A Fragile Balance: Exploring Ecosystem Restoration Through Case Studies

2015-2016 Model Curriculum Unit for Project GLACIER trip to Belize

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NOTE: This is a working draft. Please direct any questions, comments, suggestions etc. to <cab@bu.edu>

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PREFACE

In April 2016, five middle school science teachers and two Boston University doctoral students visited Belize to explore the theme of ecosystem restoration in both a sub tropical rainforest and a marine ecosystem. Belize serves as the ideal study ground because it is a small country blessed with many natural resources that put it at the forefront of the ecotourism industry. In fact, ecotourism is the second largest source of revenue in Belize after agriculture.

Belize's resources include diverse flora and fauna in protected reserves and parks, more than one-hundred cayes, and many miles of coastline. In addition, the Belize Barrier Reef along its shore is the second largest coral reef ecosystem in the world. In recent years, Belize has struggled with maintaining its natural resources due to the continuation of 'slash and burn' agricultural practices used to destroy natural habitats in order to increase agricultural production. Additionally, evidence of climate change has threatened to impact Belize's vast network of coral reefs, which could negatively impact its tourism industry. Because of its size, Belize provides a microcosm that is an excellent lens for studying the delicate balance between preservation and restoration of its natural resources and maintaining the vitality of its economy.

In order to educate students about the complicated issues involved in preserving and restoring ecosystems in Belize, the team developed six lessons centered around case studies, each a scenario depicting different ecological, social, and economical factors affecting the delicate balance in each ecosystem. The first three lessons focus on ecosystem restoration of the sub tropical rainforest and explore the threat of deforestation in Belize and the impending impact on animal habitats and the economy. The remaining three lessons focus on preservation and restoration of Belize's marine ecosystems, specifically on coral reef and mangrove habitats which are closely linked to its tourism industry.

Upon completion of this overall unit, *A Fragile Balance: Exploring Ecosystem Restoration through Case Studies*, students not only will have participated in an engaging and challenging scientific experience, but also should be better equipped and more empowered to make a direct impact on global climate change.

Used in part or in its entirety, the unit encompasses skills critical to the scientific method such as observation, surveying, research, measurement, and analysis as prescribed within the Next Generation Science Standards. Additionally, it promotes effective scientific communication by applying essential Common Core reading and writing skills.

Ultimately, students should have a much better understanding of global climate change and be inspired to slow its effects on on our planet and in our communities. They can do this not only by reducing their own planetary impact, but also by being prepared to educate and encourage others to do the same.

OVERVIEW OF LESSONS

In Lesson 1 students will read an interview with a scientist from Mexico who has spent his life studying primates. The interview sheds light on the importance of *public education* as a critical step in preserving habitats and the population of black howlers, and ultimately how to assess whether climate change related impacts might affect the population. Students will have an opportunity to identify the strategies the primatologist suggests taking to help this population, and brainstorm ideas on how to best educate a local community. They will disseminate this information in writing, audio, or video in the form of a public service announcement after being introduced to the technique.

In Lesson 2 students will take a close look at the unofficial symbol of the rainforest, the Red Eyed Tree Frog, to decide if future conservation efforts should be made to protect its population. The case study gives a detailed description of the Tree Frog habitat, coloration, reproduction, Belize rainfall patterns and weather patterns, coupled with personal observations of Melvis Vasquez, naturalist at the Rio Bravo Conservation Center in Belize. The students will use these as sources to gather information, create logical inferences from the data, and create a recommendation for future actions necessary to help the Red Eyed Tree Frog.

In Lesson 3 students will be introduced to issues of land use in Belize due to deforestation. The case study contains an interview with a local forest tour guide who is an expert at local flora and fauna in Belize. Students will understand the dynamics of the logging industry and agricultural land use and the impacts that these practices have on wildlife and ecological sustainability. Students will explore the differences between new forest growth and old forest growth to understand the long term effects of deforestation, and will then engage in a debate on land use.

In Lesson 4 students read a case study and answer a series of questions about how Lisa Carnes of Fragments of Hope collected temperature data on corals in Placencia, Belize which showed, "that during hotter periods, there were entire coral beds that were bleaching at a very rapid rate." Students begin by analyzing a variety of graphs and answering questions, and then use the evidence in the graphs, to make a claim of the correlation between temperature and bleaching events, using the claim, evidence, reasoning writing technique.

In Lesson 5 students explore the vital roles that mangrove forests play in tropical marine ecosystems, identify how climate change and human impacts are negatively affecting mangrove forests, and determine the efficacy of current restoration efforts. The case study examines the damage caused to a mangrove forest at Laughing Bird Caye due to a major hurricane, and describes the restoration efforts of local citizens. After engaging in the case study, students will analyze data taken from the restoration site and will design solutions for further restoration efforts based on their findings.

In Lesson 6 students will examine the positive and negative impacts of tourism on ecosystems and people's lives through reading a case study that showcases interviews from natives, and non-natives of Belize. Students will consider the costs and benefits of environmental issues so they can make informed decisions that may directly impact their well-being and/or the well being of those around them. Students will use the close reading technique to analyze the text, then make an argument for what they think is the best decision in regards to ecotourism utilizing the claim, evidence, reasoning technique. Teachers are supported with explanation of the techniques and appropriate graphic organizers, and rubrics.

CASE STUDY ALIGNMENT

CASE STUDY:	Howlers	Tree Frogs	Farming	Corals	Mangroves	Tourism
NGSS STANDARDS ALIGNMENT						
MS-LS2-2	X	X		X	X	
Describe how relationships among and between organisms and an ecosystem can be competitive, predatory, parasitic, and mutually beneficial and that these interactions are found across multiple ecosystems.						
MS-LS2-4	X	X	X	X	X	
Analyze data to provide evidence that disruptions (natural or human made_ to any physical or biological component of an ecosystem can lead to shifts in all its populations.						
MS-LS2-5	X			X	X	X
Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.						
MS-LS2-6 (2-1)	X		X	X	X	X
Explain how changes to the biodiversity of an ecosystem - the variety of species found in the ecosystem- may limit the availability of resources humans use.						
MS-LS1-4	X	X	X	X	X	
Explain, based on evidence, how characteristic animal behaviors as well as how animals interact with specialized plant structures increase the probability of successful reproduction of animals and plants respectively.						
MS-LS1-5		X		X		
Construct an argument based on evidence for how environmental and genetic factors influence the growth of organisms.						
MS-LS4-4				X		
Use a model to describe the process of natural selection, in which genetic variation of some traits in population increase some individuals likelihood of surviving in reproducing in a changing environment. Provide evidence that natural selection occurs over many generations.						
MS-ESS3-4			X	X		X
Construct an argument supported by evidence that human activities and technologies can be engineered to mitigate the negative impact of increase in human population in per capita consumption of natural resources on the environment.						
MS-ETS1-2				X		X
Evaluate competing solutions to a given design problem using a systematic process to determine how well each meets the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost may affect the function or effectiveness of the solution.						

CROSS CUTTING CONCEPTS						
Patterns		X	X	X	X	X
Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.						
Cause & Effect: Mechanism & Explanation		X	X	X	X	X
Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.						
Scale, Proportion & Quantity				X		
In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.						
Systems & System Models	X	X	X	X	X	X
A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.						
Energy & Matter	X			X	X	
Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.						
Structure & Function				X	X	?
The way an object is shaped or structured determines many of its properties and functions.						
Stability & Change			X	X	X	X
For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.						

PRACTICES						
Ask Questions & Define Problems	X	X	X	X	X	X
Develop and Use Models				X		
Plan & Carry Out Investigations						
Analyze & Interpret Data				X	X	
Use Mathematical & Computational Thinking					X	
Construct Explanations & Design Solutions	X			X	X	X
Engage in Argument From Evidence	X	X	X	X	X	X
Obtain, Evaluate, & Communicate Information						X

LESSON 1:
Saving the Howler Monkeys: How Should We Intervene?

Lesson Title: Saving the Howler Monkeys: How Should We Intervene?

Authors: Deborah Baird & Ryan Keser

Prerequisites: None.

Essential Questions:

1. How are humans and natural systems connected?
2. Do you have a responsibility in regards to the ecosystem?
3. How does educating others about environmental issues today, impact your future?
4. Can one person make a difference?

Objectives: Students will be able to (SWBAT):

- draw information and conclusions from a selected text
- design and evaluate solutions to educate the public about environmental concerns using a public service announcement (PSA) model

Language Objectives: I can communicate solutions to environmental issues through writing and speech.

Tier I Words: community, harmony, threatened, endangered, extinct
Tier II Words: value, strata, emerging, mitigate, vectors, diversity
Tier III Words: conservation, habitat fragmentation, primates, vegetation corridors, sustainable alternatives, [flora and fauna], and [habitat degradation and habitat restoration].

Big Idea: Students learn about and create public service announcements to educate the public about an environmental issue.

Next Generation Science/MA Standards::
MS-LS2-5: (Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.)
MS-ESS3-4: (Construct an argument supported by evidence that human activities and technologies can be engineered to mitigate the negative impact of increase in human population in per capita consumption of natural resources on the environment.)

MS-ETS1-2: (Evaluate competing solutions to a given design problem using a systematic process to determine how well each meets the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost may affect the function or effectiveness of the solution.)

Common Core Standards Addressed:
WHST.6-8.1. Write arguments focused on discipline specific content.
WHST.6-8.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
WHST.6-8.5. With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.
WHST.6-8.6. Use technology including the internet to produce and publish writing and present relationships between information and ideas clearly and efficiently.
RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.
RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.8. Distinguish among facts, reasoned judgement based on research findings, and speculation in a text.

Science Practices:
- Ask Questions & Define Problems
- Construct Explanations & Design Solutions
- Obtain, Evaluate, & Communicate Information

Cross-Cutting Concepts:
- Cause & Effect: Mechanism & Explanation
- Systems & System Models
- Stability & Change

Getting Started - Setting Up The Lesson:
One of the challenges of ecosystem restoration is educating the public on the need to take steps to change human behavior in order to mitigate the negative effects community actions may have on damaging local habitats and the organisms that live there. This interview with a primatologist from Mexico helps to shed light on the importance of public education as a critical step in preserving habitats and population of black howler monkeys. As students interact with the reading, they will have an opportunity to identify the strategies the primatologist suggested taking to help the Howlers, and then brainstorm ideas on how to best educate a local community about their plight. This strategy is approached in the spirit of designing solutions that may help mitigate the negative impact of human behavior on local ecosystems.

Materials:

- Saving the Howler Monkeys reading (adapted from: "Local Communities Key to Saving the Critically Endangered Mexican Black Howler Monkey - Environmental News for Kids)
- Science journals/interactive notebooks (INB's)
- Computers with Internet access
- Media equipment
- Examples of Public Service Announcements (PSAs) (See *Additional Readings and Resources)*
- PSA Rubric
- Optional: Camera, video camera, or tape recorder to record students' PSAs

Lesson Progression:

Elicit (5 min)
Ask students why education, in general, is important; then enlighten students that the solution to problems related to environmental conservation, or any problem for that matter, often involves educating the public. In this case, the need is to protect organisms and habitats, and the role of the student-educator is vital in creating lasting change.

Engage 1 (10 min)
Inform students that they will read an article (Case Study 1) from a primatologist who is working to preserve monkey habitats in southern Mexico. Hand out the article, Saving the Howler Monkeys and have them read it using a preferred reading strategy or refer to 3 Column Graphic Organizer in Appendix 3.

Explain (10 min)
Once completed, ask the students to address the following in their science journals/INB's:

1. What is the problem? (*habitat fragmentation is creating issues for the Black howler monkeys that places them on the critically endangered list.*)
2. Who are the responsible parties? (*humans*)
3. What actions have taken place leading up to the desire to protect primates? (*traditional research on issues such as: nutrition, exposure to emerging diseases, parasites, heavy metals, a decline in genetic diversity, and more.*)
4. What does the primatologist suggest as next steps? (*education, restoration programs, "wildlife crossing roads", sterilization program for predatory wild dogs… who also spread disease. Public education and a buy in from the community are the foremost solutions.*)

Communicate to the students that educating the public is critical for the successful protection of species, and that students will have an opportunity to create a public service announcement to practice this skill.

Engage (10 min)

Use the internet to search online for PSA (public service announcement) while incorporating descriptors such as “acid rain”, “polar bears”, “water pollution”, etc. to find plenty of examples to show to your students. Select one or two of your favorites, and play them for the class. Have students discuss what they saw. Questions: What images are involved? What kind of information is presented? How is the information organized/communicated? Note their ideas on the whiteboard, sticky notes for posting, or chart paper.

Explore

(1-2 days or more)

1. *Divide* the class into groups of two to four, depending on the children's talents and the size of the project.
2. *Model*. Allow children to listen to or watch a PSA as an example of the activity they will engage in.
3. *Brainstorm*. What messages does the public need to hear about? What are some slogans (such as "Don't Throw It All Away" or "Put Litter in Its Place") that can be used?
4. *Write*. Each group creates a "spot" (as broadcasters call them) with a statement of the problem, a suggestion, and a slogan. A writer's workshop approach with peer conferences to refine and organize their ideas is highly recommended.
5. *Publish*. Videotape or otherwise record the spot. The group may want to choose their best reader or employ a "turn-n-read" in which each member takes a portion of the script. If your students have smartphones with video capabilities, this is an appropriate place to use them. Students may use iPhones to record the video and then use iMovie to edit and publish. The recorded "spots" can be shared and evaluated within the class. Spectating peers can note one positive comment, and one, kindly worded, change that can be made to improve the PSA or presentation on a scrap of paper to submit to the presenting group. Work can also be shared with other classes, parents, or the world wide web.

Suggested Teaching Strategies:

- After showing students what a PSA is, you may want to have one of the groups do an impromptu PSA on a benign topic as a model for the class.
- Have students utilize storyboards, or templates to organize their thoughts (see resource list below for help.)

Local Connections:

This lesson plan is quite generic and can be easily adapted to make local connections. Identify issues with habitat fragmentation in your area, decreases in native species, spread of disease among organisms, road collisions, toxins and pollutants in the environment, and more. As the author of *Saving the Howler Monkeys* states, “It is very important to spread the value of wildlife...”, and what better way to do it than through education via Public Service Announcements.

Additional Readings and Resources:

Howler Monkey Facts:

- Howler Monkey - National Geographic for Kids at: http://kids.nationalgeographic.com/animals/howler-monkey/#howler-monkey-mom-baby.jpg
- Rainforest Alliance - Black Howler Monkey, *Alouatta pigra*, with sound clip at: http://www.rainforest-alliance.org/kids/species-profiles/howler-monkey
- The Belize Zoo at http://www.belizezoo.org/

Public Service Announcements Information:

- This resource includes an explanation of the PSA process, a storyboard graphic and rubric, and more. Plan Your PSA from scholastic.com at http://www.scholastic.com/browse/lessonplan.jsp?id=1504.

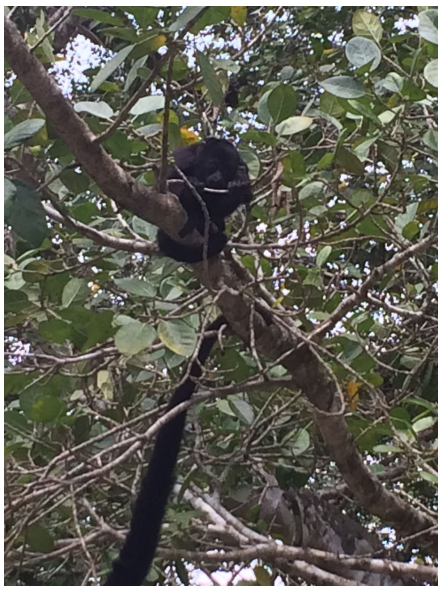
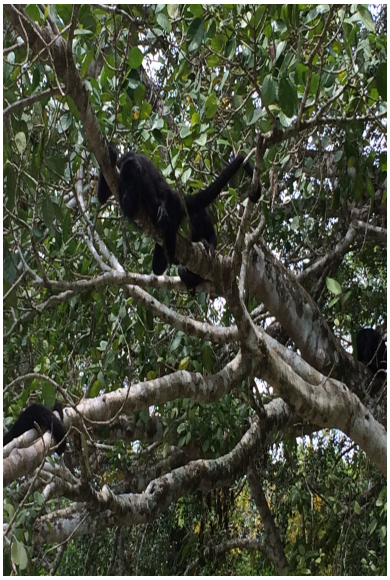
Howler Monkey Footage:

- Black Howler Monkeys - Belize: https://www.youtube.com/watch?v=BpDd573X4k4

Howler Monkey Sounds:

- The Call of the Howler Monkey: Belize tree tops at night - https://www.youtube.com/watch?v=aqhew0agfOk

Howler pictures:

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Roufs, Tiffany. "Local Communities Key to Saving the Critically Endangered Mexican Black Howler Monkey - Environmental News for Kids."Environmental News for Kids. Mongabay, 14 Feb. 2014. Web. 19 Aug. 2016.

LESSON 2:
Case of the Red Eyed Tree Frogs

Lesson Title: Case of the Red Eyed Tree Frogs

Authors: Rohan Kundari & Kareen Wilkinson

Prerequisites: Students should already know techniques to identify the main idea in reading as well as a basic concepts in populations and ecosystems. Introduction to the *close reading technique,* and the claim, evidence, reasoning (writing) technique.

Essential Questions:

1. How can evidence - quantitative and qualitative - be used to construct a scientific argument/decision?
2. What evidence supports or refutes that red eyed tree frogs population are in danger?

Objective: Students will be able to (SWBAT)

- analyze qualitative and quantitative data of red eyed tree frog populations in order to write recommendations on conservation strategies.

Language Objective: I can discuss, using evidence, the effect of climate change related trends on the red eyed tree frog.

Tier Words:

Tier 1: rainforest, climate, population, pattern, season
Tier 2: species, predator, prey, reproduce
Tier 3: endangered species, camouflage

Big Idea: Students read data and make a decision based on the presented data that may positively affect future populations of tree frogs.

Next Generation Science/MA Standards:

MS-LS2-2: Describe how relationships among and between organisms and an ecosystem can be competitive, predatory, parasitic, and mutually beneficial and that these interactions are found across multiple ecosystems.
MS-LS2-4: Analyze data to provide evidence that disruptions (natural or human made_ to any physical or biological component of an ecosystem can lead to shifts in all its populations.
MS-LS1-4: Explain, based on evidence, how characteristic animal behaviors as well as how animals interact with specialized plant structures increase the probability of successful reproduction of animals and plants respectively.

MS-LS1-5: Construct an argument based on evidence for how environmental and genetic factors influence the growth of organisms.

Common Core Standards:
WHST.6-8.1. Write arguments focused on discipline specific content.
RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.
RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific or technical context relevant to grades 6-8 texts and topics.
RST.6-8.8. Distinguish among facts, reasoned judgement based on research findings, and speculation in a text.

Science Practices:
1. Ask Questions/ Define Problems
2. Engage in Argument from Evidence

Cross-Cutting Concepts:
1. Patterns
2. Cause & Effect: Mechanism & Explanation
3. Systems & System Models

Getting Started - Setting Up The Lesson:
The Red Eyed Tree Frog is often times the symbol of the rainforest pictured on t-shirts, websites and public service announcements to protect the rainforest. While it is not endangered, this case study asks students to read about its reproduction habitat coupled with rainfall patterns in order to assess if the frog's population shows any signs of endangering in the future. Students may view the frog as safe for now, but should be pushed to think about the frog's future in the face of climate change indicators.

Prior knowledge on evidence of climate change is suggested before students complete this activity.

Materials:
Case Study: Case of the Red-Eyed Tree Frogs: Safe Now and Later? - 1 for each student
Belize Rainfall Graph - 1 for each group
Belize Rainfall Table - 1 for each group
3 Column Vocabulary Reading Sheet - 1 for each student

General Materials: pencil, dictionary, highlighter

Lesson Progression:

Elicit (5 min)
Begin by asking students to consider what organisms come to mind when thinking about the rainforest. Some anticipated answers may include frogs, bugs, monkeys and large trees. Ask students what does it mean for something to be endangered? Who determines it? How is it determined?

Explain (10 min)
Tell students that an endangered species is a species at risk of extinction because of human activity, changes in climate, changes in predator-prey ratios, etc., especially when officially designated as such by a governmental agency such as the U.S. Fish and Wildlife Service. Source: http://www.dictionary.com/browse/endangered-species

A plant or animal species existing in such small numbers that it is in danger of becoming extinct,especially such a species placed in jeopardy as a result of human activity. One of the principal factors in the endangerment or extinction of a species is the destruction or pollution of its native habitat. Other factors include overhunting, intentional extermination,and the accidental or intentional introduction of alien species that outcompete the native species for environmental resources. Source: http://www.dictionary.com/browse/endangered-species

Engage (20 min)
Pass out the Case Study Reading and the 3 Column Vocabulary Recording Worksheet. Have student either read it silently, independently or aloud in small groups.

