to conservationists at competitive prices. Contrary to popular opinion, conservation organizations can compete effectively with corporate users because of the relatively low costs. This system of conservation concessions contributes to biodiversity protection and sustainable development in several ways. As conceived by Hardner and Rice[29] the New Green Market has the following characteristics:

- It enables tropical countries to capitalize on their biological wealth and reduces their dependency on more volatile markets for timber and cash crops.
- It provides hard currency that pay government taxes and fees and that can be invested in part in local communities and social programs.
- It provides for the immediate protection of biodiversity of the leased forested land. It offers an investment opportunity for corporations wishing to promote a "greener" image.
- It is a potential conservation mechanism in areas where the establishment of national parks and other protected areas is problematical and/or more costly. It reduces risk by establishing ongoing economic incentives for continuing.
- Co-operation not susceptible to volatility and unpredictability.

The value of the biological corridor as a model

The Alexander Skutch Biological Corridor offers a possible model for the protection of tropical biodiversity within a framework of regional landscape conservation and rural sustainable development. It also represents a unique way to finance research and conservation efforts through land donation, private philanthropy, institutional collaboration, direct Costa Rican Government support through its payment for environmental services program, and indirect Canadian government support (in the form of research grants).

In summary, the objectives of this model are being achieved through the following activities:

- establish collaborative research and institutional capacity
- building private sector/university/cooperative partnership
- marketing of specialty Las Nubes Sustainable Coffee by a Canadian corporation
- reinvestment of profits from green products into research, improved farm efficiency, conservation practices, and in social services in local farm communities
- participation of local communities in landscape decision-making and small business
- promotion of a high quality agro-ecological matrix of mature forest fragments and productive sustainable farming systems which mimic natural systems

The Faculty of Environmental Studies established The Fisher Fund for Neotropical Conservation to support joint research and conservation activities with the Tropical Science Center within the biological corridor encompassing the Las Nubes Biological Reserve and Los Cusingos Neotropical Bird Sanctuary.
Both FES and TSC are committed to ecological protection and sustainable development through resource and information sharing; student and faculty research; and environmental education, local community involvement, and institutional capacity building.

The success of the overall research and development program demonstrates the value of partnership in achieving conservation goals. It also illustrates a different approach to philanthropy and conservation in tropical environments that are so threatened by unwise economic development projects. It goes beyond the conventional way of thinking of conservation as consisting solely of national parks and protected areas; explores new ways of problem-solving and international cooperation; encourages corporate social responsibility; and transforms traditional university thinking about social and environmental responsibilities.

Questions for Consideration

1. What are some of the environmental impacts which prompted the creation of the biological corridor?

2. Technified and shade-grown coffee are described in the case study. Explain the differences between the two, and the disadvantages and advantages for biodiversity.

3. What are the positive and negative ecological impacts of establishing the corridor?

4. Three management alternatives are discussed in the case study: the creation of biological corridors, green consumerism, and financial support for environmental services. How has the use of these alternatives been successful? How have they not been successful?

5. There were several important and unique partnerships that led to the creation of the corridor and the changes in coffee production. State the partnerships and explain why they were so important to the success of the project.

6. Imagine that you are responsible for improving the functioning of the biological corridor as a coffee producing region that supports biodiversity:

- What are the key issues that need to be addressed?
- Who are the key stakeholders that need to be involved and how would you go about getting them involved?
- What would some economic incentives be that could support the project (e.g. coffee, tourism, bird watching, others?)

E.14. Activity 4: Biodiversity Story Time

Objective:

Students will write a children's story, that describes an animal's life and experiences as they imagine them to be influenced by specific events that are described in a case study.

Procedure:

Have students review one of the case studies from this section. A good choice is the Costa Rica Biological Corridor case study, but any of the others will work as well.

Student Worksheet	Student Name
Read through the case study and choose an animal that is local to the region described, and has been affected by the activities and events in the case study.	
The objective of this activity is to write a story for children about this animal species. Go to the children's section of the library and look at picture books to get ideas. Try and get inside the head of the animal you have chosen, and describe its home, family, and daily routine – what it eats and does each day.	
Using the events of the case study, describe what happened from the animal's perspective – what it noticed about its home and the events that occurred. Did life get easier? More difficult? What happened?	
Keep audience and purpose in mind as you write: at what age group is your story aimed? What is the main point or feeling you want to convey about this animal?	
From what point of view is the story written? (i.e., who is the narrator?) How will you use setting? How will you develop the theme, the plot, and the characters? How will you use external and internal conflict? How will you show rising action? What is the story's climax?	

E.15. Activity 5: Case Comparisons

Method:

Students will work in pairs to review and compare two case studies and assess the strategies used to solve the issues described.

Case Studies:

Alexander Skutch Biological Corridor, Costa Rica and *Regenerating the Dominican Dry Forest*.

Procedure:

Work with a partner to review and compare the two case studies – both of which deal with involving local people in the management of natural areas.

1. Make sure you have a copy of each of the case studies to refer to. Read both case studies through carefully, and review the similarities between the two cases.

Divide a large piece of flipchart paper into two sections, and label each section with the name of the case study. Design the layout of your chart however you wish, but include the following five categories:

Key Issues: What are the main problems described in each case study?

Economy: How do the local people make their living in both situations? What has changed for them since the projects started?

Biodiversity: List the threats to each regions' biodiversity (the Biological Corridor and the Dry Forest).

Solutions: What were some of the strategies tried in solving the problems of each case study?

Future Steps: What are some ideas for future activities or plans to improve the case study situations for both the environment and the local people?

Answer the above questions in note form by filling in the appropriate sections on the chart paper.

2. As stated in the introduction to the dry forest case study, *"Experience has shown that sustainable management of natural resources can succeed only with the support of the local population*."

Describe how the planning strategies used in each project tried to work with this theory. Which project do you believe succeeded better in doing this? Why?