Evaluate (20 min)
Once students have completed the reading, have them complete the Analysis Questions that accompany the reading.

1) The rainy season in Belize is typically from June to November. What data from the Belize Rainfall Data Table supports this information?
2) Melvis said that in June he used to see high numbers of treefrogs compared to recent years. What factors do you think have contributed to him seeing less?
3) The Rio Bravo Area typically has it's highest rainfall in the months of June and October. Look at the data table. Does the data confirm this trend for each year?
4) Based on the data and article, Red eye tree frogs are not considered endangered, but could these concerns be the first sign of a population decline?
5) How might a change in population of the tree frogs affect other living things in the Rio Bravo?
6) What do you recommend Melvis do and why?

Have students present their recommendations to question #6.

Local Connections:
This lesson can be easily connected to the Cod Industry in Massachusetts. The Atlantic Cod stands as the national fish of the state yet its population has fluctuated over many years due to overfishing. The New England Aquarium works in partnership with many fisheries to help study survivability research. Students can read what action steps have been taken to help the cod population.

Suggested Teacher Strategies:

- 3 column Vocabulary
- Introducing the Main Idea

Additional Reading Resources:

Red Eyed Tree Frog: National Geographic:
http://animals.nationalgeographic.com/animals/amphibians/red-eyed-tree-frog/

Red Eyed Tree Frog - Rainforest Alliance
http://www.rainforest-alliance.org/kids/species-profiles/tree-frog

Red Eyed Tree Frog - Tree of Life Web Project:
http://tolweb.org/treehouses/?treehouse_id=4841

The IUCN List of Threatened Species: http://www.iucnredlist.org/details/55290/0

Sources:

University of Massachusetts Boston: Atlantic Cod:
https://www.umb.edu/academics/environment/boston_harbor_marine_ecosystem/atlantic_cod

New England Aquarium:

http://www.neaq.org/wp-content/uploads/2016/07/Blue_Summer2016_web.pdf

LESSON 3:
Forest versus Farm: Land Use in Belize

Lesson Title: Forest versus Farm - Land Use in Belize

Authors: Brittany Colford and Jennifer Barborek

Prerequisites: Students should be introduced to the 3 column vocabulary strategies guide prior to the activity. A basic understanding of the rules and procedures of a classroom debate will expedite this lesson.

Essential Questions:
1. How has land in Belize been used over many years?
2. How does deforestation affect wildlife and contribute to global climate change?

Objectives: Students will be able to (SWBAT)
- identify the reasons why forests are fragmented in Belize
- Identify how deforestation negatively affects local species
- Identify how deforestation contributes to global climate change.

Language Objectives: I can analyze information and make arguments for the best way to utilize natural resources.

Tier I Words: Belize, Mennonites, agriculture, debris, juvenile
Tier II Words: conservation, habitat, naturalist, climate change, mahogany, sustainable
Tier III Words: deforestation, vegetation, carbon dioxide

Big Idea: In this lesson, an eco-tourism guide explains how land has been used in Belize in the past and present. He discusses how current practices of clear-cutting, destroy habitat and contribute to greenhouse gas emissions.

Next Generation Science/MA Standards:
MS-LS2-4: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Common Core Standards:
RST.6-8.2
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.4
Determine the meaning of words and phrases as they are used in a text, including vocabulary specific to domains related to history/social studies.
RST.6-8.8
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
RST.6-8.1.B
Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
RST.6-8.1.E
Provide a concluding statement or section that follows from and supports the argument presented.

Science Practices:
- Ask Questions & Define Problems
- Engage in Argument From Evidence

Cross-Cutting Concepts:
- Patterns
- Cause & Effect: Mechanism & Explanation
- Systems & System Models
- Stability & Change

Getting Started - Setting Up The Lesson:
Students will use a combination of reading, writing, and speaking skills to draw conclusions and debate their viewpoint on the ethics of land use. These are skills that will transfer into their daily lives. The experience of this lesson will be enriched if the teachers could make unbiased distinctions between the Belizean and Mennonite cultures.

Materials:
- "Forest Fragmentation" document
- "An interview with Melvis Velasquez"- one worksheet for each student or group
- Video of interview
- Debate prompt: "Food, furniture, and forests: should Mennonites stop clearing land?"- one worksheet per group
- Debate Organizer- one worksheet per group

Lesson Progression:

Day 1

Elicit (8 min.)
Begin with a brainstorm on how humans use land- for farming, housing, businesses, roads, recreation, flower gardens, etc. Students should then discuss how the use of any specific piece of property is determined.

Engage (7 min.)
Discuss the pictures in the supporting document Forest Fragmentation. Students should identify the differences in flora and fauna between a primary forest and a secondary forest.

Explore (40 min.)
Each student should receive a copy of "An Interview with Melvis Velasquez." Students may read the transcript of the interview in groups or aloud as a class, and may use the 3 Column Vocabulary reading strategies as a guide. Alternatively, the students may view the video. At the end of the interview, students should complete the "Reading Comprehension" questions, and then discuss answers as a class. There are many themes discussed in the interview, so the teacher may decide to focus on a particular topic such as wildlife, ancient and modern land use, primary vs secondary forest, deforestation policy, illegal logging, or agriculture.

Day 2

Explain and Engage (45 minutes)
After exploring the interview, students will elaborate on the topics that Melvis Velasquez discusses in the form of a debate. Students should be split into two or more groups, and each group will debate one side of the argument, either in favor of keeping the forest intact or in favor of allowing forests to be cleared for the timber and agricultural industries. Students should read the debate prompt entitled Forest Fragmentation Debate Activity, and then form an argument using the Debate Organizer for their chosen position. After groups are sufficiently prepared, groups may engage systematically in debating land use policies in Belize.

Evaluate
Reading comprehension questions and participation in class debate may serve as an evaluation for this case study. For further evaluation, students may write a reflective response on their participation in the debate or describe their understanding of land use in Belize after engaging with this case study.
Suggested Teacher Strategies:
Prior to viewing the video and interview transcript, discuss with students the fact that there are language discrepancies that may make the typed text seem grammatically incorrect and that students should use the transcript as a *loose* guide for their activities.

Local Connections:
Habitat fragmentation occurs globally although crowded cities and their surrounding suburbs may feel its impact more heavily. It is hard not to cringe when yet another pharmacy, parking lot, or box-store is established. Students can use the Belize land use lesson to make connections with their local community, debating their viewpoints along the way.

LESSON 4:

Analyzing Coral Reef Trends through Graphs: Linking Cause and Effect, with Communication

Lesson Title: Analyzing Coral Reef Trends through Graphs: Linking Cause and Effect, with Communication

Authors: Debbie Baird, Jen Barborek, and Karina Scavo

Prerequisites:

- Students should have some basic graphing skills: i.e. be able to identify the *'x'*, and *'y'* axises, identify the independent (manipulated) variable, and the dependent (responding) variable.
- Students should be familiar with "Claim and Evidence" style writing (see appendix 3 for supporting materials.)
- Students may need an introduction to creating infographics (using Piktochart, Easel.ly, Glogster, etc.) per the extension activity.

Essential Questions:

1. How can analyzing scientific graphs help us find solutions to global issues?
2. Why are data analysis skills important?
3. What is the significance of healthy reef system for both marine life and humans?

Objective: Students will be able to (SWBAT):

- Explain the importance of coral reefs to marine ecosystems and in turn, local and global human populations.
- Identify cause and effects of coral bleaching
- Communicate scientific findings to a broader audience

Language Objectives: I can read and analyze information, make scientific claims through writing, and raise awareness for protecting coral reef ecosystems.

Tier I Words: marine, erosion, nurseries, algae, corals
Tier II Words: immersed, ecotourism, species, fragments, outplanting, greenhouse effect
Tier III Words: coral bleaching, acroporid corals, staghorn, elkhorn

Big Idea: Student analysis of graphs and subsequent infographic production's can have a profound impact on educating others.

Next Generation/MA Science Standards:
6.MS-ETS1-6(MA). Communicate a design solution to an intended user, including design features and limitations of the solution.
7.MS-LS2-1. Analyze and interpret data to provide evidence for the effects of periods of abundant and scarce resources on the growth of organisms and the size of populations in an ecosystem.
7.MS-LS2-4. Analyze data to provide evidence that disruptions (natural or human-made) to any physical or biological component of an ecosystem can lead to shifts in all its populations.
7.MS-LS2-6. Explain how changes to the biodiversity of an ecosystem—the variety of species found in the ecosystem—may limit the availability of resources humans use.

Common Core Standards Addressed:
WHST.6-8.1. Write arguments focused on discipline specific content.
WHST.6-8.7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.
RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.8. Distinguish among facts, reasoned judgement based on research findings, and speculation in a text.
RST.6-8.9. Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

Science Practices:
- Asking Questions/Designing Solutions
- Analyzing and Interpreting Data
- Constructing Explanations
- Engaging in Argument from Evidence

Cross-Cutting Concepts:
- Patterns
- Cause & Effect: Mechanism & Exploration
- Systems & Systems Models

Getting Started - Setting Up The Lesson : Middle-school students benefit greatly from graphical analysis as it is a transferrable skill. They are prompted to analyze information and make arguments as to how anthropogenic factors contribute to, and ultimately can reduce, influences related to climate change and coral bleaching events. Students participate in writing, research, argument, and effective communication through various tried techniques.

Materials:

- Presentation computer/Internet access (for pictures of corals and sharing multimedia); alternatively, copies of images may be handed out.)
- Copies of Case Study - Coral Reef Restoration Case Study: *Lisa Carne and Fragments of Hope;* one per student.
- Copies of graphs for analysis (8 total)
- Question sheets and answer key are below each graph
- Rulers or straight edge for analyzing graph axes
- Claim, Evidence, Reasoning teacher instruction, student rubric, graphic organizer (see appendix 3)
- Pencils, student supplied

Lesson Progression:

Elicit (10 min)
Allow students a few moments to turn and talk, and answer the following question. Record answers to question one on the board.

1. You ask your neighbor to come over and care for your prized pet-fish for one week while you are away on vacation. When you come back you see that the fish is dead. What do you think happened? How did he die? What are some possible explanations?

Show students pictures of healthy reef system, and unhealthy reef system and ask them to make and share out inferences; use *Down to Earth's - Bleached to Death* at http://www.downtoearth.org.in/coverage/bleached-to-death-56019 or comparable websites.

Engage (15 min)
Have students read the case study, *Lisa Carne and Fragments of Hope* and answer the accompanying questions in their science notebooks.

Explore (30 min)
Set up eight *graph analysis stations,* one for each of the graphs provided in this lesson. Provide each student with a question packet. Have students rotate in groups of three or four to each station, answering corresponding graph analysis questions with their peers.

Evaluate (homework)
Students will use evidence in the graphs and their question packets to make a claim, supported with reasoning, regarding a finding of their choice. Topics may include, but are not limited to: correlation of temperature and bleaching events, global coral reef locations, trends for bleaching events or temperature anomalies, etc.

Explain (20 min)

Teacher led
Did you know that corals are actually animals? Yes, they are! They may not look like your typical animal, but on a cellular level, you'll see that corals cannot be classified as plants. They do not have a cell wall, nor do they perform photosynthesis. Instead, they are heterotrophic, which means they can't make their own food. To get food, they have a symbiotic relationship with a type of algae that lives inside it. The coral provides a home for the algae, while the algae provides the coral with nutrients. This relationship helps corals to grow and thrive into large coral reef systems that provide homes and protection for a wide range of species, including fish and small aquatic life such as crabs and lobsters. Also, coral reefs help protect shorelines from erosion. This protection prevents beaches and villages on the shore from washing away during natural disasters! As you can see, both humans and aquatic life need healthy coral reefs!

Lisa Carne, a marine ecologist working in Belize, has developed one strategy for restoring the reef systems off the coast of Placencia. Her organization, Fragments of Hope, has been working hard to restore the unhealthy reefs using nurseries and coral reef outplanting. To learn more about their efforts, watch the video titled, *Coral Reef Restoration*, which can be found at the Fragments of Hope website, at http://fragmentsofhope.org/. The video is also available on YouTube by searching: *Coral Reef Restoration*, Fragments of Hope, at https://www.youtube.com/watch?v=3DwtFJLdxLw

Explore
Additional research on cause and effect of increased atmospheric/ocean temperatures and coral bleaching and mitigation of is optional.

Extend
Students could create infographics using Piktochart, Easel.ly, Glogster, etc., to share findings of anthropogenic factors by answering questions such as: Why do corals matter? What is coral bleaching? What can we do to reduce climate change factors, greenhouse gas emissions, and subsequent coral bleaching events?

Suggested Teacher Strategies:

- Prompt students to identify something of interest in the graphical-analysis, station activity to focus on for their claim, evidence, reasoning writing assignment. You may want to provide extra copies of graphs for students to do their writing assignments with.
- Some students will struggle with analyzing the graphs so pair accordingly and/or provide a list of graph terms and definitions.

Local Connections:

Coral reefs worldwide are disappearing from our oceans due to many factors: pollution, sewage, overfishing, tourism, and coastal development by humans. While all of these factors hurt our reefs in their own way, the most significant threat to our reef systems is climate change. Increased ocean temperatures leads to coral reef bleaching and even death. It is estimated that 75% of the world's coral population is at risk from these combined threats. Why should we care so much about these reefs, and who is working to protect them?

So, if we know that we need healthy reef systems, and we also know that humans are causing many of the common threats to those systems, what can we do to stop it? Who can show us the way?

Additional Readings and Resources:

Coral Videos

- Fragments of Hope

Coral Readings

-

Water Quality Parameters

- SCORE MODULE

Infographic Resources

- Piktochart at https://piktochart.com/
- Easel.ly at https://www.easel.ly/
- Glogster.edu at http://edu.glogster.com/

Claim, Evidence, Reasoning Technique

- Designing Science inquiry - Claim + Evidence + Reasoning = Explanation (from Edutopia) http://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell
- CER Writing PDF http://www.gcisd-k12.org/cms/lib4/TX01000829/Centricity/Domain/2410/cerwriting.pdf

LESSON 5:
Mangroves: Keystone Species of the Shore

Lesson Title: Mangroves: The Keystone Species of the Shore

Authors: Brittany Colford and Rohan Kundargi

Prerequisites: Students should be introduced to the 3 column vocabulary strategies guide prior to the activity.

Essential Questions:

1. What roles do mangrove trees play in a tropical marine ecosystem?
2. Which methods are effective for restoring destroyed mangrove forests?

Objectives: Students Will Be Able To (SWBAT)

- Identify the important roles that mangroves play in a tropical marine ecosystem
- Identify how climate change is negatively affecting mangrove trees.
- Investigate methods of mangrove forest restoration and efficacy of existing solutions
- Design alternative solutions according to their findings.

Language Objectives: I can read and analyze information and data and communicate solutions according to my findings.

Forests of the Tide (back ground reading)
Tier I Words: nursery, species, timber, adapters, canopy
Tier 2 Words: buttresses, desiccating, diminishes, conservation
Tier 3 Words: Mangrove, legumes, pneumatophores

Mangrove Restoration Case Study: Hurricane Iris
Tier I Words: hurricane, environment, corals, barriers
Tier 2 Words: eroding, restoration, translucent
Tier 3 Words: mangrove forest, crustaceans, Reily Encasement Method (REM)

Big Ideas: Students will identify a problem, utilize data to draw conclusions, and design solutions which may help solve the problem.

Next Generation/MA Science Standards:
MS-LS1-4: Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

MS-LS2-2: Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect population.

MS-LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Common Core Standards Addressed:

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
WHST.6-8.7: Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

Science Practices:
- Asking Questions/Designing Solutions
- Analyzing and Interpreting Data
- Using Mathematical and Computational Thinking
- Constructing Explanations
- Engaging in Argument from Evidence

Cross-Cutting Concepts:
- Patterns
- Cause & Effect: Mechanism & Exploration
- Systems & Systems Models
- Energy & Matter
- Structure and Function
- Stability & Change

Getting Started - Setting Up The Lesson : Pictures of mangrove trees and forests with their unique root structure will enlighten students who are not familiar with them and drive curiosity. For more information about the Reily Encasement Methodology (REM) of mangrove restoration at Laughing Bird Caye, the teacher should refer to the link under "Further Reading." A natural progression may be to introduce students to other methods of mangrove restoration as a comparison to the REM.

Materials:

- Copies of "Forests of the Tide" background reading (with 3 Column Vocab Reading Sheet)
- Copies of "Mangrove Restoration Case Study: Hurricane Iris"
- Copies of Mangrove Pipe Lab- Collecting Data (Option A) or Mangrove Pipe Lab- Creating a Model (Option B)
- Copies of Mangrove Pipe Lab Data Chart (Option A) or Mangrove Pipe Lab Data Chart (Option B)

Lesson Progression:

Day 1

Elicit (5 min)
Students brainstorm the marine species with which they are familiar. They can also investigate which species they believe are most "important" in the ecosystem.

Engage (40 min)

Have students read "Forests of the Tide" utilizing the 3 Column Vocab Reading strategy sheet, then discuss (in groups or as a class) how mangroves support other life forms. Introduce the concept of a "keystone" species. Students should make an argument whether or not they think mangroves should be considered a keystone species.

Day 2

Engage (20 min.)
Students read "Mangrove Restoration Case Study: Hurricane Iris" and complete the comprehension questions at the end of the reading.

Explore (class period)

Students will utilize data recorded on site at Laughing Bird Caye to make their own determination of the efficacy of the REM to repair damage from Hurricane Iris. Students may work in partners or small groups. Each group should receive a copy of the "Mangrove Pipe Lab" and "Mangrove Pipe Lab Data Chart." There are two options for this lab according to whether the teacher prefers to focus on gathering data from a graphic or using data to create a visual image.

- ***Option A***: "Mangrove Pipe Lab-Collecting Data" contains visuals with color coded pipes that denote presence of a seedling (with or without a sprout) or an absence of a seedling, which determines whether the method was effective or not for each plant. Students can fill in the Mangrove Pipe Lab Data Chart to make a determination of the percentage of successful replants. This option emphasizes collecting data from a model.
- ***Option B:*** "Mangrove Pipe Lab- Creating a Model" contains blank pipes displayed along the shore of the caye. Students use the Mangrove Pipe Lab Data Chart to fill in each pipe and create a model for what the restoration project looks like. This option emphasizes creating a model using data.

Explain

After the "explore" activity, students should explain whether or not they think the REM replanting on Laughing Bird Caye was successful or not. They must use evidence from the lab exercise to explain their answer. Student groups can compare answers to determine accuracy of results.

Elaborate/Extend

Students can research other methods of mangrove restoration that are used in various tropical mangrove forests to determine whether or not the REM is the most effective strategy.

Suggested Teacher Strategies: Option A above allows students to look at a visual representation of seedlings and sprouts and collect data, while Option B steers students to analyze the data and create a visual model of seeds and sprouts. Teachers may want to let students decide which option they are most interested in and have both sides report out.

Additional Readings and Resources:

- Mangrove Restoration Methods- Reily Encasement Methodology at https://www.cbd.int/doc/case-studies/tttc/tttc-00159-en.pdf
- "Hurricane Iris devastates southern Belize." The San Pedro Sun. Vol 11. No 40. 11 October 2001. http://www.sanpedrosun.com/old/01-401.html

LESSON 6:

Tourism's Impact on Local Environment and Community: Norwegian Cruise Line at Harvest Caye, Belize

Lesson Title - Tourism's Impact on Local Environment and Community: Norwegian Cruise Line at Harvest Caye, Belize

Authors: Debbie Baird and Kareen Wilkinson

Prerequisites: Introduction to the *close reading technique,* and the claim, evidence, reasoning (writing) technique. See appendix 2 for supporting materials. Alternative, teacher-preferred reading and writing techniques may be substituted.

Essential Questions:

1. What happens when ecosystems are altered for human use?
2. Should humans be allowed to restructure ecosystems to suit their own needs or should they be left as is?
3. How can humans share habit-space with plants and animals?
4. How can thinking sustainably help humans survive?

Objectives: Students will be able to (SWBAT):

- weigh costs and benefits of the impact of tourism on ecosystems and communities
- consider ecosystem management of corals
- make a claim, support it with evidence from the text, and provide reasoning

Language Objectives: I can make a claim and support it with evidence in regards to ecosystem use and management.

Tier I Words: tourism/tourists, environment, communities, habitat.
Tier II Words: exotic, influx, self-sustaining, indigenous, refuge, allocation, imminent.
Tier III Words: cayes, anthropogenic, catch and release, conservation (awareness), environmental impacts, ecotourism.

Big Idea: Weighing costs and benefits of environmental issues produces informed decision makers.

Next Generation Science Standards:

MS-LS2-5: Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.

MS-LS2-6 (2-1): Explain how changes to the biodiversity of an ecosystem - the variety of species found in the ecosystem- may limit the availability of resources humans use.

MS-ESS3-4: Construct an argument supported by evidence that human activities and technologies can be engineered to mitigate the negative impact of increase in human population in per capita consumption of natural resources on the environment.

MS-ETS1-2: Evaluate competing solutions to a given design problem using a systematic process to determine how well each meets the criteria and constraints of the problem. Use a model of each solution to evaluate how variations in one or more design features, including size, shape, weight, or cost may affect the function or effectiveness of the solution.

Common Core Standards

WHST.6-8.1. Write arguments focused on discipline specific content.

WHST.6-8.7. Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.8. Distinguish among facts, reasoned judgement based on research findings, and speculation in a text.

Science Practices:

- Ask Questions & Define Problems
- Construct Explanations & Design Solutions
- Engage in Argument from Evidence
- Obtain, Evaluate, & Communicate Information

Cross-Cutting Concepts:

- Patterns
- Cause & Effect: Mechanism & Explanation
- Systems & System Models
- Structure and Function
- Stability and Change

Getting Started – Setting up the Lesson: Students need practice weighing costs and benefits of environmental issues so they can make informed decisions that may directly impact their well-being and/or the well being of those around them. This case study prompts consideration of the positive and negative impacts the tourist, cruise line, industry has on ecosystems and livelihoods. Students will use the close reading technique to analyze the text, then make an argument for what they think is the best decision in regards to ecotourism utilizing the claim, evidence, reasoning technique.

Materials:

- Presentation computer/Internet access (for Maps of Belize and sharing multimedia); alternatively, copies of maps and images may be handed out.
- Copies of Case Study - *Tourism's Impact on Local Environment and Community: Norwegian Cruise Line at Harvest Caye, Belize; one per student.*
- Highlighters for close reading technique; any color, one per student
- Think, Pair, Share graphic organizers, teacher supplied
- Close Reading teacher instructions
- Claim, Evidence, Reasoning teacher instruction
- Claim, Evidence, Reasoning rubric; one per student
- Claim, Evidence, Reasoning graphic organizers; one per student
- Pencils, student supplied
- Access to computer lab for engage activity

Lesson Progression:

Day 1

Elicit (5 min.)
Show students pre-selected maps of the country of Belize in orientation to their geographic location. Display accompanying picto-map of Belize on whiteboard probing students to identify natural features, of marine and terrestrial organisms. Students may also notice dive flags and Maya symbolism representative of recreational activities and local culture respectively. Hopefully students will recognize Belize to be a very biodiverse area.

Engage (20 min.)
Close reading technique - Have students read case study independently (or this may be done aloud as a group as deemed necessary) without any front-loading by the teacher utilizing the close reading technique: highlight pertinent information and main ideas, circle unknown words with a pencil, and annotate on the margins of the document (with comments, aha moments, questions, comparisons, etc).

Students complete their portion of the think, pair, and share graphic organizer then complete the activity with a partner. (15 min)

Students should re-read the text on their own or hone in on a specific portion of the text the teacher feels is valuable (remember the close reading technique is designed for close examination of a selected reading which may be as simple as a paragraph or two). (10 min)

(Remaining time or homework)
Students should independently answer the text-dependent questions 1-3 in their science journals saving discussion for day two.

Day 2

Engage (20 min.)
Students share answers to text-dependent questions 1-3 as a whole group; engage students in discussion and analysis.

Explain (10 min.)
Teacher clarifies pertinent vocabulary or lingering questions

Evaluate (25 min.)
Students respond to question four of the student comprehension questions, using the claims, evidence, reasoning graphic organizer: *Should large cruise ship companies be allowed to dredge (dig up) and recontour (add stone and materials and supports) coastal environments for their own use?* Teachers can use the accompanying NSTA CER Rubric for grading.

Engage (1-4) days
In this mini-research project students work on individual parts of a collective activity to be shared with a wider audience in the form of an ebook or printed book. The goal is to research the structure, function, anthropogenic effects, and sustainable practices in a coral ecosystem. Have students work in groups of two or three and choose one of the topics below for their part in the activity:

1. Structure of Coral
2. Function of Coral
3. Biodiversity in Coral Reefs
4. Nutrient Pollution/Agricultural Runoff and Coral Reefs
5. The Impact of Coastal Development on Coral Reefs
6. The Impact of Tourism on Coral Reefs
7. Overfishing and Coral Reefs
8. Sustainable Practices and Coral Reefs (several groups can be assigned to this topic as there are a wide variety of sustainable practices.)

Each student group should provide information about their topic in the framework of the already practiced claim, evidence, reasoning (CER) technique. Students should do their best to condense their information onto one 8.5” x 11” piece of paper; no more than two. If permissible, students can work in Google Documents and later compile their information that can be shared

directly with via a link… or work can be created as a video or e-book format. Alternatively, students may print their book in PDF format.

Teacher example of project using CER format:

Biodiversity in Coral Reefs

Claim:

Healthy coral reefs are very biodiverse ecosystems.

Student adds picture here

Evidence

There are many different corals in a range of colors.
Corals reefs have a wide variety of fish living amongst them.
Corals have a symbiotic relationship with zooxanthella.

Reasoning

Students then go on in paragraph form to support their claims maybe naming a variety of species of coral, identifying different species of fish, and explaining how the coral and the zooxanthellae, mutualistically benefit from each other. Any scientific explanation, related to the evidence and the original claim is acceptable.

Students are expected to source all research including use of others digital images.
Teachers can use the NSTA CER Rubric to grade project pages.

Extend

Students can study impacts on ocean, lake, drinking water, etc. from activities such as dredging and filling in shipping and boat channels and near estuaries, surface and agricultural run-off, human activities that impact drinking water, etc.

Suggested Teacher Strategies:

- Provide a CER graphic organizer to students who are struggling see resources below for ideas.
- Remind students that this is a mini-project and they do not need to gain volumes of information, but should rather focus on depth in their topic.

Local Connections:

This lesson plan can be adapted to make local connections: Student's from coastal and lake communities can consider the impact of tourist and recreational activities on ecosystems such as cruise lines, boating, jet ski's and skidoos, whale watching, diving, fishing, beach-bathing, etc.

Additional Readings and Resources:

Belize

- Belize Dive Map and Reef Creature Identification Guide

http://ambergriscaye.com/fieldguide/franko-Belize_Fish_ID_Cards.html

- Amandala "Belize's Leading Newspaper" Cruise port exclusivity in Belize – a thing of the past at http://amandala.com.bz/news/cruise-port-exclusivity-belize/

Corals

- Fragments of Hope: Work is focused on coral reef restoration and management of associated habitats at http://fragmentsofhope.org/

Estuaries

- Estuary education: This website provides 15, middle school curriculum units to teach students about the geographical features and significance of estuaries' and the importance of stewardship in these ecosystems. http://estuaries.noaa.gov/Teachers/MiddleSchool.aspx

Claim, Evidence, Reasoning Technique

- Designing Science inquiry - Claim + Evidence + Reasoning = Explanation (from Edutopia) http://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsell
- CER Writing PDF http://www.gcisd-k12.org/cms/lib4/TX01000829/Centricity/Domain/2410/cerwriting.pdf
- Science Notebooks: A tool for increasing student understanding of inquiry and science content (JCPS Analytical and Applied Sciences) http://www.indps.k12.wi.us/cms_files/resources/Notebooking%20ideas_including%20claim%20evidence%20reasoning.pdf

Coral Reefs, videos

- Coral Reef Restoration Program (Youtube): https://www.youtube.com/watch?v=3DwtFJLdxLw
- Saving Coral Reefs One Fragment at a Time (World Wildlife Foundation): https://www.youtube.com/watch?v=MLHfPgC3Yac

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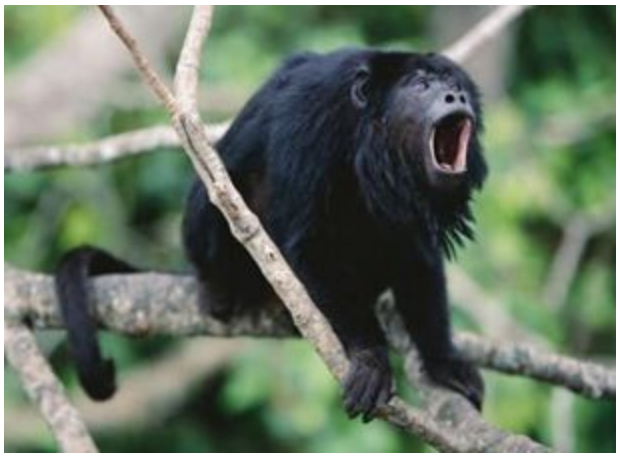
APPENDIX 1:
CASE STUDIES

Case Study 1: Saving the Howler Monkeys



MEXICAN PRIMATES

For conservation initiatives around the world, community involvement is often crucial. An additional challenge is how to conserve species once their habitats have become fragmented. A primatologist in Mexico is bringing these together in a celebration of a Critically Endangered primate species: the Mexican black howler monkey. Juan Carlos Serio-Silva, of the Instituto de Ecología, in Xalapa, Veracruz, has worked with Mexican primates for 25 years.

“Probably the most important and urgent activity is to promote more environmental education in all places where scientific research is conducted. It is very important to spread the value of wildlife (including primates) and the forested areas where they survive,” Serio-Silva explained in a recent interview, adding that, “We cannot be only spectators but we must act, researching, protecting, and restoring. Only then will our primate diversity and communities be able to live in harmony.”

The focus of his research team is to identify the way in which Mexican primates (black and mantled howler monkeys and spider monkeys) adapt behaviorally, ecologically and physiologically to the serious problems of habitat fragmentation. Thus, our research includes working with monkeys in several projects, for example: a) aspects of nutrition and food selection in different strata of the fragmented forest, b) exposure of wild primates to emerging diseases, c) parasite incidence and exposure to heavy metals, d) loss of genetic diversity by fragmentation of the environment, and e) the use of probiotics for the maintenance of captive animals and subsequent release of wildlife, among others.

Wild monkeys are extremely sensitive to the alteration of their habitat and although they have good behavioral flexibility to temporarily adapt to these changes, the reality is that we are slowly beginning to see their populations affected by isolation and by exposure to events and risks that were not present before (e.g., illness or deaths from collisions on the roads). In many places, these monkey populations are doomed to extinction and that is why in our research we seek the best strategies (academic and social) to mitigate these events.

CONSERVATION ACTION

“There are different options to increase the chances of preserving Mexican primates and their habitat, Serio-Silva says.” “But probably the most important and urgent activity is to promote more environmental education in all places where scientific research is conducted. It is very

important to spread the value of wildlife (including primates) and the forested areas where they survive. Besides these actions, we must perform restoration programs to develop vegetation corridors between forest fragments, which connect areas to help animals without having to go down to the ground exposing themselves to predators or be infected by diseases. These activities also provide temporary jobs for local people and will increase understanding of the value of preserving forested habitat on their properties and ranches."

Serio-Silva goes on to say, "We think that the link between researchers and leaders at all levels should be strengthened to propose sustainable alternatives and follow the "progress" without destroying the habitat of the species. One example of this should be ensuring that road construction companies create "wildlife crossing roads" to help avoid the many deaths caused by vehicles.

In several local sites, health authorities should also conduct sterilization programs for dogs on ranches where there is an incredible overpopulation of individuals. These animals are predators of many species of wildlife, and at the same time these dogs could be vectors for many diseases in the human-environment-primate interface.

Finally, the most important thing in all these different conservationist approaches is the organization with all people involved to try to include their interests and reconcile with the value of a better life for the future. This better life may only be obtained by combining productive activities with low impacts on the environment and restoration strategies for what is currently degraded."

FUTURE PLANS

"After devoting more than half of my life on this planet to study wild monkeys, many times I felt that there is something we have not done well, because forests are still being altered and primates are ever more threatened. When I meet many people in the local communities it seems that the reason for this unfortunate situation is that we had not been working together, and during many years many researchers around the world forgot the responsibility of teaching local communities and people involved in government offices about the importance of conserving the environment and primary species in the tropical forest like wild monkeys. Instead, some scientists said it was not their responsibility, and didn't return to the communities where they studied, and failed to provide information on the flora and fauna in the local language.

My plans for the future are much more than just undertaking more traditional research with Mexican primates. I wish that every moment I will have to do my research always involves a

component of education and conversion of habitat degraded to habitat restored. We cannot be only spectators but we must act, researching, protecting, and restoring. Only then will our primate diversity and communities be able to live in harmony."

Adaptated from:
Roufs, Tiffany. "Local Communities Key to Saving the Critically Endangered Mexican Black Howler Monkey - Environmental News for Kids."Environmental News for Kids. Mongabay, 14 Feb. 2014. Web. 19 Aug. 2016.

Comprehension Questions

1. What is the problem?

2. Who are the responsible parties?

3. What actions have taken place leading up to the desire to protect primates?

4. What does the primatologist suggest as next steps?

Comprehension Questions and Answers

1. What is the problem? (*habitat fragmentation is creating issues for the Black howler monkeys that places them on the critically endangered list.*)

2. Who are the responsible parties? (*humans*)

3. What actions have taken place leading up to the desire to protect primates? (*traditional research on issues such as: nutrition, exposure to emerging diseases, parasites, heavy metals, a decline in genetic diversity, and more.*)

4. What does the primatologist suggest as next steps? (*education, restoration programs, "wildlife crossing roads", sterilization program for predatory wild dogs… who also spread disease. Public education and a buy in from the community are the foremost solutions.*)

Case Study 2: Case of the Red-Eyed Tree Frogs

Melvis Vasquez, a naturalist at the Rio Bravo Conservation area, has been a passionate advocate and champion of the rainforest ecosystem for the past 20 years. A native of Belize, Melvis is considered an expert of the biodiversity of the rainforest. Leading a group on a nature walk he is able to identify hundreds of over 200 plants, 580 species birds and nearly all animals in the Rio Bravo area. Educating local Belizeans, school child and outside tourist groups on the importance of the rainforest is his passion, but will there come a time when there is nothing to show people? In recent years Melvis has began to notice fewer Red-Eyed tree frogs on his hikes than in past years. “You used to be able to walk around during the first week of June (beginning of the rainy season) and see 20 tree frogs hanging from a single leaf, hundreds in a single day, but for the last two years I’ve only seen 5 or 10 total a day.”

SPECIES DESCRIPTION

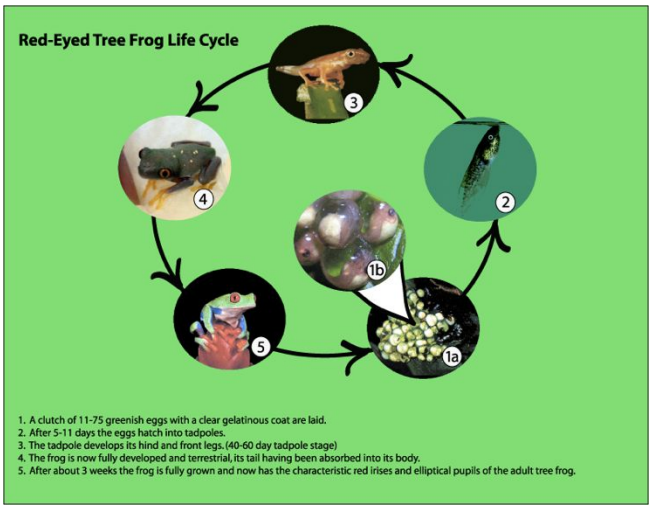
Belize is home to over 40 species of tree frogs, the Red-eyed tree frog (*Agalychnis callidryas*) can be found in Belize and stands out as one of the most photographed and recognizable frogs in the world. Red-eyed tree frogs are a small and delicate frog, averaging about 2-4 inches in length. Red-eyed tree frogs are nocturnal and carnivorous animals, eating insects such as crickets, moths, flies, and beetles by catching them with their long and sticky tongues. The frog exhibits bright coloration with orange webbed feet, and a green back that often matches the leaves it rests upon. This green varies between a fluorescent to dark forest green depending on time of day and temperature. Both the male and female species exhibit sky blue coloration on their hind legs and yellow spots along its sides. As its name suggests, the eyes of this frog are red with vertical pupils that appear to bulge out of its head (a common trait among the *Hylidae* family of frogs).

Red-eyed tree frogs are primarily arboreal found in low and tropical rainforest, throughout Mexico, Central America, and as far south as the upper parts of South America. Their environment is warm with high levels of rain, like most amphibians they depend on water for most of their lives. During the day these frogs spend most of their time sleeping, their coloring helps hide them from potential predators such as bats, snakes, birds, small mammals and lizards. When its eyes are closed and legs are tucked over its blue siding, it can appear perfectly blended into its environment. If disturbed while resting the frog will open its eyes and

move its legs as a way to confuse a predator. This is an attempt to startle the predator, giving the frog just enough time to escape. This defense mechanism, as well as camouflage may evolutionarily compensate for it being non-toxic since many brightly colored animals use toxicity as an adaptation. While awake at night it is more susceptible to predation as their bright eyes are open and their florescent coloration can be easily observed.

REPRODUCTION

Despite being arboreal, red-eyed frogs require a number of specific conditions to be fulfilled in order to successfully reproduce. Like many tropical frogs, red-eyed frogs enter their breeding mode during the rainy season, and require significant amounts of water on the ground in order to reproduce. Male frogs croak loudly to attract any nearby females, and will fight with nearby males to drive away competition. Male frogs will fertilize anywhere between 30 to 50 eggs. Once this is done females deposit these fertilized eggs onto vegetation and leaves located over pools of standing water. Bromeliads are an ideal plant for Red-eyed frog reproduction because their leaves grow in a circular pattern creating a natural water collection reservoir. After 5-10 days the eggs hatch and release small tadpoles (~0.5 inches) into the pools of water beneath, where they live for approximately 3 months. As the tadpoles mature they lose their tales and switch from using gills to newly grown lungs to help breathe out of the water. After 80 days the tadpoles are fully metamorphosed into adult red-eyed tree frogs and spend the rest of their lives in the rain forest canopy.



RAINFALL PATTERNS

Over the last few years Melvis has noticed a concerning trend regarding the Red Eye Tree frogs. “You used to be able to walk around during the first week of June (beginning of the rainy season) and see 20 tree frogs hanging from a single leaf, hundreds in a single day, but for the last two years I’ve only seen 5 or 10 total a day.” He and others at the Programme for Belize are beginning to wonder if any of their observations are an indication of a larger problem**.** In the last half decade, Melvis has lived through severe deviations from this pattern, observing multiple years of drought followed by only two or three months of rain which is different than the historical patterns.

Historically rainfall patterns in the rainforest follow predictable patterns with a rainy season between June and November while the dry season usually occurs between late November and May. The rainfall data shown in Figure 1 depicts the average rainfall for Belize from 2013 to 2016.