3. With your partner, discuss and list ways that the results of each of the case study results could have been improved.

4. Which case study focused more on preserving biodiversity and why? What would you do differently to support biodiversity in each of the 2 regions?

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Table of Contents

V/ Appendix I: Teachers Tips & Strategies

This section of the guide contains some background information about the benefits and challenges of taking students outdoors. Teacher tip sheets cover planning logistics and help teachers develop a conservation ethic with their students. Several hands-on, sensory awareness activities help increase our ability to observe and be present in nature, emphasize getting to know local species and their habitats, and inspire local action and stewardship.

Discover Backyard Biodiversity: Educational Benefits of the Outdoor Classroom

Stepping outdoors opens up a huge array of teaching and learning opportunities, and generates excitement and enthusiasm in students of all ages. Direct experiences with the biodiversity in our own backyards help learners to make meaning for themselves, and develop a felt connection to the natural world. Providing direct opportunities to observe local plants and animals helps students develop an understanding of relationships and processes in nature, and the importance of biodiversity. Hands-on, experience-based learning engages the body and brain in kinesthetic, discovery-based activities, through awakening our senses to smells, textures, sounds and colours. Also, learning outdoors is fun! For many, field trips and outdoor learning experiences are the most memorable part of a school year. However, the barriers to taking students outside the classroom walls are considerable. We asked experienced educators for their ideas and strategies, and share some of them below.

Beating the Barriers to Going Outside: Challenges and Solutions from Teacher Experts

Over-full teaching schedules, more and more prescribed learning outcomes to meet, bigger class sizes and reduced funding for field trips are some of the challenges that teachers face when taking students outdoors. Many teachers contributed some excellent ideas and tips for overcoming the challenges of getting students outside while providing memorable and valuable learning experiences.

Stay Close to Home / School

Many worthwhile activities can be done right outside the school. Start small - head outside and do one or two sensory awareness activities in the schoolyard. This will get both you and your students used to being outdoors and learning how to learn together outside. Do some sensory wakeup activities, then include outdoor silent reading, journaling, observation, and art activities.

Beating the Dreaded Recess Syndrome

Loss of control is an issue for most teachers when pondering outdoor activities. Students are not accustomed to be taken outside for any reason other than to "play" at recess - hence the term "recess syndrome" for the boundless energy and enthusiasm they often display. This energy can be overwhelming to a teacher and not productive for learning, leading to a less than successful outing that teachers are loathe to repeat. Most of us have experienced formalized learning as essentially an indoor experience, sitting at a desk and using books, pencils and paper. See the following tips for group management.

"Expertise" Not Necessary

Many teachers feel insecure about their natural history knowledge of the plants and animals around us. However, you don't need to be an "expert"! Don't let a lack of knowledge intimidate you – it is the exploration and discovery that is important in outdoor activities. Many educators encourage students to make up their own names for organisms they discover, based on their characteristics: after all, that's what the scientists do!

Teacher Tip Sheets

Teacher Tip Sheet 1. Outdoor Group Management Tips

1. Before You Go: Planning, Preparation and Practice

Since most of us have not had opportunities to experience outdoor education, it's important to teach and practice skills and behaviours with students. Practice behaviours indoors so everyone knows what to expect. Ask students for suggestions for ground rules and agree on them as a group. Use a whistle, horn or other audible signal to gather the group together, and let them know it's time to look and listen when they hear it. While doing tasks indoors, practice the group behaviours such as responding to the whistle, ensuring everyone can see you, and forming a circle to discuss activities.

2. Set the stage

The day before, explain where you'll be going and what you'll be doing. Talk together about what to wear: good footwear (no sandals or high heels) and a wind / waterproof jacket and/ or sun protection are very important.

Once outside, set clear physical boundaries that students understand and can't wander beyond, e.g. " Don't go past the big fig tree and the edge of the field", or "If I can't see you, you've gone too far."

Try out the whistle or other audible signal to gather the group together, and agree on a meeting place where the group will gather when called.

Make sure all students can be seen and stress that they must be able to see you at all times.

3. Heading Out: Small Steps Close By

Start in the school grounds. Local explorations are perhaps the most important, as there is more opportunity to do return visits to build on experiences and develop a sense of place. Also, students can return to them on their own time. Always begin by gathering the group in a circle and outlining the planned activities. Keep students' backs to the sun so they can see you. Then start with a short activity such as the Sensory Warm-up Circle or Rainbow Chips, that lasts just ten minutes. Later, increase your time outdoors to twenty minutes, then thirty minutes, and so on. This helps both you and the students feel comfortable and in control of each stage. A big bonus is that students tend to monitor their behaviour outdoors themselves – they really enjoy the opportunity to go outside to learn, and tend to behave appropriately in order to keep that opportunity.

4. Use well - defined activities rather than loose explorations

Gather the group together before each activity, explain and demonstrate the task, and set boundaries for exploration ("Stay between the fence and that row of trees"). Simple tools such as paint chips or magnifying glasses help focus student's attention. End the activity back in a circle with a sharing and quick discussion.

5. Visit the site beforehand and plan your program well

For field trips offsite, it is important to visit the location before taking your group there, even if it is just to the local park down the street. Check out the site beforehand and use the Field Trip Planning Sheet in this section to help you remember details. Find the easiest access points to a beach or field, and note any unique features such as big trees to serve as boundaries and gathering places. Note clear directions to the site for all adult drivers, correct bus routes if applicable, and see if there is a map available to copy.

6. Bad Weather Backup Plans

Have some backup plans in case of poor weather, such as a shelter or big tree to retreat to, or a tarp strung between trees. You can still get out and do activities in the rain or cold as long as people are dressed for it. Remember that paper "melts" in the rain – bring big zip lock plastic bags to put any paper or books in. Bring along some "emergency ponchos" – big garbage bags with holes cut out for head and arms, some plastic grocery bags to stuff into leaky boots or shoes, and a few hats. If the weather is terrible, postpone the trip: no sense in making the experience a misery for all involved.