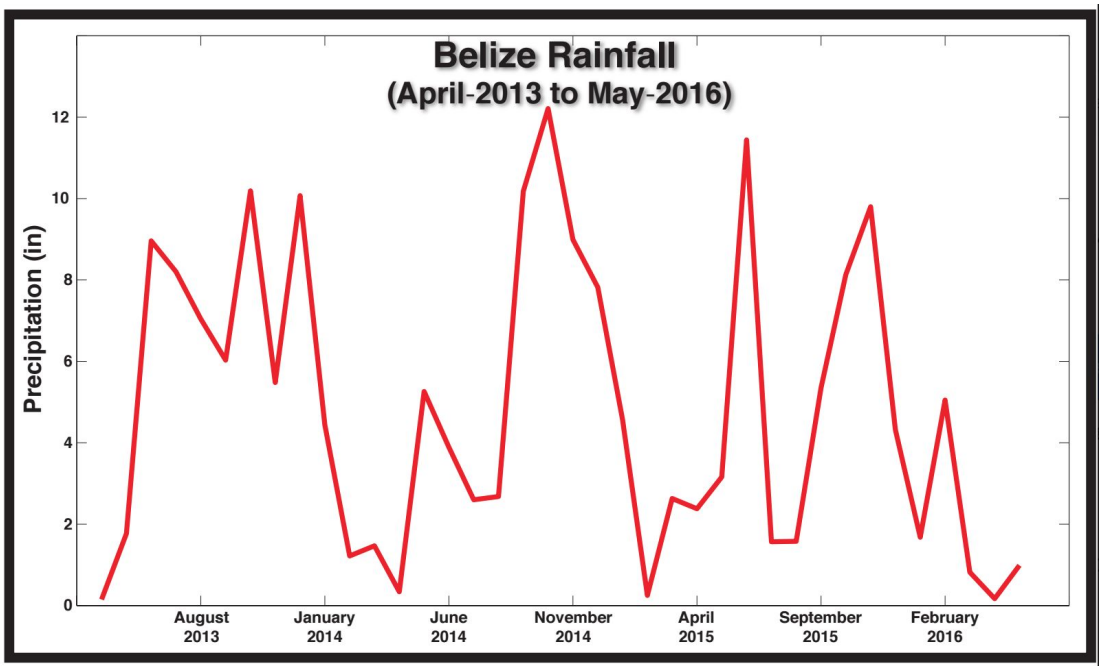


Figure 1. Belize monthly average rainfall from April 2013 to May 2016

IMPACT OF WEATHER PATTERNS

First, when a drought occurs the grounds become extremely dry, sometimes cracking open. With the lack of rain that the tree frogs depend on, they can't lay eggs in puddles and bromeliads. Second, scientists studying tree frogs worldwide have reported a fungus hurting tree frog populations. In the Rio Bravo, Melvis has seen indications of this fungus on some red-eyed tree frogs. The fungus grows as a white film over the back of the frog, changing its coloration and causing respiratory problems by hindering the ability of a frog to breathe through their skin. Third, higher temperatures have been recorded in the Rio Bravo area for the past 10-15 years. These higher temperatures have been linked to accelerated fungal growth on tree frogs in South America and may be the cause of the irregular drought and rainfall cycles.

Melvis simply cannot picture the Rio Bravo without the red eyed tree frog. Red eye tree frogs are not considered endangered, but could these concerns be the first sign of a population decline? How might a change in population of the tree frogs affect other living things in the Rio Bravo? What do you recommend Melvis do and why?

Case Study 3: Interview with Melvis Vasquez

Following is a transcript of an interview with Melvis Vasquez that is meant to be used in conjunction with a YouTube video presentation. The transcript has been edited slightly for readability. Melvis is a naturalist guide at La Milpa EcoLodge, Rio Bravo Conservation Area, Belize.

Hi Melvis! Can you please explain to us what Rio Bravo is, and what your role is here at La MIlpa?
Hi kids, I'm Melvis. Rio Bravo is an area set apart for conservation and protection. The Rio Bravo, here, is a very special place, because it creates a habitat for wildlife. What I mean by wildlife is birds, mammals, deer, jaguars, pumas, ocelots, you know, all of the wild cats in the forest. And not just wild cats, but insects as well.

And what do you do here again?
My role at Rio Bravo: I am a naturalist guide, and I've been doing this for quite some years, but I've worked at Rio Bravo for six years now.

There are Mayan ruins here at this property. Can you explain to us what the land might have looked like when the Mayans lived here?
Yes, there are fifteen Mayan cities in the Rio Bravo property. When the Mayans were around, these cities were huge. And when I say huge, tremendously huge with populations up to 30,000 people per city, and the land was pretty much deforested and was pretty much cleared. So there was not much forest left when the Mayans were around.

So when the Mayans lived here, the land was cleared. Was that for farming purposes?
Yes, most of the time, because of the huge populations that the Mayan cities had back in those days, the land was cleared for farming, for agriculture, for slash and burn. Again, not just for slash and burn [for agriculture], but also the deforestation was because the Mayans needed the firewood to burn white lime for the construction of their buildings, which are the temples.

So how has the land changed then since the Mayan left this area?
The Mayans left somewhere around one to two thousand years ago, and the land has pretty much recovered. The forest and vegetation has pretty much recovered to the stage where you will find trees that are 150 years old, which is more like a primary forest. Trees in a secondary forest would be closer to 80 to 85 years old. So it's kind of coming back which is very, very, very good because again, it provides habitat for animals.

You said something about primary and secondary forest. Is there a way that I can look at a forest and be able to tell if it's older or newer?

Yes definitely the height of trees in the tropics can literally tell you more or less the age of the forest. Again, secondary forests in the tropics here in Belize are between 80 to 85 years old, or feet in height (these trees grow approximately one foot per year.)

What if today we had people in Belize who started changing the land and using it like the Mayans used to?
If we were to do that, we would be in big trouble. Definitely very big trouble. Because again, [deforestation] is not a good thing. It's a huge contributor to global warming, [and] also climate change, and that is not good. If we were to do that, again here is a second reason. We would provide more and more global warming, and what does that bring? That brings natural disasters to us in the tropics. Like for example, hurricanes. If there is global warming we get more shallow sea waters of the Caribbean Sea and that is a recipe for [strong] hurricanes.

All right, so who currently today farms the land and provides food for Belizeans?
It's a group of people called the Mennonites. And you guys probably know who the Mennonites are, because you have them in North America and in the states. These people are the largest farmers in the country of Belize as we speak. And they usually farm for agriculture, and they use the land for pastures or cows.

So when they clear that land, are there any sort of rules about how they clear the land?
For them, the rules don't really work, but they clear the land anyway. For example, they should not be burning the debris, which they do. The way the forest is deforested is the trees are uprooted with bulldozers, which are very strong mechanical tractors with huge chains. It's pretty sad to see all of that. And when they do deforest, they pile them up together and they burn them. Again, a very huge contribution to pollution.

One of the other sites within Rio Bravo is Hill Bank, and in the history of Hill Bank, there was a lot of logging that happened here back in the day. Today, would you say that there is still any sort of illegal logging that happens in this area?
Most definitely. The logging was done by the British in the 19th century until the mid nineteen-eighties here at Rio Bravo, and they were destroying mahogany. And yes, because mahogany is our national symbol, it's our national tree of Belize, it's one of the most valuable woods in the tropics. Illegal logging is definitely occurring here and is done by the locals. And, I mean, these people will never let [trees] mature, or a baby tree, juvenile mahogany get into an adult stage or a mature stage.

If I were to get logs or wood in a sustainable way, how could I prove that?
There are many ways you can do that. There is the forestry department of the government and there is an agent that actually comes and checks us every year [to see] if we are doing this in a sustainable way. There are certain rules and regulations that we follow or protocols that we follow. For us, one pretty good way to show that we are [logging] sustainably or [in] a legal way is a stamp on the underside or point of the log, whether it is mahogany or cedar or costa or any

other species of tree, it has to have that stamp from our conservation area, Programme for Belize, and also one from the forestry department.

It sounds like there's some really strict regulations on how we use the forest. Is it such a big deal if we cut down these trees?
It is a big deal, because remember that the we need the forest. One way I can tell you, that we need the forest and the trees standing here is because we need the oxygen that these trees are releasing, and they are trapping carbon dioxide into them to grow much, much bigger, to reduce the amount of carbon dioxide in the air.

Are the trees home for any of the other organisms that live here?
Yes trees, or one specific tree, or one single tree, one single shrub in the forest can be a home for many, many insects, birds, and even mammals. Mammals live in cavities of trees, of old trees. So one tree can provide a great habitat for anything in the forest; any living organism in the forest.

You told us that the Mennonites cut down some of the trees for agriculture. What else do they do with the trees after they've cut them down?
Well if it's a mahogany, they will use it for furniture making. If it's a cedar, they would also use it for furniture making, because Mennonites are not just farmers, they are also carpenters, and that's the reason why they support the black market and illegal logging.

Is there any one takeaway that you would like to tell us about land use past, present, or future here at La Milpa or Belize? One final lesson to be learned here about land use in Belize?
One lesson to be learned, I can say: Use the forest the way it should be. Again, when we say that, remember that most of our food sources come from the forest. And most of our medicinal stuff that you buy in your local drugstore or that you buy over the counter comes from the forest. Alright, so that's a really good reason to keep the forests around. Even you out there: when you buy your prescribed medicine over the counter, keep in mind that it comes from the forest. So that's a very important way to hold that forest intact. Just remember, if you want to save the forest, you can start doing that now by educating yourself about conservation, and protect forests around your area.

Comprehension Questions

1. What is the importance of setting aside land for conservation?

2. How did the Mayan people change the land to get the food they ate?

3. How are deforestation and global warming related?

4. Why do you think it is important for the government to be involved in the logging industry?

Case Study 4: Lisa Carne and Fragments of Hope

By Jennifer Barborek

CALIFORNIA TO BELIZE

Lisa Carne grew up on the sunny, beautiful west coast of California. From a young age, she learned to appreciate the ocean, marine life, and all aspects of nature. After attending college at the University of California at Santa Cruz, she moved to Belize to continue her life of sunshine and beach living. As a tour guide, she introduced tourists to the local coral reef and whale sharks. Over the short time she had been there, she became fully immersed in the local village and culture. She also quickly realized how connected the Belizians are to nature, specifically the local coral reef environment.

Lisa's main home was in the city of Placencia, which is located on a peninsula out in the Atlantic Ocean. This area is one of the biggest ecotourism attractions in Belize due to its coastal location and variety of marine life that can be observed. Also, many villagers are deeply connected to the ocean through either fishing or working as ecotour guides themselves. Their lives are dependent on the health of the local coral reefs and other marine habitats. In addition, the healthy coral reefs protect the village itself from land erosion during tropical storms such as hurricanes. Without the reefs, the village might even get washed away!

CORAL BLEACHING

Over a short time into her care-free life, however, Lisa began noticing some changes to the beloved coral reefs nearby. As she was leading scuba tours along the reef, she saw fewer and fewer species of fish hanging out nearby. The coral itself began to show some signs of change as well. Some began to change color, from their healthy reds and browns and yellows to a paler, whitish hue. This is known as coral bleaching, which can lead to coral death. Specifically, acroporid corals, which may be some of the most important corals on the Caribbean reefs, began to disappear at a rapid rate. These species of corals are extremely important in preventing Placencia beach erosion, as well as attracting large numbers and varieties of fish species.

Not only did these changes affect Lisa's livelihood, but they also sparked her curiosity. What could be happening to the beloved corals? In order to find out more, she researched both local and global coral systems to understand why these changes were taking place. Amazingly, she discovered that this was not a local phenomenon, but rather, could be observed in nearly all coral reef environments, particularly those in warmer, tropical climates. Could heat be a factor? She knew that global temperatures had been rising due to climate change and the greenhouse effect. With a team of local fisherman and civilians, she started collecting data about the local corals and the temperatures at the Belizian coast to see if there were any connections. The data showed that during hotter periods, there were entire coral beds that were bleaching at a very rapid rate.

HOPE FOR CORALS

What was Lisa to do? Could she stop global warming in a day? No. Could she lower the temperature of the ocean? No. She needed to find a solution that would help the corals now,

and in turn, help her Belizian community. She started brainstorming ideas with old colleagues and new friends, and eventually developed a method that they believed might help regrow Placencia's coral reefs. They decided to name it Fragments of Hope, in the hope that they could restore coral fragments and also the hope of the Belizian community.

The method of Fragments of Hope seems simple, but actually required lots of planning and experimentation. First, they had to identify the best type of coral to replant. This would need to be a coral that was endangered and important to Placencia's reef system, but also could grow well in a nursery setting. The best nursery setting for corals is a place with less wave energy, where the human volunteers can easily access and scrub away harmful algae. In Lisa's case, she chose to build these nurseries at Laughing Bird Caye. It was the perfect setting. Laughing Bird Caye is a protected marine environment and also a no-take zone, which means that no fisherman nor tourists are allowed to take anything away from this coral reef ecosystem. Now that they had their location, Lisa and her team needed to pick the best coral to regrow and the type of frame to use for their nursery.

RESTORING THE REEF

Placencia is home to a large variety of both fish species and coral species. The Fragments of Hope team needed to find the best coral reef species to benefit from the restoration process. Through much observation and data collection, they chose the endangered staghorn and elkhorn corals to help regrow. These corals are the most important in Placencia for three reasons. First, they grow much faster than other corals, so they can repopulate the reefs more quickly. Second, they provide a home for many different species of fish and invertebrates. Last, these corals have long branches that extend up to the surface of the water and help slow down incoming waves. These waves then have less chance of eroding the local beaches and land.

Two of the three big problems had been solved. Now, Lisa's team needed to find the most successful strategy for regrowing and then outplanting the corals. She reached out to other coral reef scientists for help in designing the best solution. Through many different attempts, they settled on a table-style nursery involving a metal frame with ropes draped across. The endangered corals are first found growing naturally out on the reef. A small fragment is carefully broken off, and then attached between the fibers of the rope. The corals grow on these nurseries for several months while human volunteers help by watching over them and scrubbing off any harmful algae. Once the corals are big enough, they are removed from the nurseries and out-planted to local dead reefs. While this process is highly successful, their work is not quite done. From that point, the Fragments of Hope team continues to monitor these corals and their growth, as well as collect data on the number and variety of marine life they attract.

Over the past ten years, the Fragments of Hope team have out-planted corals to over a dozen sites in Placencia, and are beginning to expand their efforts to other reefs in Belize. Their successes have become so well known, that many other marine scientists across the world have started to adapt their strategies for coral regrowth. Lisa has proven that with a little bit of education, and a lot of help from her community, she could actually make huge impact on ecosystems worldwide. Do you also have an idea that could change the world?

Comprehension Questions

1. What do the natives of Placencia, Belize depend on?
2. What is coral bleaching?
3. Why are corals important?
4. According to Lisa's data collection, when do corals tend to bleach?
5. Why are Staghorn and Elkhorn coral important?

Answer Key

1. Fishing, ecotourism, health of coral reefs and other marine habitats.
2. Change in color from healthy reds, browns, and yellows, to a paler, whitish hue.
3. Prevents beach erosion, attracts a wide variety of fish species.
4. When temperatures are higher.
5. A. they grow fast, b. They provide homes for different species and invertebrates, and c. they have long branches that breach the surface of the ocean waters and slow wave action to protect the island.

Case Study 5: Mangrove Restoration after Hurricane Iris

By Brittany Colford

THE DAMAGE

On October 7th into October 8th of 2001, a huge storm called Hurricane Iris swept through the southern part of Belize. It hit the small fishing town of Placencia, Belize and caused damage to 95% of the buildings there. The wind speeds in the hurricane reached 140 miles per hour, making it the strongest hurricane in the Atlantic ocean during that season. Luckily, there was a low number of human deaths, but it cost the Belizeans in many ways- electricity was cut, almost four thousand homes were destroyed, and farms and businesses were ruined.

Hurricane Iris also caused catastrophic damage to the environment in and around Placencia. One of the areas severely affected was an island off the coast called Laughing Bird Caye. Before the hurricane, Laughing Bird Caye was home to a large number of corals and a small red mangrove forest. During the storm, large waves up to 18 feet tall crashed over the island, which ripped the leaves off of the mangroves and uprooted most of the trees. This left a channel of water flowing through the middle of the island with little habitat for other animal and plant species around the area. It also left the island exposed with few barriers left to guard against possible damage in future storms. With few trees roots left on the island, the sand started to erode over the years. This meant that other trees and grasses started to fall over as the sand around them washed off into the ocean. The island was beginning to shrink! The people realized that if they needed to find a way to prevent the rest of the sand from eroding away.

The people of Belize cared very much for their national park and wanted to protect the organisms which were still living in and around the island. In the town of Placencia, there was a group of people who worked for an organization called Fragments of Hope. This organization focused mainly on rebuilding the coral reef, but two workers, Dale and Mariko, decided to try to keep the island intact by restoring the mangrove forest. If the mangrove forest regrew, then the roots would hold the soil together and provide a nursery for baby fish and crustaceans around the Caye.

RESTORING THE FOREST

Dale and Mariko knew they wanted to replant some mangrove seeds in the channel where the trees were washed away. However, they faced some problems. In the past when conservationists tried to plant mangrove trees directly in the sandy shore, the waves washed them away. If they grew to be large enough to sprout,

Reilly Encasement Methodology (REM) for planting Mangrove seedlings.

animals could eat them for food. Dale and Mariko decided to plant their mangrove seeds in a way that would protect the seedling called the Reily Encasement Methodology (REM). Using this method, they planted mangrove seedlings in PVC pipes that were anchored to the ground. The pipes stood about three feet above the ground, so that no animals could eat the young, fragile plants. They were translucent so that some light could enter to allow the plants to grow. The PVC also had some specific slits cut in the side, so that as the plants grew, they could expand and eventually fall off as the tree grew tall and strong.

Dale and Mariko planted 84 total mangrove seeds along the shore of Laughing Bird Caye. As the plants grew, they checked up on the seedlings periodically. In order to know if the REM was working, they had to count the number of pipes that had seedlings growing and how many had sprouts with leaves in them.

Sources

Comprehension Questions

1.How did the storm damage the town?

2. How did the storm damage the mangrove forest on Laughing Bird Caye?

3. What happened to Laughing Bird Caye after many years?

4.Where did Dale and Mariko decide to grow the new mangrove trees?

5. What did Dale and Mariko put in the ground to protect the mangrove seedlings?

Case Study 6: Interviews in Placencia

By Debbie Baird and Kareen Wilkinson

Likeness of Harvest Caye, Belize with cruise ship in port.

Norwegian Cruise Line (NCL) is one of many vacation options available to explorers of the world. Their brochures entice customers with pristine-like destinations and alluring activities. Once onboard, passengers relax on a floating buffet of food, drink, and entertainment, as they sail off to an exotic adventure.

Communities on the receiving end of the cruise line, particularly those that are establishing themselves, are sometimes conflicted about the arrival of tourists. The sudden influx of large groups of people can be overwhelming. They know the visiting ship will bring a boon to the local economy, but at what cost? There are legitimate concerns over infrastructure, waste management, destruction to ecosystems, and invasion of privacy to name a few of the problems that can arise when a less developed area becomes a tourist destination.

Placencia, a small town on the mainland of Belize, currently deals with conflict between tourism and habitat preservation. Belize's coast is dotted with hundreds of island-like structures called cayes most of which are a few kilometers squared or less. The cayes serve an ecological purpose in that they buffer storm systems, provide nesting areas for migratory birds, and a habitat for a myriad of marine life such as turtles, manatees, crocodiles, and corals.

NCL will institute its new cruise-port destination in November of 2016 on a caye approximately three miles off the coast of Placencia called Harvest Caye. They will dock one ship per week and eventually increase this number to four. The visits may bring tens, or even hundreds of thousands of tourists to the caye and mainland per year. There are mixed opinions as to the disadvantages and benefits of this tourist industry. A team of graduate level students from Boston University, MA, U.S.A, and affiliated middle-school science teachers visited Placencia to do some studies on coral reef habitats and to consider anthropogenic influences. The team was led by Lisa Carne of Fragments of Hope, a community based organization that is finding success in farming corals and protecting associated habitat. Together they were able to interview some locals and gather their opinions on how they think NCL will impact them. Following are the results.

The research team and associates on Laughing Bird Caye; April of 2016.

INTERVIEW WITH OLIVIA (aka Olive)

Olive is a Kekchi Maya. She lives in Punta Gorda with her husband and eight children in a place called Big Falls Village. Her husband is a farmer who works his own plot of land where he grows cassava (a starchy root vegetable) and cacao. In keeping with the earlier Maya tradition for girls, Olive has no formal education. Seventeen years ago she learned to speak English through a women's literacy group that caters to ten to fifteen women in each of the thirty-six surrounding villages. She completed her training over the course of nine months. Aside from reading and writing, the organization taught her how to make pastry, sew clothes, and be successful at maintaining a family gardening. Olive's way of life is tough but is already getting better as her new skills help her rise above poverty and become more self-sufficient. She is able to help other women develop these self-sustaining skills as well.

Ms. Wilkinson, one of the research team members, with Olive displaying one of her hand woven tapestries.

Olive's primary income is derived from selling handmade wares to tourists in Placencia during peak tourist season – the months of January, February, and March. She fills two large packs with woven baskets and bracelets, wood-carvings, beaded jewelry, and tapestry made in the ancient, hand-woven tradition. Her boys help with the wood carvings and her eleven year old daughter has perfected beaded jewelry. She leaves her house at 4:30 in the morning, takes a

two-hour bus ride to town, and then walks amidst the hustle and bustle of tourist traffic. As the season winds down she is forced to walk up and down the hot boardwalk, dusty streets, and even onto the burning sand in search of customers. She travels to the city two days a week and spends the remaining days crafting her items.

When asked about the arrival of the November 2016 NCL at Harvest Key and the possible impact on her business, Olive's eyes widen. She anticipates her prospects will improve. A "kiosk" in the vicinity of the ship would be less draining, allowing her to be stationary and bring the customers to her. She feels it is important that people know her work is authentic and a stable location that includes demonstrations would convince tourists of her skills. Olive passionately envisions being able to share the artistic side of her trade through demonstrations of weaving fabrics on a loom, beading, and jewelry and basket making. Her vision is to see that her eight children receive an education so they will have more choices in their futures.

Olive has been to Laughing Bird Caye. She has observed some of her fellow Mayas stepping on the coral. She states, "They don't care." She understands the significance of the coral and the role it plays in bringing tourists, some as possible customers, since she adds, "Coral, that is what attracts people."

INTERVIEW WITH IAN AUGUST

Ian August lives in Belmopan, the capital of Belize. He is a divemaster and works with the Seahorse Dive Shop in Placencia. He has a Bachelor's Degree in Tourism Management and has combined that expertise with eighteen years of dive tours. Most recently he came down to Placencia for the start of Whale Shark season. On today's dive the group saw snappers, dolphins, bull sharks, a hawksbill turtle, and many fish indigenous to the area.

Ian is a native of Belize. He states that, "thirty-three percent of the country" depends on "marine and forestry" industries which provide a major platform for tourism. Since Hurricane Iris in 2001,

Placencia has flourished due to help from the international community and motivated community leaders. He informed us that NCL had bought Harvest Caye and “cleaned it up,” turning formerly hard to navigate terrain into accessible walking paths, swimming pools, and clean, sandy beachfronts.

Ian understands the importance of coral reefs. Along with the mangroves, they are an essential line of defense against storms that erode the coastline. The reefs and mangroves also act as a refuge for juvenile fish, an essential habitat for a fishing village. He is aware of the controversy surrounding the stress major cruise companies put on ecosystems. Ian admits he has been adapting himself mentally for the changes the industry will bring.

Ian envisions Belize as a miniature United States, progressive, but with its own set of issues. Belize presently has a population of approximately 360,000 citizens. “A lot of Americans are coming to Belize, putting capital investments in boats, restaurants, and gift shops. The economy is very stable,” he states. Traditionally, Placencia is a fishing village but is no longer able to produce the same catch as it has in previous seasons due to a decrease in the fish population. In response, the Belizean government has limited fishing licenses, closed seasons, and encouraged alternatives to fishing. Suggested alternatives are selling aquarium fish, harvesting Sea Cucumbers, seaweed farming, guided fish tours (some with catch and release), crafting with conch shells, and a stronger focus on tourism. The government hopes these measures will induce replenishment of fish populations thereby assisting local fishermen.

Overall Ian feels tourism is a vital part of the Belizean economy; it is definitely a part of his livelihood and he does not show concern about cruise line tourism off the coast.

INTERVIEW WITH NICOLE AND MIKE, TOURISTS

Nicole and Mike are certified, recreational divers. They came to Belize this April primarily for Whale Shark season and to visit a premier dive location called the Blue Hole. Today's visit brought them to Silk Caye where they did two depth dives, the first at 90 feet and a second at 60 feet. They saw big lobsters, a moray eel, a multitude of tropical fish, the invasive lionfish, groupers, a variety of soft corals (purple, pinks, and greens), and lots of other sea life.

Nicole and Mike love diving and overall they have few, if any, issues with the cruise ship coming in. They have been to many locations as tourists but one of their most memorable experiences was the Great Barrier Reef in Australia. Aside from personally enjoying snorkeling and diving as a hobby, they believe, "it is good for conservation awareness." Nicole and Mike adeptly stated, "Trained divers know not to touch corals and wildlife."

INTERVIEW WITH GEOF LEIBEL

Geof Leibel is the owner of a quaint, local restaurant called Tranquilo which is only accessible by boat as it is built over the water as a sort of stand-alone dock. Geof, originally from the southern United States, had been visiting Belize for the last fourteen years He took up residence five and a half years ago, and finally became a restaurateur two years ago.

Tranquilo Restaurant, Placencia Caye, Belize

Leibel's opinion of NCL's impact on Harvest Caye contrasts sharply with those of the other interviewees. He has deep felt concerns over the environmental impacts this new tourism will bring, especially concerning the Manatee habitat during calving season. He claims there is, "photographic evidence of dredging" and boulders that were brought in to re-contour the Caye both of which have disrupted this ecosystem. He questions rhetorically, "How will this barrier reef absorb impact of too much eco-tourism?"

In addition, there are concerns about wastewater management (especially since Placencia presently has only one public restroom), available drinking water, and trash. "Easter is the busiest time of the year," Geof states, "and water pressure comes to a trickle." Even the physical layout of the town is problematic: Placencia is listed as having the world's most narrow main street in the Guinness Book of World Records, a road that will be expected to support hundreds of added pedestrians during peak season. There is mild exasperation in Geof's voice as he rattles off other justifiable concerns such as available man-power, regulatory issues in the midst of "an already taxed court system," and proper allocation of tourist/business funds to benefit the community. Geof states, "Some people are not concerned," they have a kind of "wait and see attitude." But he notes in the same breath that some local residents took an emphatic "NO" stance when NCL tried to create all-terrain vehicle tours through their community and manatee tours on the lagoon.

Geof is clear in his understanding for the need to provide employment for the indigent population. He states, there is "no manufacturing here in Belize." Belize relies heavily on its eco-tourism industry. The government provides opportunities for natives to train to become tourist guides through a rigorous education process. Guides must be Belizean born and adhere to strict regulations. The guides have a vested interest in their environment and that is a win-win for everyone.

Geoff is not making any preparations in anticipation of NCL yet. He knows the tourists will stay on board to eat the “free” food incorporated into the cost of the cruise line package and that cruise lines are on tight itineraries. He’s “happy with” his “own business after two years” and he is “not looking to deal with explosive growth.” Geof’s gaze drifts off toward the ocean as he grapples with the imminent presence of the Norwegian Cruise Line.

Only time will tell whether NCL offers a positive or negative outcome for the small town of Placencia. As observed by some of the people interviewed, the increase in tourism might bring new wealth into a rather poor area. Tourist dollars can improve living conditions, educational opportunities, and business options. But that optimistic view is diminished if the environment suffers the fate of irresponsible stewardship. All parties involved--the Belizean government, NCL, citizens of Placencia--must tend to the preservation of the natural habitats that make this area a desirable destination for tourists.

Student Comprehension Questions for Tourism in Belize

1. Create a graphic organizer of the costs and benefits of the tourism industry in Placencia, Belize.

2. Name three ways coral reef systems can be managed so they can provide habitat for juvenile fish and act as a storm buffering system (hard coral structures absorb some of the energy from hurricanes to reduce erosion and impact on the shore).

3. List and explain three things could you do in your own community to help protect habitats and the environment?

4. Answer the following question using the Claim, Evidence, Reasoning (CER) technique and graphic organizer: *Should large cruise ship companies be allowed to dredge (dig up) and recontour (add stone and materials and supports) coastal environments for their own use?*

Answer Key for Tourism in Belize

1.

Costs	**Benefits**
Damage to coral reef and mangroves, and associated habitats (fish, manatees, turtles, etc.) Damage to corals and mangroves will increase erosion of cayes.	More jobs to support increased tourism (guides, divemasters, staffing of restaurants and local businesses.)
Increased use of local resources, primarily water	Increased revenue for locals and Belizean government
Stress on infrastructure (i.e. small streets, one public restroom, etc.)	Improvement of infrastructure due to indirect demand from tourists.
Decrease in privacy and quaintness of present town	Chance to share and learn about cultural differences (on both sides)
Damage to cayes could threaten geographical stability to coasts (as the cayes act as a buffering system against storms)	Chance for increased education of ecosystems for tourists and natives alike.

2. Restrict access to certain areas of the reef or have a guide lead tourists, etc. through reef, educate people on the significance of corals and the importance of not stepping on them, harvesting them, or even touching them, increase awareness of corals to boaters, do not pollute the water, fund coral restoration programs, etc.

3. Answers may include, don't litter, conserve water, conserve electricity, educate self and others, etc.

4. Answers will vary based on student's stance (see accompanying Claim, Evidence, Reasoning (CER) instructions and rubric.

Work Cited

"Norwegian Cruise Line to Develop Belize Port." - Norwegian Cruise Line. N.p., n.d. Web. 09 Aug. 2016.

Lesson Title: The Rainforest Game

Authors: Ryan Keser (adapted with permission from *The Shape of Change by R. Quaden, A. Ticotsky and D. Lyneis)*

Objective: **Students will be able to (SWBAT)**:compare and contrast planting and harvesting policies related to managing a renewable resource.

Big Idea: Students play a fun, interactive game and act out the lives of trees while learning about responsible ecosystem management.

Next Generation/MA Science Standards:
MS-LS2-5: (Evaluate competing design solutions for protecting an ecosystem. Discuss benefits and limitations of each design.)
Science Practices: Analyze & Interpret Data, Use Mathematical & Computational Thinking, Construct Explanations & Design Solutions, Engage in Argument From Evidence
MS-ESS3-4: (Construct an argument supported by evidence that human activities and technologies can be engineered to mitigate the negative impact of increase in human population in per capita consumption of natural resources on the environment.)

Science Practices:
- Ask Questions & Define Problems
- Construct Explanations & Design Solutions
- Obtain, Evaluate, & Communicate Information

Cross-Cutting Concepts:
- Cause & Effect
- Systems and System Models
- Stability and Change

Getting Started - Setting Up The Lesson:

This is a simulated game where students act out the lives of trees by following various planting and harvesting policies. In doing so they learn about managing a renewable resource. Additionally, students will work with some basic data analysis by recording data in tables, graphing data, predicting outcomes and looking at the patterns of behavior over time.
In Belize, forestry practices are exploiting the bounty of natural resources that exist. It is a common practice for huge sections of forest to be bulldozed to the ground and burned as they are converted to farmland. There are no efforts to mitigate the destruction of animal habitat and the resultant relocation of any species.
Students will recognize that rainforests are threatened, but may not understand how to mitigate the negative effects of human action in these fragile ecosystems. Playing this game gives them a chance to discover different planting and harvesting scenarios and discuss the impact on each to the larger systems threatened.
Materials

- large display board or overhead projector
- markers
- one copy of three worksheets for each student:
  1. *What Happened to the Trees?*
  2. *Yearly Forest Inventory*
  3. *Mature Trees in the Forest*

Students play a simulation game in which they pretend to be trees that grow from seeds to mature trees in four years. Over the course of the game, students enact three different sets of planting and harvesting policies. After playing, they use a table and a graph to analyze what happened.

First policy: students play years 1 to 5 of the simulation game which demonstrates linear growth. The number of mature trees remains constant at zero until year three, after which it grows at a constant rate.

Second policy: students play years 6 to 8 which demonstrates equilibrium; the number of mature trees remains the same when the planting and harvesting rates are equal.

Third policy: students play out years 9 through 12 and test the results of increased planting and harvesting. Delays produce surprising results.

Finally students reflect on the game, complete their tables, plot their graphs, and draw conclusions. It's important not to announce the purpose of each policy to the students. Let them learn from experience and draw their own conclusions.

Also, students complete the table after they play the completed game. Do not share information or interrupt the flow of the game with details about what will happen. Let the students play and build their own understanding.

You can download the entire lesson here: The Rainforest Game.pdf

Lesson Progression: (Suggested format in the 7E model)
Engage (30 min)
Procedure

1. After discussing the current condition of the rainforest, tell students that they are going to play a simulation game to examine what happens to a forest when trees are planted and cut down over time. Since real trees cannot grow in the classroom, students will act out the growth of trees in an imaginary forest. They will be told how many trees to plant and harvest each year.

2. Point out that it takes time for trees to grow, but this game will speed things up. They will pretend that a tree takes only four years to reach maturity: seeds are planted in year one, sprout

and grow a little in year two, become taller in year three, and mature to full grown in year four. Students will pantomime these stages.

OVERVIEW OF LESSON SEQUENCE

1. Policy 1: Play years 1 – 5 of the simulation to demonstrate linear growth. The number of mature trees will grow at a steady rate.

2. Policy 2: Play years 6– 8 to demonstrate equilibrium. The number of mature trees will remain the same when the planting and harvesting rates are equal.

3. Policy 3: Play years 9 – 12 to test increased planting and harvesting. Delays will produce surprising results.

4. Students reflect on the game, complete tables, plot graphs, and draw conclusions.

Do not announce the purpose of each policy to students– let them learn it from experience.

3. At first, all the students in the class represent seeds stored in a warehouse. At the beginning of the game, there are no trees in the forest and many seeds in the warehouse.

STUDENTS AS TREES

Year 1 Seed – curled up or sitting on the floor

Year 2 Sprout – kneeling

Year 3 Sapling – standing, hands at sides.

Year 4 Mature Tree – standing, hands clasped behind head, elbows out

4. Policy 1. Select one student in the class to be the Forest Manager. The responsibility of the manager is to count the number of mature trees and report that number to the class at the end of each year.

- To start the forest, select three students to be “planted” as seeds in the forest area of the classroom.
- For the first year, choose three different students to be “planted” while the original seeds “sprout.”
- For the second year, plant three new seeds while the earlier plantings grow into sprouts and saplings.
- Continue planting three new seeds and growing the forest for a total of 5 years.
- At the end of the 5th year, ask the Forest Manager to count the stock of mature trees once again and report the results to the class.

Pause for a minute. Help students understand the behavior of the system by asking for a brief recap of what they have observed. It took four years for the first seeds to become mature trees. After that, adding three seeds per year caused the mature forest to increase by three trees per

year. Although there is a delay between planting and maturity, the forest has a steady supply of trees at each stage of growth.

Note: This discussion should be very brief. It is intended to encourage students to start thinking about the issues. A more complete discussion and understanding will come at the end of the lesson. Throughout the lesson, the idea is to just let students play the game. They will stop and think about it later. It is OK to clarify the rules of the game, but resist every urge to step in and explain what is happening to the forest.

For your information only, below is a table showing the number of trees at each stage of growth each year. Notice that the first seeds planted (in bold font) move diagonally down the table as they become sprouts, saplings and, finally, mature trees in four years. Again, do not share this table with students or interrupt the flow of the game with this information.

5. Policy 2. Next, change the policy and try the following scenario:

- Beginning in Year 6, while continuing to plant three new seeds each year, harvest three mature trees per year to sell. (Remove three mature trees from the forest and return them to the warehouse as seeds.)
- Ask the Manager to count and report the number of mature trees now remaining at the end of Year 6. (There will be nine trees left.)
- Continue planting three seeds and harvesting three trees per year in Years 7 and 8.
- Ask the Forest Managers to count the number of mature trees and again announce the results to the class.

Pause briefly again. Ask students to predict the results of this policy. Continuing to plant three seeds and remove three trees each turn will produce equilibrium, or a stable situation in which numbers remain constant. Every year, three saplings grow and replace the three harvested mature trees. The number of new seeds in the ground matches the number of mature trees harvested, and everything is in balance (as shown below for your information only).

6. Policy 3. Suggest that you have an opportunity to make more money by selling more trees. The forest area in the classroom has a surplus of mature trees, and since you have more seeds in the warehouse, you can also plant more trees per year.

- In Year 9, increase the harvesting number to five, and match that by planting five new seeds each year as well.
- Ask students to predict the outcome of that strategy.
- Play four rounds to see what happens.
- Once again ask the Forest Managers to count the number of mature trees. It may surprise the class that the number of mature trees has declined.

7. After playing the game, ask students to reflect using the worksheet, What Happened to the Trees?

- Students write a few sentences about the game.

- They draw a behavior over time graph of the number of mature trees in the forest as the game progressed.
- Writing a short, one paragraph summary serves two purposes: students settle down after an active game, and they organize their thoughts, preparing to analyze what happened.

Explain (15 min.)

Now students are ready to tabulate the results of the game on their Yearly Forest Inventory worksheets.

Project this worksheet to help students complete the table by asking guiding questions.

1) How many plants did we have to start?

- We planted three seeds and there were no other plants, so we have the number 3 in the first column and zeros in all other columns.

2) What happened in Year 1?

- The three seeds grew into sprouts and we planted 3 new seeds.

3) Where do the sprouts come from?

- One year's seeds are the next year's sprouts. Then the sprouts become the saplings in the table for the following year. The year after that, they become mature trees. Therefore, a number entered in the seed column will move diagonally down to the right through the table until reaching the mature trees column.

4) Why did the first mature trees appear in Year 3?

- Trees take four years to mature from seeds. We had seeds in the ground to start. Review Years 0-3 as you enter the numbers of trees at each stage.

5) In Years 4 and 5, the number of mature trees increased each year. Why?

- Three seeds were being planted each year and no trees were being harvested so the forest grew steadily.

6) Harvesting three trees per year began in Year 6 and continued in 7 and 8. What happened to the number of mature trees?

- It remained steady, in equilibrium, at nine trees because the harvesting rate equaled the planting rate. (Note: To compute these, the number of mature trees increases to twelve trees but is reduced to nine after three trees are cut.)

8) In Year 9, harvesting and planting were increased. What was the result?

- The number of mature trees declined for three years. This is because of the delay in the growth of the five new seeds. At first, only three saplings were still maturing, but five trees were cut down each year.

9) What happened in Years 10-12?

- The forest reached a new lower equilibrium at three trees.

When the table is completed, students use it to graph the number of mature trees on the Mature Trees in the Forest graph worksheet. The horizontal axis measures Time in years and the vertical axis represents the number of Mature Trees in the forest each year.

- Some students may need close guidance plotting the first few points.
- After students have plotted the points, ask them to connect the points to produce a behavior over time graph.

Extend (20 min.)

Bringing the Lesson Home

Students need to think and talk about their experience in the game to build understanding. Use the graph and the table to focus a discussion on the game and its implications.

1. What happened to the forest in this game?

Use a question like this to start a class discussion. Some students will be quite articulate, but others may be confused about the exact nature of the dynamics in this game. The questions below help to bring home the important points.

2. What happened to the forest during the first 5 years?

Once the first seeds had matured, the forest grew at a steady rate.

3. How did the graph show the stock of mature trees in Years 1-2?

The line stayed at zero because there were no mature trees yet.

4. When did the stock of mature trees remain constant?

It was constant when the number of saplings that became mature trees was the same as the number of mature trees cut. At that point, the number of mature trees was represented by a flat horizontal line on the graph.

5. What happened when the number of trees harvested was raised and the number of seeds planted increased to match the larger harvest?

The number of mature trees declined steadily, reaching equilibrium at a lower number of trees than it held before the increased harvest.

6. Was this a surprise? Why doesn't the forest maintain equilibrium when you increase planting and harvesting at the same time?

Even though planting was increased to match a rise in harvesting, there were three years when the forest suffered a net decline in mature trees. The delay in trees reaching maturity caused the outflow to be greater than the inflow.

7. How does your final graph compare to your original sketch?

Help students reflect on their thinking. How have their mental models changed during the lesson?

8. Sustainable yield means having enough of a resource in the pipeline to replace what removed from the system. How can a forest manager be assured of having enough trees year after year?

The forester must plan to have a steady flow of new trees to replace those that are cut down.

9. Summarize in your own words what happened in this game.

The supply, or stock, of mature trees was at zero for three years; then it rose by three trees each year. When harvesting began in Year 6, the number leveled off, or reached equilibrium, at 9 trees. In Year 9, after harvesting and planting rates went up, the stock of mature trees went down. It leveled off at 3 trees, a lower level than the first equilibrium period.

Students are surprised by the effect of delays on the number of trees in the forest. By acting out the growth of trees and thinking about it together, students develop a good understanding of this important and sometimes elusive concept.

10. What would happen if we decided to harvest more than 5 trees in Year 9 (while also planting more seeds)?

The delay, along with the more aggressive cutting policies would result in the ELIMINATION of the mature forest. For example, cutting nine trees in Year 9 would leave only 3 mature trees in Year 10, which then would all need to be cut in an attempt to maintain the more aggressive policy.