7. Safety Rules

Review some basic safety rules with the group before you head out on bigger adventures:
1) Choose a buddy and keep them in sight all day.

2) If you get separated from the group, Stay Put! Hug a Tree – stay in one place and the group will find you quicker.

3) Ensure students are dressed properly, have adequate water and food with them, and know who has First Aid kits (the teacher and/or at least one parent/helper).

Teacher Tip Sheet 2.
Outdoor Field Trip Planner Sheet

To the teacher: Bring this along with you when you check out a field trip site, use it to review site specifics with someone who's been there before, and make a final copy for all parents / helpers coming with you.

Destination:
Date of Field Trip:
Description of Area:
Driving Directions: *(if available, attach a MapQuest map or local map that shows the route)*
Meeting Spot (location/specifics):
Benefits of Using This Area **Space For Large Group Activity:** Y/N **Special Features:** **Description of Trails:** **Washrooms/Water:** Y/N **Rest and Lunch Spots:** Y/N **Potential Hazards/Precautions:** Y/N **Special Considerations: (site and group)** **Contingency Plans:**
Site Specific Emergency Contact Numbers **Is the site within Cell phone range?** Y/N
Cell phone contact number(s):
Nearest Land Phone location:
Nearest Medical Facility:
Nearest Hospital:
School phone number:

Teacher Tip Sheet 3.
A Note on Conservation:
Model A Reverence for Nature

The living things that inhabit this planet with us are all uniquely adapted to live in particular habitats. Effective environmental learning involves direct experience with the natural world, but care must be taken not to jeopardize the very life forms and environments we are learning from. These basic guidelines form part of a conservation ethic that should be an essential part of all outdoor experiences. We have found that instead of "preaching" these guidelines to your class or group, it is much more effective to have them generate their own list through a brainstorming activity.

Stay on the Trail / Footpath

This minimizes your impact on plant life and allows animals to adapt to human use of an area.

Patting Prevents Picking

Explore, feel, smell, and sense natural objects such as leaves, shells, tree branches and feathers, but do not pick any live plant material or remove things from their location: this is their home.

Turn the Rocks or Logs Back Over

When exploring under a rock or log, do so gently. Try not to crush plants and animals that may be living on, beside or under it, and put the rock or log back the way it was when you've finished investigating.

Fill in Any Holes

Whether digging on a beach for burrowing animals or exploring the soil layers of a forest floor, fill in any holes you create. Plants, insects and animals living in the area will be disturbed by piles of dirt covering their burrows and trails.

Wildlife Viewing Etiquette

Observe wildlife as quietly as possible – stress is harmful to animals, so respect their space and habitat. Never chase animals, touch or feed them. Remember that birds and animals need resting periods during the day - use binoculars and keep a respectable distance away.

Leave all Specimens, Alive or Dead, in Their Natural Habitat

Do all of your discovering on-site – observe living things in their home place. Do not move plants or animals from one location to another, and do not take any organisms away. Dead leaves, fungi, shells of animals, stones, and seeds all have a role to play in their ecosystem. Don't allow activities that stress collecting, pressing and drying of specimens: their teaching potential is limited, and students can demonstrate the same skills of identification, observation, and categorizing with live specimens in their natural habitat.

Leave No Trace

In every way, try to leave the environment and its inhabitants unchanged by your visit. Pack out all garbage, even though you may not have brought it in. Bring along some garbage bags, and protect garbage collectors' hands with small plastic bags or gloves.

Easy Activities to Help Tune into the Natural World

Sensory Awareness: An Introduction

We have a whole network of senses that connect us to the world around us. The five senses of sight, hearing, smelling, touching and tasting are most commonly referred to, but we have many more, including our ability to sense temperature, weight, gravity, balance, sense of time, and pressure. Most of us spend much of our time indoors, separated from the natural world by buildings, cars and clothing, and many of our senses get "shut down" by lack of use. Much of our formal education takes place indoors as well. When we go outside, it is useful to "wake up" our senses, to better connect with the world around us, and tune into our environment in new and different ways.

1. Sensory Wakeup Circle

Time required: 5 - 10 minutes
Materials: None
Audience: All ages

This is a nice introductory and "awakening" activity to do each time you take a group outdoors. Gather the group in a circle and tell participants that you'll be waking up their senses to be better able to explore and observe the environment. Ask for a listing of our main senses, and remind the group of ones they may not think of beyond the 5 general ones (sensing temperature, hunger, air currents, etc).

Wake the senses up individually:

Touch: have everyone rub their hands together vigorously until they feel heat energy being generated between their palms when they pull them apart slightly. Do this until everyone has made some energy and "woken up" their fingers.

Hearing: Have everyone put on "deer ears" – cup hands around their ears so the area for capturing sound is enlarged. To demonstrate how effective larger ears are, have everyone take their "deer ears" off as you keep speaking, and then put them on again, noting how much louder your voice or other sounds become.

Try having the group put the "ears" on backwards to hear sounds behind them. Now have everyone close their eyes (to block out the dominant sense of sight) and count the number of different sounds they hear in a 20 – 30 second time frame. Younger students might want to hold up their fingers for each sound. Ask people how many sounds they heard, and to describe some of them.

Smell: Have everyone close their eyes and focus on their sense of smell by taking a breath through their mouths and then two big breaths through their nose. Have different people in the circle describe what they smell. Now have the group turn to face out of the circle and repeat the smell sampling, asking for any different scents.

Taste: If it is raining, have everyone taste a raindrop, or some seawater if you are on the beach, but otherwise save the tasting for lunchtime!

Sight: Send the group out from the circle to do the Rainbow Chips activity (see below).

Discussion Questions:
Which sense could you give up?
Which sense could you not live without?

Adaptations for Older Students
Small Group Sessions
Secondary school students may feel uncomfortable doing the sensory awareness activities in a large group, but thoroughly enjoy them in smaller gatherings. Put older students in groups of two or three, and give each group a piece of string about three metres long. Have them move to an area away from other groups and lay down the string so it forms a circle. Ask each group to do one or two of the sensory activities – e.g. Sound Mapping, Rainbow Chips, and/or recording the smells, colours and textures found inside their circle.

2. Rainbow Chips

Time required: 15 minutes
Materials: Bag of 30 – 40 paint colour chips from a paint store
Audience: All ages

This is a fun and easy activity that gets participants looking closely at things around them, and hones their observation skills. It is an excellent way to being a discussion on biodiversity, for the range of colours in only a small natural area is a good example of the variety of living things. Collect a selection of paint chips from your local paint store, ensuring that you get a good range of colours and shades. Cut up the chips if they are in strips, and place them in a bag. Hand each participant a "rainbow chip", telling them that every colour of the rainbow exists in nature all around us, and send them off to match their chip colour as closely as possible with something natural (human-made items like garbage or clothing don't count!). Ask them not to pick their matched item if it is alive, but to show it to someone close by. Offer some hints: turn leaves and stems over to see colours beneath, look closely at rocks and pebbles, lichen, tree bark and sap. Once they have found a match, give them another colour chip to try. OR give students a whole strip of paint chips of similar shades to match.

Extension: Paint Chip Poetry
Based on the name and colour of their paint chip, have students write a haiku, cinquain or other type of poem.

Discussion Questions:
What surprised you the most about this activity?
What colours were hardest to find?

3. Sound Mapping

Time required: 15 minutes
Materials: Pencils and index cards or journals, "sit-upons" (cardboard square inside a plastic bag)
Audience: All ages

This is another a good warm-up activity for focusing students' attention outdoors and illustrating the diversity of sounds in our environment. Gather your group in a circle and have them listen and count the number of different sounds they hear around them. Now that their sense of hearing is tuned up, give each student an index card, or have them use a page in their journals. Tell students they'll be drawing a sound map of this area, as well as a key to the sounds they hear. Have them make an "X" in the middle of the page to represent themselves. As each sound is heard, a symbol for the sound is recorded on the map where it was heard relative to the "X". Students can choose anything they want for the sound symbols key: e.g. pictures, musical notes, squiggly lines. To begin, have students move apart and sit on the ground or on a "sit-upon" (see Materials list) several metres away from one another. After a few minutes of recording, have students pair up, share their maps and symbols, and discuss their favourite sounds.

Discussion Questions:
What's the quietest place near or in your home? Your school?
How far would you have to go to find no human-made noises?
Absolute silence?

VI/ Appendix II: Biodiversity Resources for Educators

Books & Articles

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Sutty, Lesley. (1993). *Fauna of the Caribbean: The Last Survivors*. MacMillan Press / London / Caribbean.

WGBH Educational Foundation. (2009). *Teachers' domain*. Retrieved from: teachersdomain.org/.

Useful Websites on Biodiversity

natureserve.org/infonatura
A conservation and educational resource on the animals, and ecosystems of Latin America and the Caribbean. You can use InfoNatura to learn about more than 8,500 common, rare and endangered species and 788 ecosystems.

biodiversity911.org
World Wildlife Fund's website for educators and students.

bagheera.com
A website for Earth's Endangered Animals: some classroom resources.

iucn.org
The International Union for Conservation of Nature (IUCN) website – a global environmental network set up to tackle environmental problems and conserve biodiversity. The IUCN works in 160 countries, and publishes yearly status reports of threatened, endangered and critically endangered species worldwide.

redlist.org
The IUCN Red List of Threatened Species.

cites.org
Convention on International Trade in Endangered Species of Wild Flora and Fauna.

biodiversityhotspots.org
Conservation International's website that profiles the most diverse and threatened places on Earth.

investigate.conservation.org
Educational website of Conservation International for students to investigate biodiversity.
Take the Ecological Impact quiz to measure your personal impact and investigate ways to conserve biodiversity.

cbd.int/doc/bioday/2007/ibd-2007-booklet-01-en.pdf
Convention on Biological Diversity: Downloadable booklet on Biodiversity and Climate Change (2007).

conserveonline.org
ConserveOnline is a "one-stop" online, public library, created and maintained by The Nature Conservancy in partnership with other conservation organizations. Information on biodiversity, conservation, ecotourism and research is available.

Useful Websites on Conservation in the Caribbean

ccdc.org.jm/caricomp_main.html
Caribbean Coastal Marine Productivity Program (CARICOMP)
The Caribbean Coastal Marine Productivity (CARICOMP) Programme is a regional scientific effort to study land-sea interaction process, to monitor for change, and to provide appropriate scientific information for management within the Caribbean. The Programme focuses on understanding the productivity, structure and functions of three important coastal ecosystems: mangroves, seagrasses and reefs, throughout the region.

canari.org
Caribbean Natural Resources Institute (CANARI)
The Caribbean Natural Resources Institute promotes participatory natural resource management in the Caribbean. Based out of Trinidad and Tobago and St. Lucia, it is emphasizing projects involving coastal areas, coral reefs, mangrove forests, rainforests, and marine environments within the Caribbean.

edf.org
Environmental Defense Fund
The Environmental Defense Fund is based out of the United States and specializes in helping businesses, governments and communities to find practical environmental solutions. They provide funding and guidance to many of the countries within the Eastern Caribbean.

oecs.org/esdu/about.html
OECS Environment & Sustainable Development Unit
The Environment & Sustainable Development Unit of the Organisation of Eastern Caribbean States (OECS-ESDU) is the entity within the OECS Secretariat that is responsible for the provision of natural resource and environmental management services to the member states of the OECS.