11. Are there other situations in which maintaining a steady supply of some resource is necessary?

- Other renewable resources such as livestock, fisheries, and aquifers experience similar delays.
- Stock in a warehouse, factory, or retail store follows a similar pattern.
- Veteran members of a sports team or organization also need to be developed over time

APPENDIX 2:

Supporting Lesson Materials

Lesson 1: Public Service Announcements Rubric

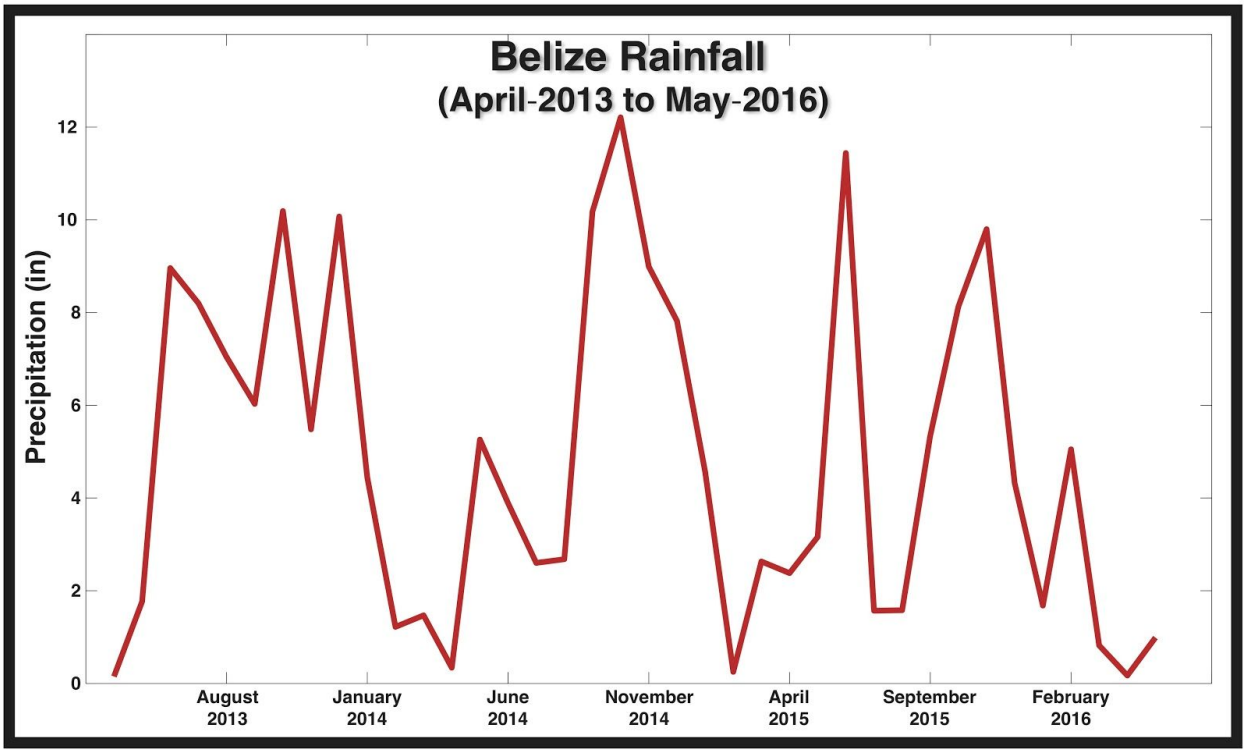
Public Service Announcement Rubric

CATEGORY	4	3	2	1
Content	Students create an original, accurate and interesting PSA that adequately addresses the issue.	Students create an accurate PSA that adequately addresses the issue.	Students create an accurate PSA but it does not adequately address the issue.	The PSA is not accurate.
Fair Use	The PSA follows fair use for all music and sound effects that are included. All text is the original work of the group members or is used with permission.	The PSA follows fair use for most music and sound effects that are included. All text is the original work or is used with permission. There are some minor issues with copyright and fair use.	Most PSA is the original work of the group members, but some material is used without permission or in violation of copyright.	The PSA does not follow fair use practices. Text, sound effects and/or music is used without permission and/or in violation of copyright.
Collaboration with Peers	Almost always listens to, shares with, and supports the efforts of others in the group. Tries to keep people working well together.	Usually listens to, shares with, and supports the efforts of others in the group. Does not cause problems in the group.	Often listens to, shares with, and supports the efforts of others in the group but sometimes is not a good team member.	Rarely listens to, shares with, and supports the efforts of others in the group. Often is not a good team member.
Technical Production	Tone and voice convey emotions and enthusiasm. The recording is clear and loud enough to be heard. Background sounds and effects blend with the PSA's message.	Tone and voice frequently convey emotions and enthusiasm. The recording is clear and loud enough to be heard. Background sounds and effects usually blend with the PSA's message.	Tone and voice frequently convey emotions or enthusiasm. Most of the recording is clear and loud enough to be heard. Background sounds and effects sometimes distract from thee PSA's message.	Tone and voice rarely convey emotions or enthusiasm. Recording is unclear and/or not loud enough to be heard. Background sounds and effects absent or distract from the PSA's message.

Lesson 2
Belize Rainfall Table

Month	Rainfall (inches)		Month	Rainfall (inches)
Apr-13	0.15		Nov-14	8.99
May-13	1.77		Dec-14	7.82
Jun-13	8.96		Jan-15	4.57
Jul-13	8.2		Feb-15	0.25
Aug-13	7.04		Mar-15	2.63
Sep-13	6.03		Apr-15	2.38
Oct-13	10.19		May-15	3.16
Nov-13	5.48		Jun-15	11.44
Dec-13	10.07		Jul-15	1.57
Jan-14	4.44		Aug-15	1.58
Feb-14	1.22		Sep-15	5.35
Mar-14	1.47		Oct-15	8.13
Apr-14	0.34		Nov-15	9.8
May-14	5.26		Dec-15	4.32
Jun-14	3.89		Jan-16	1.68
Jul-14	2.6		Feb-16	5.05
Aug-14	2.68		Mar-16	0.82
Sep-14	10.18		Apr-16	0.17
Oct-14	12.21		May-16	0.99

Belize Rainfall



Lesson 3
Forest Fragmentation

The following pictures provide examples of differences in Belizean rain forest sites due to human disruption. Figures 1 and 2 show a “primary growth” forest with an undisturbed canopy that has not been touched by humans for hundreds of years. Figures 3 and 4 show “secondary growth” of an area of land which was fragmented within the past few years. The forest is slowly starting to grow back, but the majority of the greenery is in the understory. Figure 5 displays a slash-and-burn site, where the forest is cleared entirely for farming and timber.

Figure 1. Example of a “primary growth” forest canopy. This undisturbed forest has not been cleared in recent history (at least for hundreds of years) and thus the trees have reached mature height and form a dense canopy. It is difficult for sunlight to reach the forest floor, as trees compete for sunlight many meters above the ground.

Figure 2. Example of a “primary growth” forest ground covering. Plants and leaves are sparse as the canopy allows a small amount of light to pass through. Visibility is high as the brush consists mainly of vines and small shrubs or leaves.

Figure 3. Example of a “secondary growth” forest canopy. This forest experienced recent disruption (within the last 50 years). Therefore, the canopy is open, which allows plenty of light to reach the forest floor. Young trees take advantage of this light and begin to grow on the forest floor where the sunlight can reach.

Figure 4. Example of a “secondary growth” forest ground covering. Young trees compete for space near the forest floor. Visibility through the forest is low since the brush is quite thick.

Figure 5. Example of slash-and-burn agriculture. After land is burned, logs are sold to the timber industry, and the land is converted to fields for growing crops.

Questions for discussion:

1. How do the canopies in Figures 1 and 3 look different from one another? How might a dense canopy affect the plants which live below it?
2. What types of animals might live in a tree? How would they be affected if someone cut down the tree?
3. How does Figure 5 look different from the first figures?

Forest Fragmentation Debate Activity

Food, furniture, and forests: should Mennonites stop clearing land?

In the interview which you just read, Melvis mentions an ongoing conflict in the Belizean rainforest: whether or not forests should be cleared for farmland and for timber to make furniture. There are many people involved in agriculture and the timber industry, but Melvis specifically points out that the religious group of people called the Mennonites are responsible for the majority of farming and furniture making in the country. From one perspective, it may seem that this group is disregarding the critical importance of the forest as a habitat for many species and are taking land for their own use. From another perspective, Mennonites are hard working farmers and carpenters who provide the food and wood that all Belizeans need.

Directions:

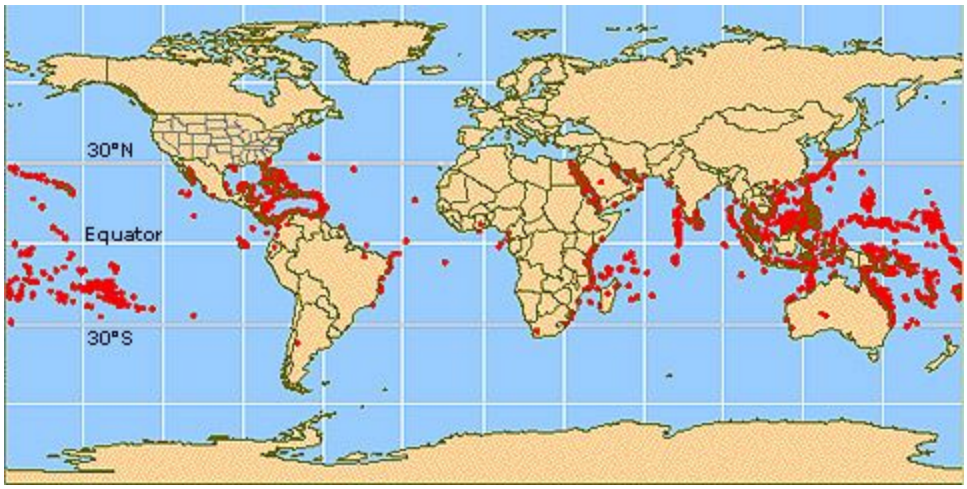
1. Pretend you are a citizen of Belize and there is an upcoming election to vote on whether or not to create stricter rules for regulating deforestation. This would mean that it would be more difficult for farmers and people in the timber industry to cut down trees in the tropical rain forest.
2. Pick one side of the debate- either food/furniture, or forests- and develop a solid argument using evidence to show why Belizeans should vote for your perspective.
3. You may cite evidence from Melvis' interview or may research further information online. Remember to cite any outside sources.
4. Finally, your group will present your argument to the class in a debate style.
5. Hint: When forming your argument, consider the evidence which a group from the opposing side may use against you so that you may counter their argument.

Debate Organizer

Topic	
Our Perspective	
Our Audience	
Main Idea	
Brainstorm Ideas	**Most Persuasive Ideas**
What is one counter argument which the other side may form against our idea?	

Lesson 4 Graphs for Analysis

TROPICAL CORAL DISTRIBUTION MAP



Station I

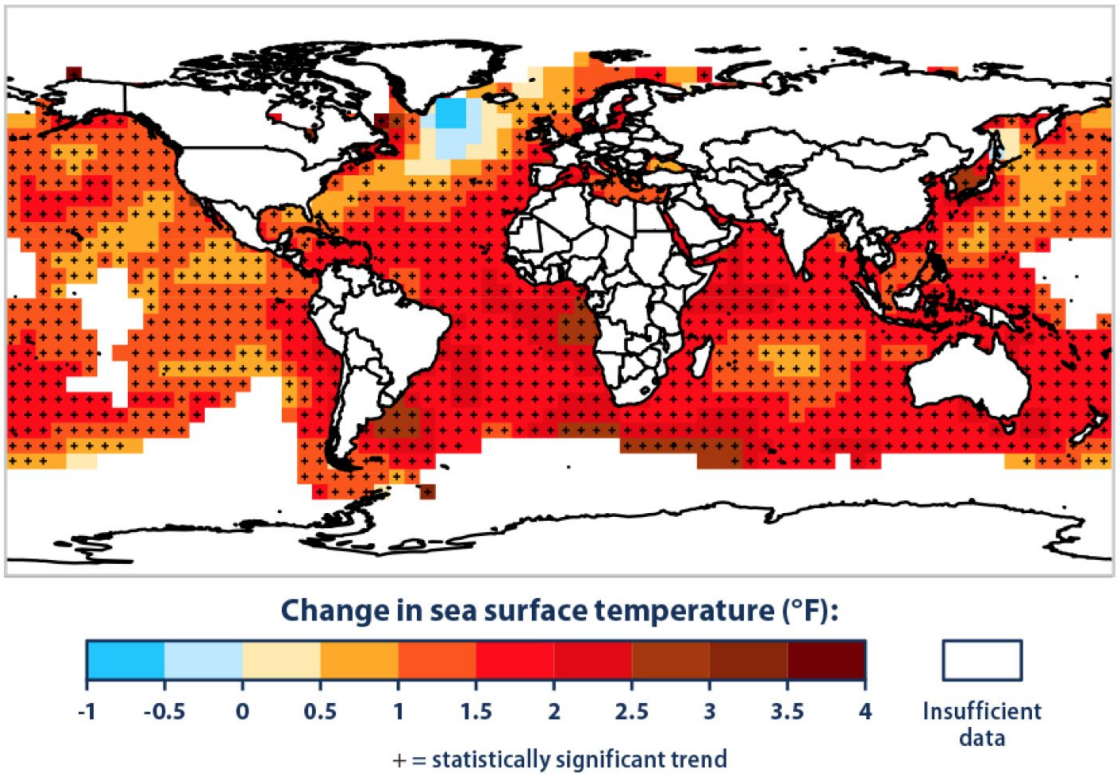
Questions

1. Between which two latitudinal lines do we find the most coral reefs?
2. Based on what you know about climate and geography, why do you think corals thrive in these areas?
3. Which countries do you predict are MOST affected by changes in coral reef systems?

Answers

1. Most coral reef ecosystems are found between latitude 30 degrees north and latitude 30 degrees south.
2. These two latitude lines are close to the equator, which receives the most direct sunlight throughout the year. Because of this, the climate in this area is very hot, and stays pretty constant most of the year, without varying much over the seasons. Corals live well in these areas because of the temperature, and the access to sunlight.
3. The countries that are most affected by changes in coral reef systems are those on the coasts, close to the equator. For example: central american countries, Australia, nations in southeastern Asia, and the east coast of Africa, by Madagascar.

CHANGES IN SEA SURFACE TEMPERATURE (1901-2015)



Station II

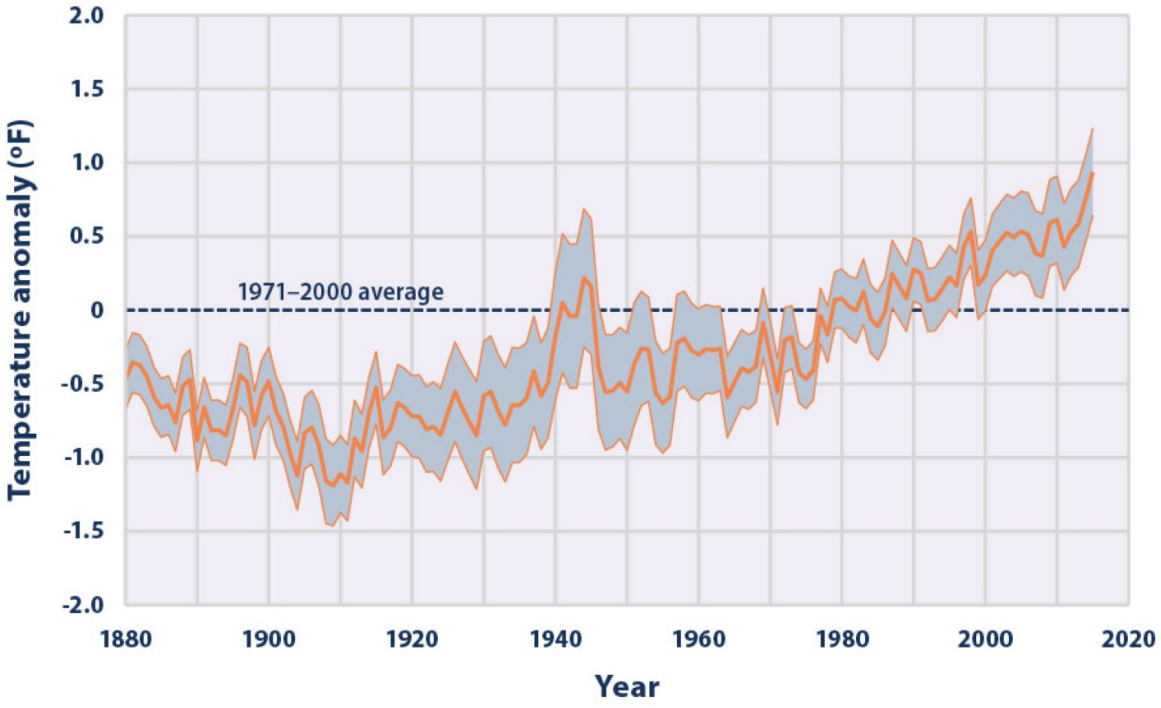
Questions

1. Based on the map, what is happening to the sea surface temperature in most of the world?
2. There is a small blue part of the map. Explain what this means, and make an inference as to why it might be located there.
3. What areas are more likely to have an increase in sea surface temperature? Why do you think this is the case?

Answers

1. Most of the world is seeing an increase in sea surface temperature, on average between 1 and 2 degrees Fahrenheit.
2. The blue spot is located to the southeast of Greenland in the Atlantic Ocean. This drop in temperature may be caused by ice chunks breaking off from glaciers and falling into the ocean. These glaciers have been breaking apart because of the rise in global temperatures.
3. Sea surface temperatures are more likely to increase around the equator. This may be because the equator receives more direct sunlight throughout the year, or because ocean convection currents do not carry all of the heat away. Instead, most remains fairly close to the equator; the third "Temperature anomaly" shows this increase in SST in graph form. This graph was a taken from a lesson put together by the EPA- see attached.

SEA SURFACE TEMPERATURE CHANGES OVER TIME



Station III

Questions

1. In what years were sea surface temperatures the lowest and the highest?
2. From 1880 to now, what is the overall trend of sea surface temperature?
3. A) How much higher is the 2015 temperature than the average temperature for 1971-2000?

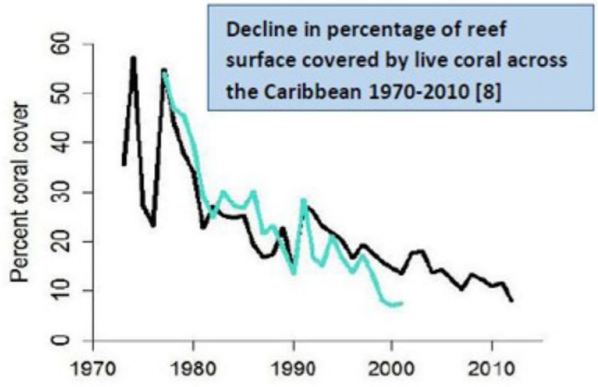
   B) Do you think this increase would have any significant effect on marine ecosystems?

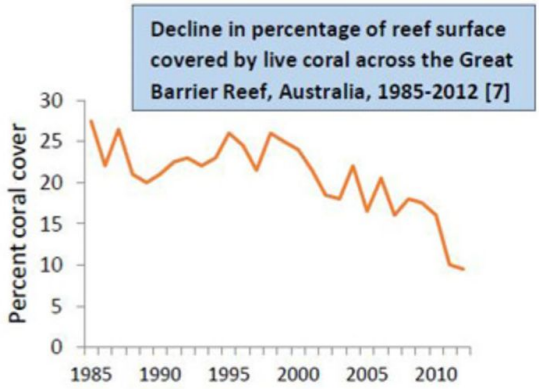
Answers

1. The lowest sea surface temperatures occurred in 1910. The highest sea surface temperature occurred in 2015.
2. From 1880 to now, the sea surface temperature has gradually risen. Each individual year may go up and down, but the overall trend shows an increase in temperature
3. A) The temperature in 2015 is about 1 degree Fahrenheit higher than the average temperature from 1971-2000.

   B) Student answers may vary here. Generally, a one degree difference may not seem like much, but really it can be the difference between life and death for many coral species, and in turn, those species that they provide homes for.