panoscaribbean.org
Panos Institute of the Caribbean
Panos Caribbean is a non-profit NGO based in Washington, DC; Jacmel, Haiti; Kingston, Jamaica; and Port-au-Prince, Haiti. It is a regional organization that works to strengthen civil society by helping journalists to cover sustainable development issues that are overlooked and misunderstood, in particular those whose impact transcends national boundaries.

nature.org/wherewework/caribbean
The Nature Conservancy in the Caribbean
The Nature Conservancy is working in the Bahamas, Dominican Republic, Eastern Caribbean, and Jamaica and working on conservation projects involving coral reefs, forests, islands, rainforests, and tropical forests.

cep.unep.org
United Nations Environment Program - Caribbean Environment Programme (UNEP - CEP)
This organization is promoting regional cooperation for the protection and development of the marine environment of the Wider Caribbean Region.

usaid.gov/locations/latin_america_caribbean
United States Aid - Latin America & the Caribbean
The U.S. Agency for International Development (USAID) is a U.S. Government agency implementing important foreign assistance programs throughout the Caribbean region. Many programs include provisions for economic growth and sustainable resource management.

panda.org
World Wide Fund for Nature (WWF)
This organization is active in the Caribbean, working on projects involving climate change, forests, freshwater, marine, and species conservation.

worldwildlife.org
World Wildlife Fund
This organization has been doing conservation work to protect the coral reefs within the Caribbean. Particular projects include work on the Mesoamerican reef.

VII/ Appendix III: Glossary

GLOSSARY OF TERMS FOR PART 1:
Biodiversity Basics: The Spice of Life

abiotic: a non-living factor in an environment; e.g. light, water, temperature, climate.

adaptation: the process of making adjustments to the environment. For example, forests develop only where soil types, moisture, and sunlight are balanced to the proper degree. Arctic plants have made adjustments so as to be able to live under harsh conditions.

amphibian: an animal that typically lives partially in an aquatic habitat breathing by gills as young, and primarily in a terrestrial habitat breathing by lungs and through moist glandular skin as an adult e.g. frog.

biodegradable: the property of a substance that permits it to be broken down by microorganisms into simple, stable compounds such as carbon dioxide and water.

biodiversity: the term used to describe the variety of life on Earth including plants, animals, fungi and micro-organisms.

biosphere: the part of the earth's crust, water and atmosphere where living organisms can subsist.

community: an association of organisms - plant and animal - each occupying a certain position or ecological niche, inhabiting a common environment, and interacting with each other; all the plants and animals in a particular habitat that are bound together by food chains and other interrelations.

condensation: the process of substance changing from a gas to a liquid, usually as a result of cooling.

conservation: the use of natural resources in a way that assures their continuing availability to future generations; the wise and intelligent use or protection of natural resources.

consumer: the first part of an ecosystem is the non-living substance; the second part consists of those organisms that are called "producers", or food makers; part three of this system is called the "consumer" because it utilizes the producer for its food; it may in turn be used as food by a secondary consumer. A rabbit is a primary consumer. A fox would be a secondary consumer.

decomposer: those organisms (bacteria, fungi) which convert dead organic materials into inorganic materials; a plant or animal that feeds on dead materials and causes its mechanical or chemical breakdown.

ecological niche: the role played by an organism in a biological community; its food preferences, requirements for shelter, special behaviours, and the timing of its activities (e.g. nocturnal or diurnal). The ecological niche of an organism has little to do with where it is found but much more to do with its function or role, e.g. predator, decomposer and with how it performs that function.

ecological services: services which humans derive from ecological functions including photosynthesis, oxygen production, and water purification.

ecologist: a scientist who studies the interrelations of living things to one another and their environment.

ecology: the study of the relation of organisms or groups of organisms to their environment; or the science of the interrelations between living organisms and their environment.

ecosystem: a natural unit that includes living and nonliving parts interacting to produce a stable system in which the exchange of materials between the living and nonliving parts follows between closed paths; all living things and their environment in an are of any size, with all linked together by energy and nutrient flow.

effluent: any matter that enters the environment from a specific source; the term generally refers to waste water from a sewage treatment or industrial plant.

endangered: any indigenous species of fauna or flora whose existence is threatened with immediate extinction through all or significant portion of its range, owing to the action of humans.

energy: a thermodynamic quantity equal to a physical system's capability to do work; measured in joules or ergs.

environment: the total of all of the surroundings - air, water, vegetation, human element, wildlife - that has influence on you and your existence, including physical, biological, and all other factors; the surroundings of a plant or animal including other plants and animals, climate, and location.

erosion: the removal or wearing away of soil or rock by water, wind, or other forces or processes.

eutrophication: enrichment of soils and water due to fertilization, sewage, effluent, or other waters that carry a high plant-nutrient component.

evaporation: the process of a substance changing from a liquid to a gas by exposure to the air and/or heat.

extinction: the condition of having been removed from existence. An animal or plant facing extinction is one in danger of vanishing from our world.

food chain: the transfer of food energy from the source in plants through a series of animals.

food web: an interconnected pattern or "web" of food chains.

fresh water: clean, unpolluted water without salinity.

Glossary Terms: Part 1

groundwater: water found under the ground, in the zones of soil and bedrock.

habitat: the arrangement of food, water, shelter, and space suitable to an organism's needs.

herbicide: weed-killing chemical.

herbivore: a plant eater.

life cycle: the continuous sequence of changes undergone by an organism from one primary form to the development of the same form again.

micro-consumers: basic consumers at the basis of the food chain; includes flagellates, ciliates, and nematodes.

micro-organism: an organism microscopic in size, observable only through a microscope.

omnivore: an animal which eats both plant and animal materials.

organism: a living thing; a form of life composed of mutually dependent parts that maintain various vital processes.

pesticide: any chemical preparation used to control populations of organism, including plants and animals, perceived to be injurious.

plant communities: an association of plants, each occupying a certain position or ecological niche, inhabiting a common environment, and interacting with each other. Dominant plants usually define the community, e.g., a mangrove community. photosynthesis: the basic photosynthetic process; an oxidation-reduction reaction as follows: Carbon dioxide + water + light energy = carbohydrate + water + oxygen.

photosynthesis: the basic photosynthetic process; an oxidation-reduction reaction as follows: Carbon dioxide + water + light energy = carbohydrate + water + oxygen.

pollution: harmful substances deposited in the air or water or land, leading to a state of dirtiness, impurity, unhealthiness, or hazard.

population: the number of a particular species in a defined area.

predation: the act of preying upon.

predator: an animal that kills and eats other animals.

producer: organisms which are capable of producing their own food from inorganic compounds and a source of energy.

rain shadow: an area on the leeward side of a mountain barrier that receives little rainfall.

resilience: the ability of an ecosystem to return to initial state after a disturbance.

resource: a portion of an environment upon which people have placed or assigned value, or see as being available for use. riparian: located or living along or near a stream, river, or body of water.

season: a period of time, usually when something specific occurs; for example, any of four times of the year characterized by differences or changes, as in plant growth and temperature. In wildlife management or conservation terms, that time when hunting, fishing, or trapping is permitted for a particular species.

shelter: cover; cover from elements, for natal activity, to travel in, for breeding, for bedding, etc.; varies depending upon species. slough: an inlet from a river; backwater; tide flat; a creek in a marsh.

species: a population of individuals that are more or less alike, and that are able to breed and produce fertile offspring under natural conditions; a category of biological classification immediately below the genus or subgenus.

stewardship: relate the environment, the concept of responsible caretaking; based on the premise that we do not own resources, but are managers of resources and are responsible to future generations for their condition.

symbiosis: a close living relationship between organisms.

terrestrial: ground dweller.

vegetation: the mass of plants that covers a given area. Flora, a term often wrongly used interchangeably with vegetation, is a list of the species of plants that compose the vegetation.

water cycle: the continuous circulation of water in systems throughout the planet, involving condensation, precipitation, runoff, evaporation, and transpiration.

wetlands: any land area that tends to be regularly wet or flooded.

wild: not tamed or domesticated, living in a basically free condition. A wild animal provides for its own food, shelter, and other needs in an environment that serves as a suitable habitat.

wildlife: animals that are not tamed or domesticated; may be small organisms only visible to humans if seen through a microscope, or as large as a whale. Wildlife includes, but is not limited to, insects, spiders, birds, reptiles, fish, amphibians, and mammals, if non-domesticated.

zooplankton: plankton that is composed of tiny animals and animal matter.

PART 1: ADDITIONAL/RELATED TERMS
The following is a list of additional and related terms that may be of use during your study of the concepts of biodiversity. Teachers and students are encouraged to continue to build on this list, inserting new terms and definitions, expanding the Glossary to meet your educational needs.

aerate: to supply with air or oxygen; to supply the blood with oxygen as in the function of lungs: to supply running water with additional oxygen as when a stream runs over falls or rapids, or when wind creates waves on a lake.

aquaculture: deliberate growing of plants and animals in aquatic environments.

aquatic: growing, living in, or frequenting water.

biotic community: commonly the living organisms in a given community. It includes all plant and animal life within the community. The non-living parts are considered the abiotic parts of the community.

bog: a wetland formed where low oxygen levels and soil temperature cause incomplete decomposition and limited drainage, in an accumulation of fibrous peat.

detritus: dead plant, animal, and other organic matter.

domesticated: referring to animals, those which humans have tamed, kept in captivity, and bred form special purposes. All domesticated animals have their origins in wild ancestors. Cattle used for food and other products; sheep for wool and other products; as well as dogs, cats, birds, and fish commonly kept as pets are all examples of domesticated animals.

estuary: a site where fresh water and salt water meet.
evapo-transpiration: the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants.

extinction: the condition of having been removed from existence. An animal or plant facing extinction is one in danger of vanishing from our world.

feral: used in wildlife as referring to domesticated animals gone wild; e.g. pigeons, goats, cats, dogs.

fish ladder: a series of ascending pools of constructed by humans as mechanisms to enable salmon or other fish to swim upstream around or over a dam.

forage: refers to vegetation taken naturally by herbivorous animals, both wild an domesticated.

freshwater marsh: a wetland where standing fresh water exists year round in most conditions.

fry: the young of fish.

gill net: curtain-like fishing net, suspended vertically in he water, with meshes of such a size as to catch a fish by the gills that has thrust its head through the mesh netting.

hydrology: the area of science dealing with the study of the waters of the earth and its atmosphere.

limnology: the area of science dealing with the study of freshwater aquatic ecology.

matter: the basic structural component of the universe; occupies space and possesses mass.

microhabitat: a small habitat within a larger one in which environmental conditions differ from those in the surrounding area. A hole in a tree trunk or an animal carcass is a microhabitat within the forest.

migration: the periodic movement of animals from one area to another and back again as a natural part of their life.

nocturnal: active by night; the opposite of diurnal.

non-renewable resource: nonliving resources such as rocks and minerals; resources which do not regenerate themselves; substances such as petroleum, coal, copper, and gold which, once used cannot be replaced - at least not in this geological age.

plankton: those organism suspended in an aquatic habitat which control their own movements; usually microscopic, including bacteria, algae, protozoans, rotifers, larvae, and small crustaceans. Phytoplankton are the plant plankton; zooplankton are the animal species.

predation: the act of preying upon.

preservation: protection which emphasizes non-consumptive values and uses, including no direct use by humans, contrasted with conservation which emphasizes both consumptive and non-consumptive values and uses.