GLOBAL CORAL DECLINES





Station IV

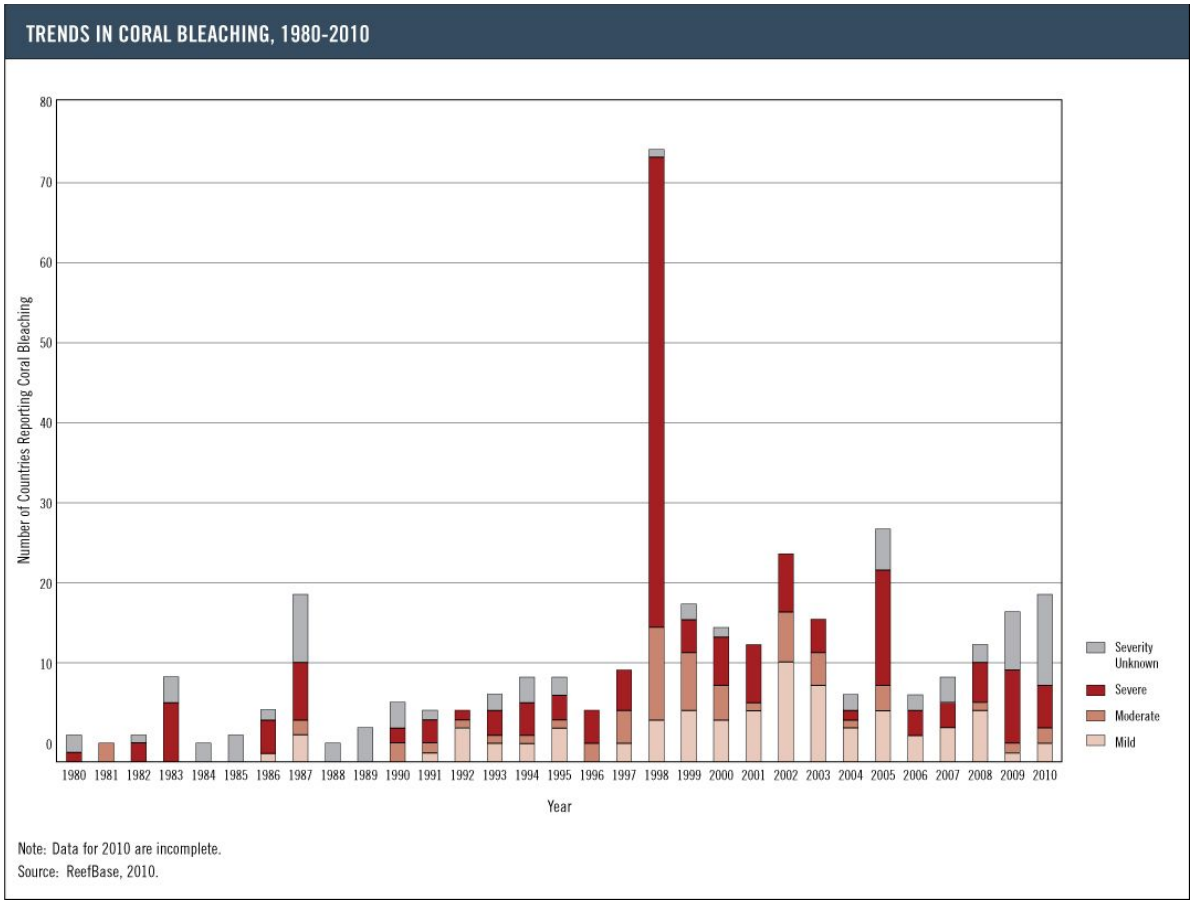
Questions

1. What type of graph is this, and why do you think it was chosen to represent this data?
2. Comparing the two graphs side by side, what similarities do you notice?
3. What do you think these two graphs tell you about coral cover from a global perspective?

Answers

1. These graphs are both line graphs. This type of graph clearly shows relationships between the data on both axes, in this case, percent coral cover and year. This way, we can clearly see the change in coral cover over the course of time, since time is a continuum.
2. Both graphs start with a high percentage of coral cover in the 1970's and 1980's. Over time, the percentage of coral cover declines into the 2010's to around 10%.
3. Since the first graph shows coral cover declining in the Caribbean, and the second graph shows coral cover declining in the Great Barrier Reef, we might be able to make the assumption that this sort of coral cover decline is occurring all across the world. However, as these are only two locations, more data would be needed to really identify a global trend with accuracy.

TRENDS IN CORAL BLEACHING 1980-2010



Station V

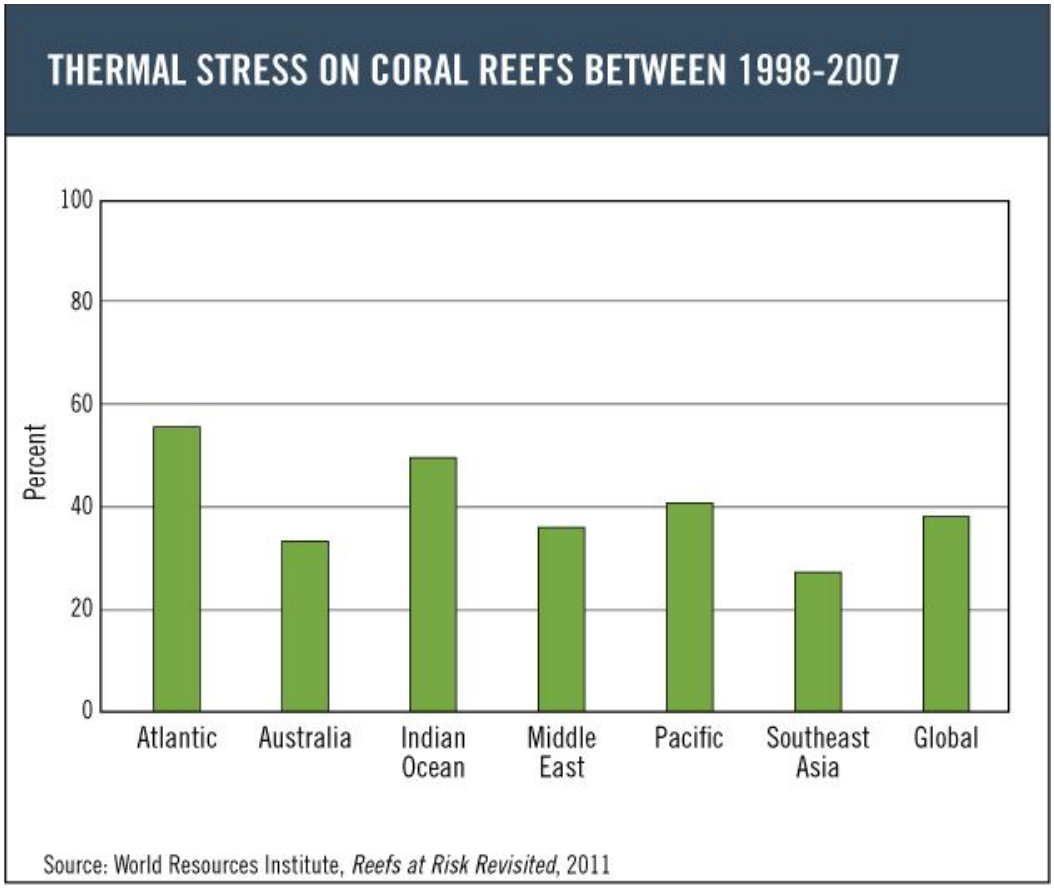
Questions

1. What is the overall trend in coral reef bleaching from 1980 to 2010?
2. If this graph showed years 2011-2016, what do you predict those bars might look like?
3. What year showed the most countries reporting severe coral bleaching? What possible explanation could there be for this event?

Answers

1. The overall trend shows an increase in the number of countries reporting coral bleaching from 1980 to 2010.
2. I would predict that years 2011-2016 would show even more countries reporting coral bleaching, probably about 20-25.
3. 1998 saw a huge increase in countries reporting coral bleaching. One possible explanation for this could be an increase in hurricane activity that season. For more information or to provide students with a reading extension, please see http://reefcheck.org/PDFs/NatureResources1999.pdf

THERMAL STRESS ON CORAL REEFS BETWEEN 1998-2007



Station VI

Questions

1. Why is this data not represented with a line graph?
2. Which three locations are seeing the highest thermal stress on corals? Why do you think this is the case?
3. Globally, what percentage of coral reefs have been under stress from 1998-2007? Is this an amount that you think is cause for concern?

Answers

1. Line graphs are used to show relationships between two variables. A bar graph is better used for this data, because we are comparing percentages for different locations side by side.
2. The Atlantic, the Indian Ocean, and the Pacific are seeing the highest thermal stress percentages. This may indicate that large areas of open ocean are more endanger of stress from thermal changes or heat.
3. Globally, almost 40% of coral reef systems are under thermal stress. This number is very large, and a great area of concern considering that many of our marine species are linked either directly or indirectly to coral reef ecosystems.

CORAL BLEACHING OBSERVATIONS

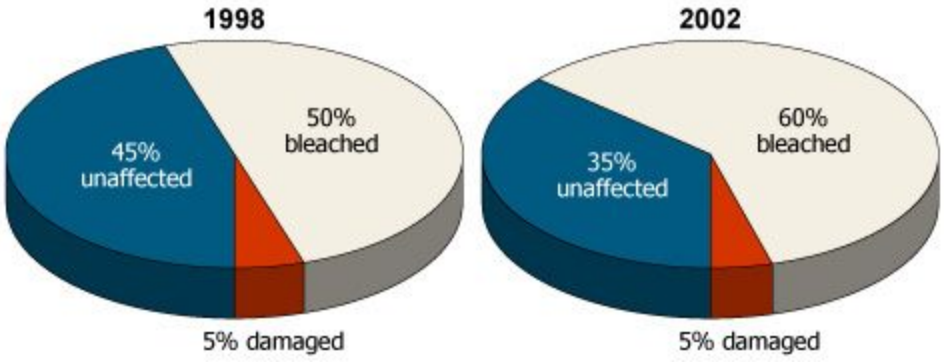
Station VII

Questions

1. When did we observe the most coral bleaching?
2. Describe the areas in this region that seem to be experiencing the most coral bleaching.
3. What do you predict the map would look like if we added data from 2004 to now?

Answers

1. The most coral reef bleaching on this map happened from 1997-2003. (There are the most dark green dots on the map.)
2. Most of the coral reef bleaching seems to be found on the coastline of different land masses (islands, peninsulas, etc.)
3. If we added data from 2004 to now, I predict there will be many more locations observing coral bleaching, specifically along the coast of Cuba, Puerto Rico, Belize, Honduras, and Mexico.



Great Barrier Reef Marine Park Authority
http://www.gbrmpa.gov.au/managing-the-reef/threats-to-the-reef/climate-change/what-does-this-mean-for-species/corals/what-is-coral-bleaching

Station VIII
Questions

1. What type of graph is this, and why do you think it was chosen to represent this data?
2. What is the percentage of bleached reef in 1998 compared to 2002? What do you think this tells you about corals on the Great Barrier Reef?
3. Both graphs show a wedge that says ‘damaged’. What do you think this means, and why do you think it stays the same from 1998 to 2002

Answers

1. This data is represented as a pie chart, because a pie chart best represents percentages or parts out of the whole. In this case, we can clearly the see the percentage of all corals that are affected or not by climate change.
2. The percentage of bleached reef increased from 50% in 1998 to 60% in 2002. Overall, the Great Barrier Reef is seeing an increase in coral bleaching as time goes on.
3. ‘Damaged’ may mean that the coral is hurt by some other method instead of bleaching. For example, maybe the coral is crushed by fishing boats or tourists. These sorts of damages would probably

“Sea Surface Temperature”

Sea surface temperature—the temperature of the water at the ocean surface—is an important physical attribute of the world’s oceans. The surface temperature of the world’s oceans varies mainly with latitude, with the warmest waters generally near the equator and the coldest waters in the Arctic and Antarctic regions. As the oceans absorb more heat, sea surface temperature increases and the ocean circulation patterns that transport warm and cold water around the globe change.

Changes in sea surface temperature can alter marine ecosystems in several ways. For example, variations in ocean temperature can affect what species of plants, animals, and microbes are present in a location, alter migration and breeding patterns, threaten sensitive ocean life such as corals, and change the frequency and intensity of harmful algal blooms such as “red tide.”[1] Over the long term, increases in sea surface temperature could also reduce the circulation patterns that bring nutrients from the deep sea to surface waters. Changes in reef habitat and nutrient supply could dramatically alter ocean ecosystems and lead to declines in fish populations, which in turn could affect people who depend on fishing for food or jobs.[2]

Because the oceans continuously interact with the atmosphere, sea surface temperature can also have profound effects on global climate. Increases in sea surface temperature have led to an increase in the amount of atmospheric water vapor over the oceans.[3] This water vapor feeds weather systems that produce precipitation, increasing the risk of heavy rain and snow (see the Heavy Precipitation and Tropical Cyclone Activity indicators). Changes in sea surface temperature can shift storm tracks, potentially contributing to droughts in some areas.[4]

Increases in sea surface temperature are also expected to lengthen the growth season for certain bacteria that can contaminate seafood and cause foodborne illnesses, thereby increasing the risk of health effects.[5]

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3. IPCC (Intergovernmental Panel on Climate Change). 2013. Climate change 2013: The physical science basis. Working Group I contribution to the IPCC Fifth Assessment Report. Cambridge, United Kingdom: Cambridge University Press. www.ipcc.ch/report/ar5/wg1.

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Lesson 5 Forests of the Tide

At the intersection of land and sea, mangrove forests support a wealth of life, from starfish to people, and may be more important to the health of the planet than we ever realized.

By Kennedy Warne (Modified by Rohan Kundargi)

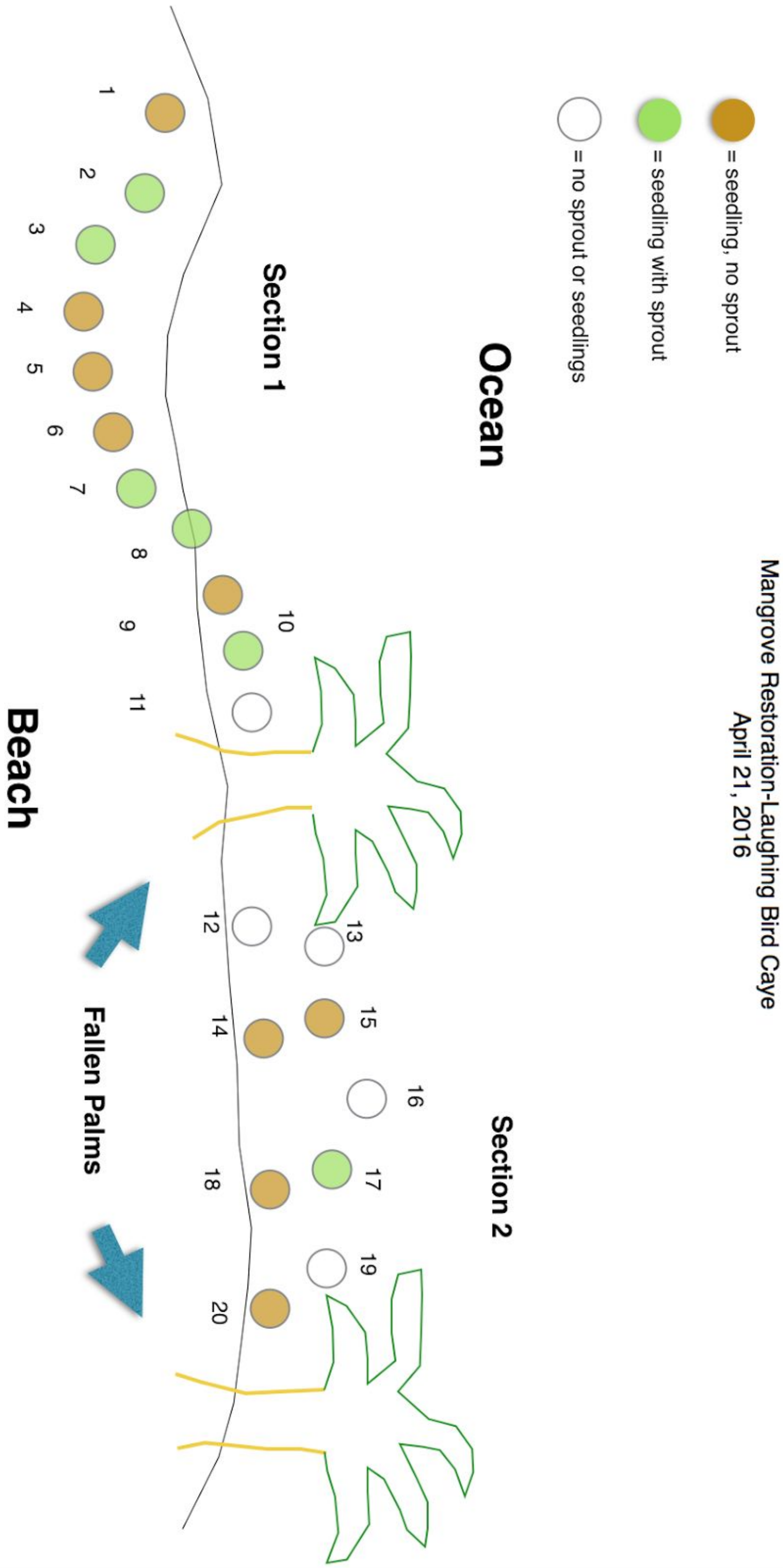
Mangroves live life on the edge. With one foot on land and one in the sea, these botanical amphibians occupy a zone of desiccating heat, choking mud, and salt levels that would kill an ordinary plant within hours. Yet the forests mangroves form are among the most productive and biologically complex ecosystems on Earth. Birds roost in the canopy, shellfish attach themselves to the roots, and snakes and crocodiles come to hunt. Mangroves provide nursery grounds for fish; a food source for monkeys, deer, tree-climbing crabs, even kangaroos; and a nectar source for bats and honeybees.

As a group, mangroves can't be defined too closely. There are some 70 species from two dozen families—among them palm, hibiscus, holly, plumbago, acanthus, legumes, and myrtle. They range from prostrate shrubs to 200-foot-high (60 meters) timber trees. Though most prolific in Southeast Asia, where they are thought to have originated, mangroves circle the globe. Most live within 30 degrees of the Equator, but a few hardy types have adapted to temperate climates, and one lives as far from the tropical sun as New Zealand. Wherever they live, they share one thing in common: They're brilliant adapters. Each mangrove has an ultrafiltration system to keep much of the salt out and a complex root system that allows it to survive in the intertidal zone. Some have snorkel-like roots called pneumatophores that stick out of the mud to help them take in air; others use prop roots or buttresses to keep their trunks upright in the soft sediments at tide's edge.

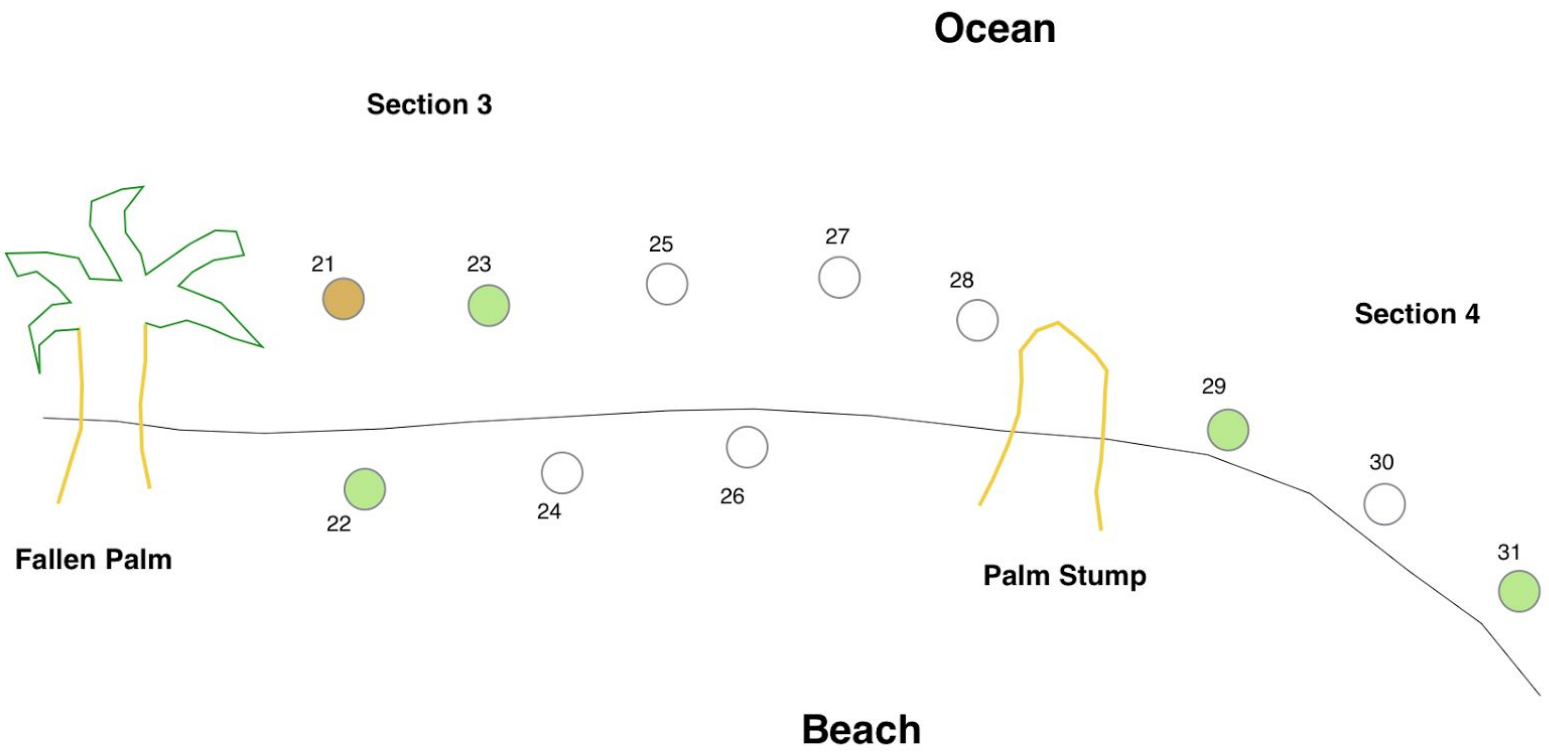
These plants are also excellent land builders. Some Aborigines in northern Australia believe one mangrove species resembles their primal ancestor, Giyapara, who walked across the mudflats and brought the tree into existence. The plants' interlocking roots stop riverborne sediments from coursing out to sea, and their trunks and branches serve as a palisade that diminishes the erosive power of waves.