riparian: located or living along or near a stream, river, or body of water.

runoff: water that drains or flows off the surface of the land.

salt marsh: a marshy land that is wet with salt water or flooded by the sea.

seine net: a fishing net that hangs vertically in the water, with floats at the upper edge and sinkers at the lower.

slough: an inlet from a river; backwater; tide flat; a creek in a marsh.

smolt: a young, silvery salmon migrating to the sea.

spawning: the act of producing or depositing eggs; usually refers to fish.

succession: the orderly, gradual, and continuous replacement of one plant or animal by another.

waterfowl: water birds, usually ducks, but including shore and wading birds, geese, etc.

waterway: a river, canal, or other body of water used as a route or way of travel or transport.

wildlife management: the application of scientific knowledge and technical skills to protect, preserve, conserve, limit, enhance, or extend the value of wildlife and its habitat.

GLOSSARY OF TERMS FOR PART 2:
The Caribbean: A Biological Diversity Hotspot

abysmal zone: the pitch-black bottom layer of the ocean where pressure is immense and water temperature is almost freezing.

algal blooms: excessive growth of algae within water bodies.

atoll reef: rings of coral reef, often encircling an island of sand and coral rubble.

barrier reef: reefs that are grow parallel to the coast but are separated from land by a lagoon.

bathypelagic zone: (or midnight zone) is the deep ocean layer where no light penetrates.

benthic species: species which live on the bottom of the ocean.

biodiversity: the variety of life on the planet, reflected in the diversity of ecosystems and species, and the genetic variation within and among species and the ecosystems.

biodiversity hotspot: region of the world that is both a significant reservoir of biological diversity and is threatened with human-caused destruction.

biomass: total mass of all living things within a specific area or habitat.

biosphere reserve: is an international conservation designation given by UNESCO under its Programme on Man and the Biosphere (MAB). It is designed as a core reserve that is surrounded by buffer zones with human use increasing away from the core.

black mangrove: species of mangrove which show marked preference for higher, drier habitats and are not usually found within habitat that is completely inundated with water.

buttonwood mangrove: species of mangrove which prefers less saline environments and has grey bark.

by-catch: catch that was not targeted by those doing the fishing (non-targeted species).

canopy: one of the uppermost levels of a forest, below the emergent layer, formed by the tree crowns.

climate change: a change in long-term weather patterns (i.e. a change in climate) caused by activities being carried out by humans such as fossil fuel burning, greenhouse gas emissions and deforestation.

coastal ecosystem: area where land and sea join to create a distinct community of organisms that interact together in the physical environment.

community: consists of the populations of several species of plants and animals living and interacting in a given locality.

continental shelf: the region of relatively shallow water surrounding every continent.

coral bleaching: the loss of color of corals, due to stress-induced expulsion of symbiotic unicellular algae.

coral polyps: small individual coral animal with a tube-shaped body and a mouth surrounded by tentacles; many together form coral reefs.

coral reef ecosystem: a community of different underwater plants, fish and other marine life in a coral reef environment.

deforestation: the conversion of forest land into non-forest land.

detrital food cycle: a food chain that begins with detritus and is followed by decomposers (including bacteria and fungi).

detritus: organic debris formed by the decomposition of plants and animals.

dry limestone forests: forests found in the rain shadow of mountains and along coastlines where soils are often poor.

ecoregion: a relatively large unit of land containing distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land use change.

ecosystem: a community of living things that interacts with each other and with their non-living environment (soil, rocks, etc).

endemic: native to or confined to a certain region.

epipelagic zone: (or sunlit zone) is the top layer of the ocean where enough sunlight penetrates for plants to carry out photosynthesis.

estuary: coastal water body where ocean tides and river water meet.

eutrophication: over-enrichment of a water body with nutrients, resulting in excessive growth of organisms (often algal blooms) and depletion of oxygen concentration.

extirpated: refers to a species that no longer exists in a country or region but does exist elsewhere.

fishing down the food chain: decline of the mean trophic level of reported catches and a reduction in the abundance of species at higher trophic levels.

food chain/ food web: the complex feeding relationships that exist in nature.

forest floor: first level of a forest; the ground layer made up of tree roots, soil and decaying matter.

fragmentation: process by which isolated patches of habitat are created through land clearing and deforestation.

fringing reefs: one type of coral reef that grows in shallow waters alongside the shore line.

global warming: a gradual warming of the Earth's atmosphere caused by the burning of fossil fuels and industrial pollutants. greenhouse gas: a gas that traps heat from the sun in the Earth's atmosphere and produces greenhouse effects; includes carbon dioxide and methane.

habitat: the place where a micro-organism, plant or animal lives.

hadal zone: the waters found in the ocean's deepest trenches.

halophytic: salt tolerant species.

hard corals: one type of coral composed of stony calcium carbonate.

holoplanktonic: organisms living their entire life in the sea, floating in the water between the bottom and surface.

hypersaline: water with a high concentration of salt; salt concentration greater than sea water.

igneous rock: the type of rock that is created when molten rocks cool.

intertidal zone: the area above the subtidal zone and between the high tide and low tide marks on the shore.

key messages: several short, concise and memorable sentences used to convey important communication.

Large Marine Ecosystems (LMEs): the jurisdictional regions of the world's oceans, encompassing coastal areas from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of the major ocean current systems.

mangal ecosystem or mangal: mangrove swamp ecosystem.

mangrove swamp ecosystem: coastal wetlands of the tropics that contain trees, shrubs, vegetation and an associated community of organisms, which exist in salt water intertidal zones.

Marine Protected Areas (MPAs): coastal or open ocean areas in which certain uses are regulated to protect natural resources, biodiversity, or human livelihoods.

mesopelagic zone: (or twilight zone) is a dimly-lit zone where some light penetrates, but not enough for plants to grow.

metamorphic rock: rocks that have morphed or "changed" into another type of rock as a result of chemical and structural changes.

muddy beaches: are made up of fine particles of organic and inorganic matter, often carried downstream by rivers.

nearshore: areas of the ocean close to land.

non-governmental organizations (NGOs): organizations created by private organizations or people with no participation or representation of any government.

ocean currents: movement of ocean water created from forces, such as planet rotation, wind, temperature and salinity differences, and the gravitation of the moon.

ocean ecosystem: body of salt water where currents, waves, and tides intermingle to create a distinct community of organisms that interact together in the physical environment.

offshore: areas of the ocean not near land.

overstory (emergent): level of forest canopy that includes the crowns of dominant, co-dominant, and intermediate trees.

pebble beaches: are formed from rocks that have been constantly pounded, rolled and polished by the active of waves.

pelagic species: species which live in the open sea, away from the sea bottom.

photosynthesis: process by which plants generate carbohydrates and oxygen from carbon dioxide, water, and light energy.

phytoplankton: tiny oceanic plants in the depths of the ocean.

platform reef: coral reefs which develop in sheltered seas, but quite far offshore and are flat-topped with small and shallow lagoons.

pneumatophores: root projections sent up to the water surface by mangrove, which help to supply the plant with oxygen.

population: a group of individual organisms (such as palm trees or frogs) of the same kind (species).

predator-prey dynamics: the relationship between predators and prey that exist in nature.

protected areas: locations which receive protection because of their environmental, cultural or other similar value.

red mangrove: most common of the mangrove species and the first to grow in muddy areas.

reforestation: the restoration (replanting) of a forest that had been reduced by fire or cutting.

range of tolerance: optimal range of abitoic factors which an organism needs to survive.

reclamation: the process of regaining an area from loss or from a less useful condition.

sandy beaches: are formed in coastal areas where the waves and currents are able to deposit sand faster than it can be carried away.

seagrass beds: large areas of underwater marine flowering plants that resemble grasslands.

sea level: the average height (mean height) of all the oceans.

sea level rise: an increase in sea level; is a result from global warming due to expansion of seawater as the oceans warm, and melting of ice in cold regions.

sedimentary rock: rock made from the consolidation of solid fragments, such as other rocks or organic remains, or by precipitation of minerals from solution.

soft corals: one type of coral that is composed of a protein and calcium carbonate material.

stewardship: the careful and responsible management of something; concept of responsible caretaking, usually of natural resources.

St. Georges' Declaration of Principles for Environmental Sustainability: principles to ensure environmental sustainability within the Eastern Caribbean developed by the Organization of Eastern Caribbean States (OECS) in 1999 and updated in 2006.

shrub layer: layer of the forest where woody shrubs grow; is a dark layer, with limited sunlight.

subtidal zone: the area of the shoreline that lies below the low-tide mark and is the lowest level of tidal zone.

supratidal zone: (or splash zone) is the tidal zone which lies above the intertidal zone just beyond the reach of the water at high tide.

symbiotic relationship: a relationship between two or more organisms they co-exist together in a mutually advantageous relationship, each derives benefits from the relationship.

territorial waters: the area of coastal water 12 nautical miles from the shoreline.

tidal zones: area along the beach shoreline that is affected by the rise and fall of the tide; is a complex ecological zone at the water's edge.

trophic levels: feeding levels or energy levels in a food chain or food web (such as primary producer, primary consumer, secondary consumer, tertiary consumer).

tropical (and subtropical) coniferous forests: forest type located in regions of semi-humid climate at tropical and subtropical latitudes.

tropical and subtropical dry forests: forest type located at tropical and subtropical latitudes which endures long dry seasons.

tropical and subtropical moist forests: forest type located near the equator which receives high overall rainfall.

tropical montane cloud (or mist) forests: rare mountain forest found in tropical areas where local climatic conditions cause cloud and mist to be regularly in contact with the forest vegetation.

understory: the second layer of a rainforest; the layer of forest beneath the canopy and includes small trees and young canopy trees.

water balance: flow of water in and out of a watershed.

white mangrove: species of mangrove which has white bark.

zonation: presence of organisms within a particular range as a result of predetermined characteristics.

zooxanthellae: single-celled algae which live as symbionts within the tissues of corals; they help coral produce limestone or calcium carbonate and give the corals their characteristic greenish color.

PART 2: ADDITIONAL/RELATED TERMS

The following is a list of additional and related terms that may be of use during your study of the concepts of biodiversity. Teachers and students are encouraged to continue to build on this list, inserting new terms and definitions, expanding the Glossary to meet your educational needs.

biological corridor: a strip of habitat connecting wildlife populations and separated by human activities (such as roads, development, or logging).

biosphere: the part of Earth's atmosphere, land and oceans that supports any living plant, animal or other organism; the place where plants and animals, including humans, live.

environmental impact assessments: an assessment of the possible impacts (positive or negative) that a proposed project may have on the natural environment.

genetic erosion: the loss of genetic diversity within a species; can be represented by the loss of entire populations genetically differentiated from others, the loss or change in frequency of specific alleles (different forms of genes) within populations, or over the species as a whole, or the loss of allele combinations.

indicator species: a species of plant or animal used to predict the quality and characteristics of a site.

integrated management approach: planning process in which interested parties and stakeholders reach general agreement on the best mix of conservation, sustainable resource use and economic development for coastal and marine areas (so that the long term sustainable benefits are optimized and conflicts among users are minimized).

nitrogen fixation: process in which nitrogen gas (N_2) is converted into compounds that contain nitrate (NO_3) or ammonium (NH_4). Both of these compounds are useable by plants.

saline: a solution comprised primarily of salt water.

sustainable harvest: the amount of catch of species does not exceed the amount that can naturally replacement themselves through reproduction.