Despite their strategic importance, mangroves are under threat worldwide. They are sacrificed for salt pans, aquaculture ponds, housing developments, roads, port facilities, hotels, golf courses, and farms. And they die from a thousand indirect cuts: oil spills, chemical pollution, sediment overload, and disruption of their sensitive water and salinity balance. Calls for mangrove conservation gained a brief but significant hearing following the 2004 Indian Ocean tsunami. Where mangrove forests were intact, they served as natural breakwaters, dissipating the energy of the waves, mitigating property damage, perhaps saving lives. Post-tsunami, the logic of allowing a country's mangrove "bioshields" to be bulldozed looked not just flawed but reprehensible.

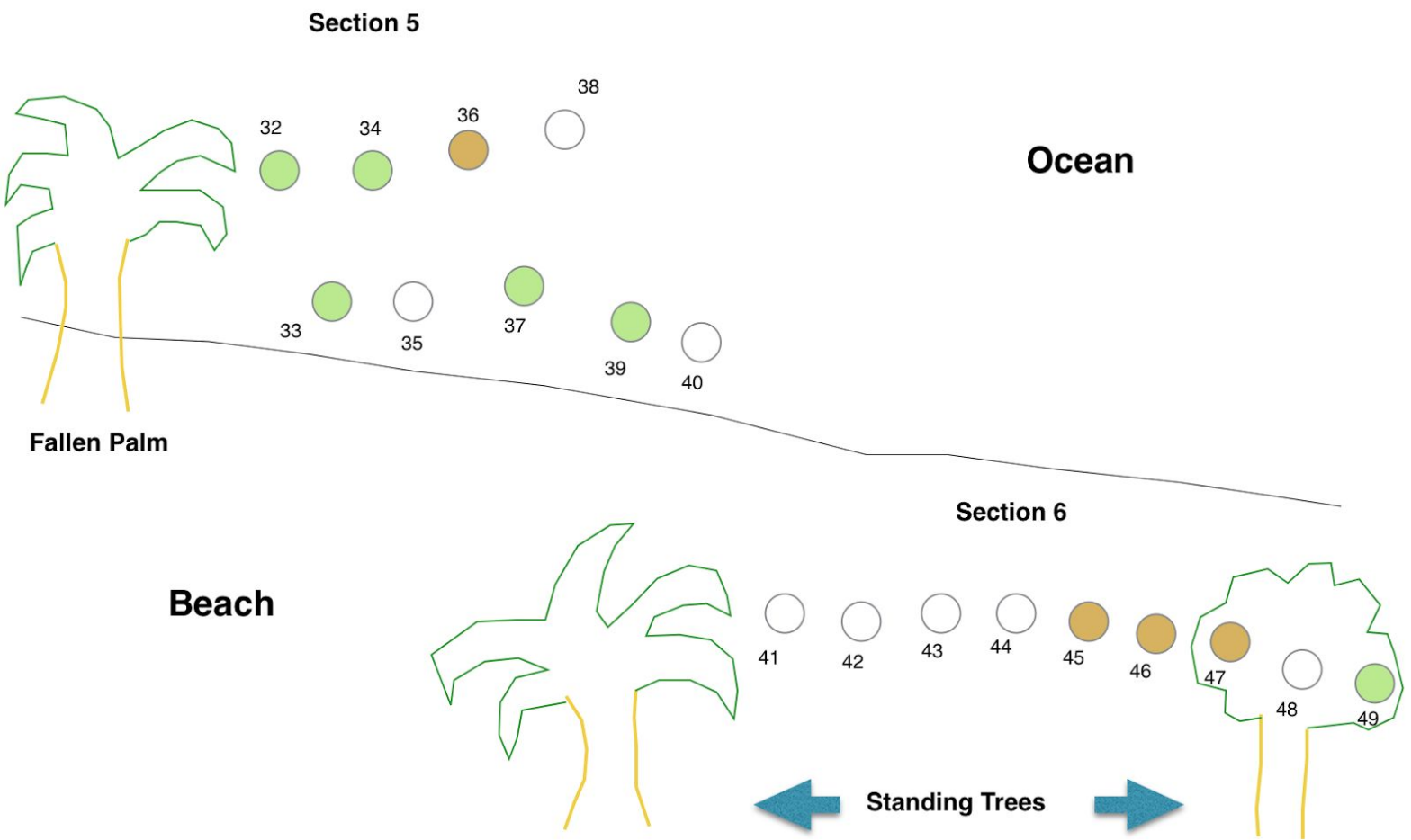
Mangrove Pipe Lab- Collecting Data (Option A)



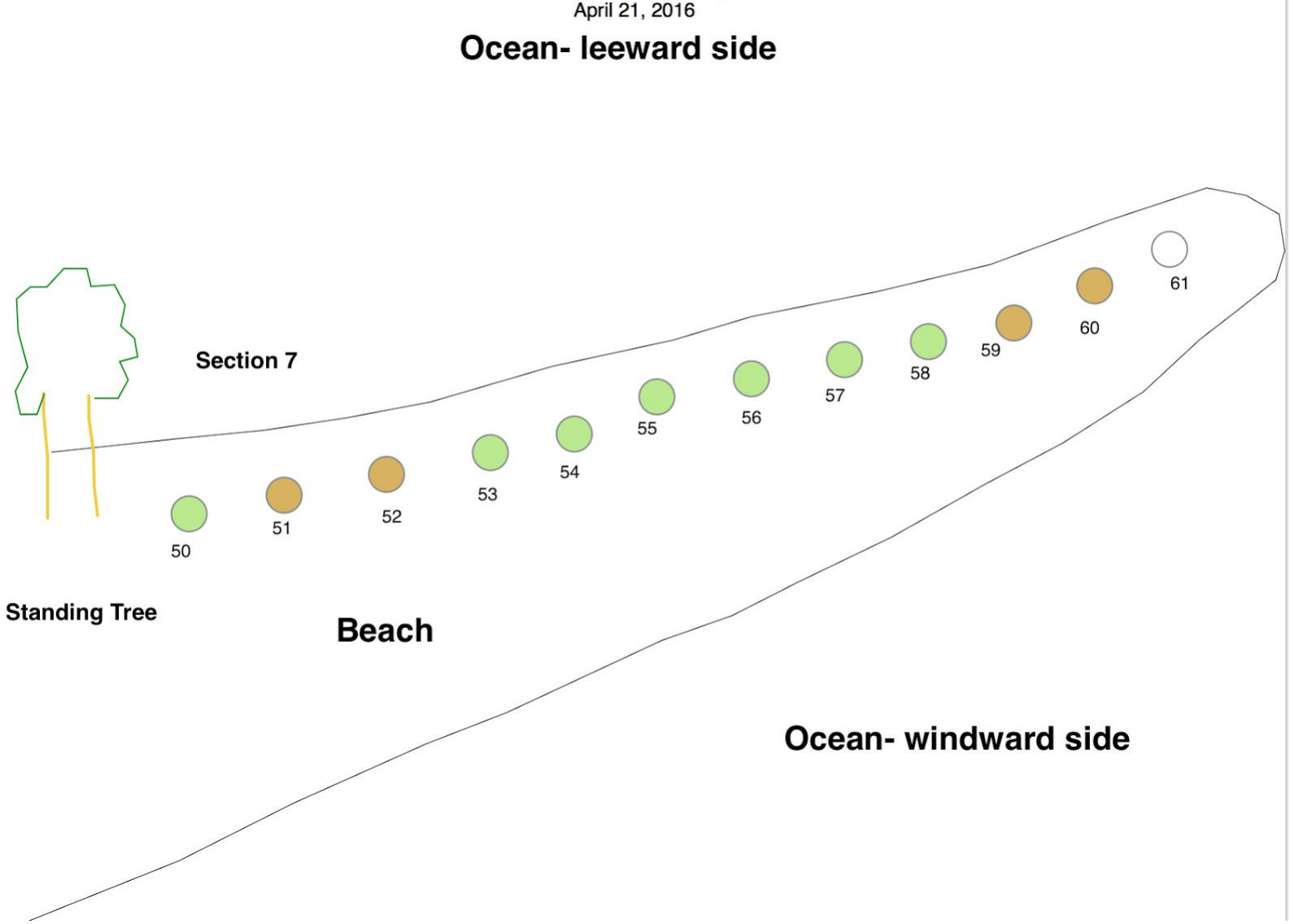
Mangrove Restoration-Laughing Bird Caye
April 21, 2016



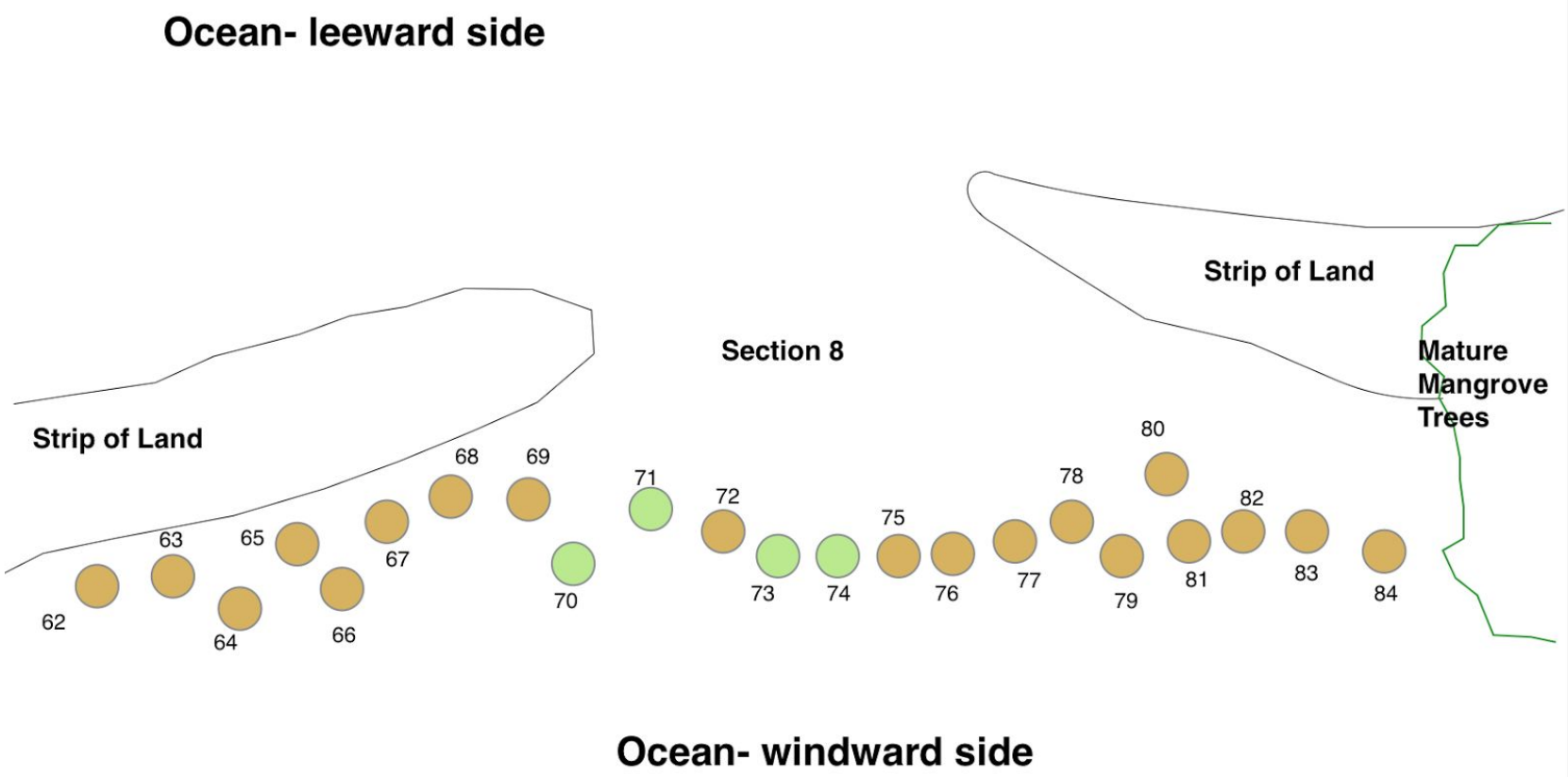
Mangrove Restoration-Laughing Bird Caye
April 21, 2016



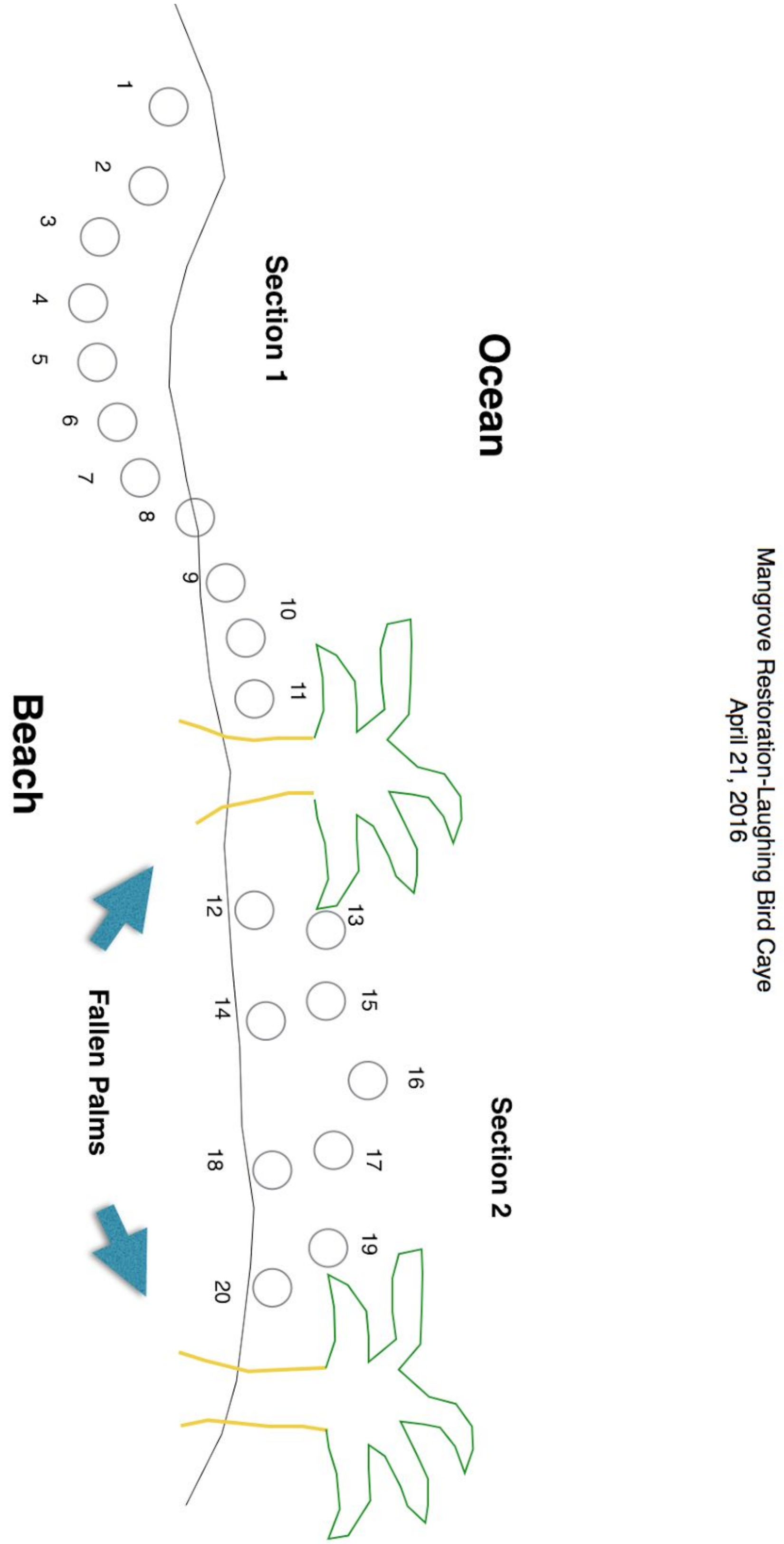
Mangrove Restoration-Laughing Bird Caye
April 21, 2016



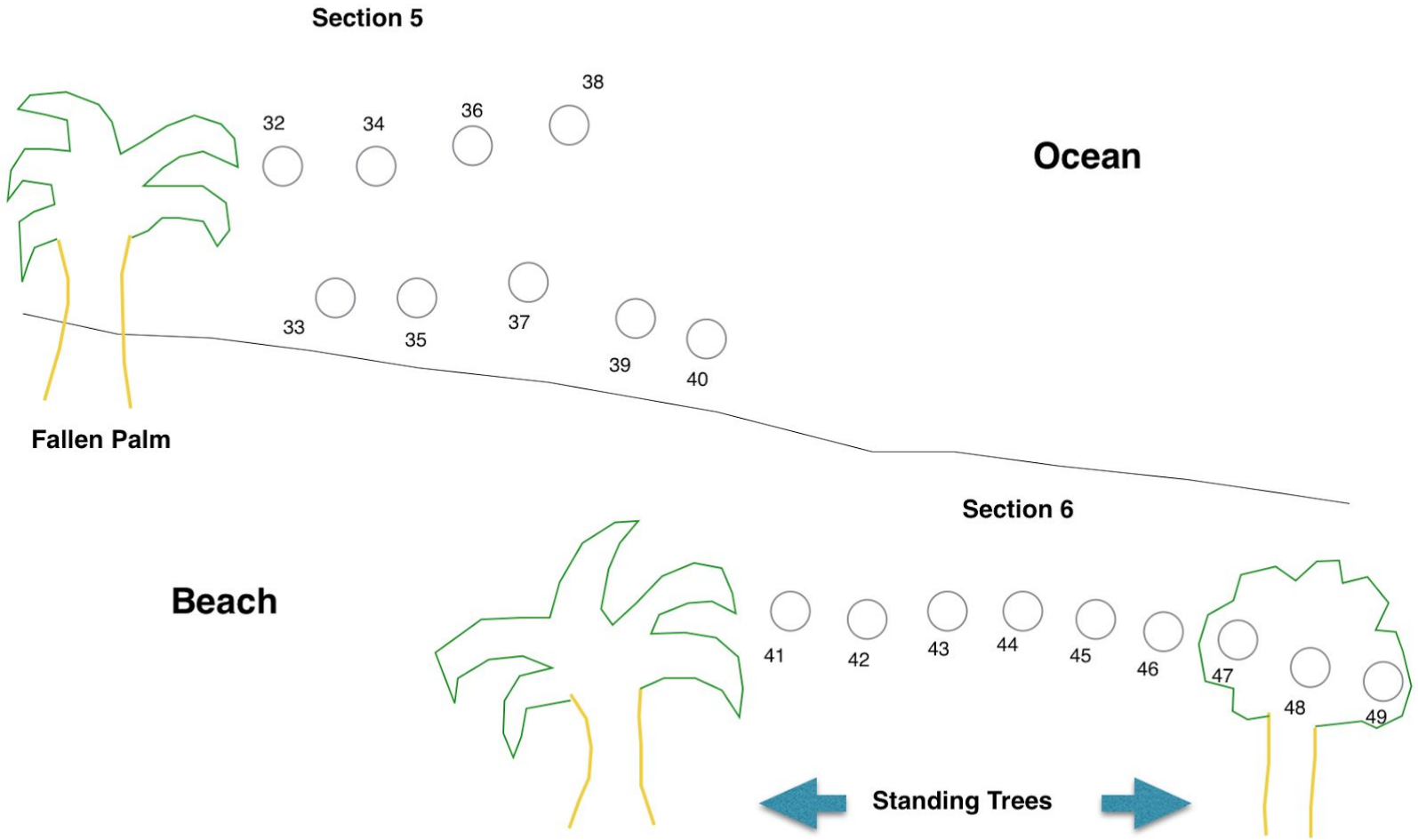
Mangrove Restoration-Laughing Bird Caye
April 21, 2016



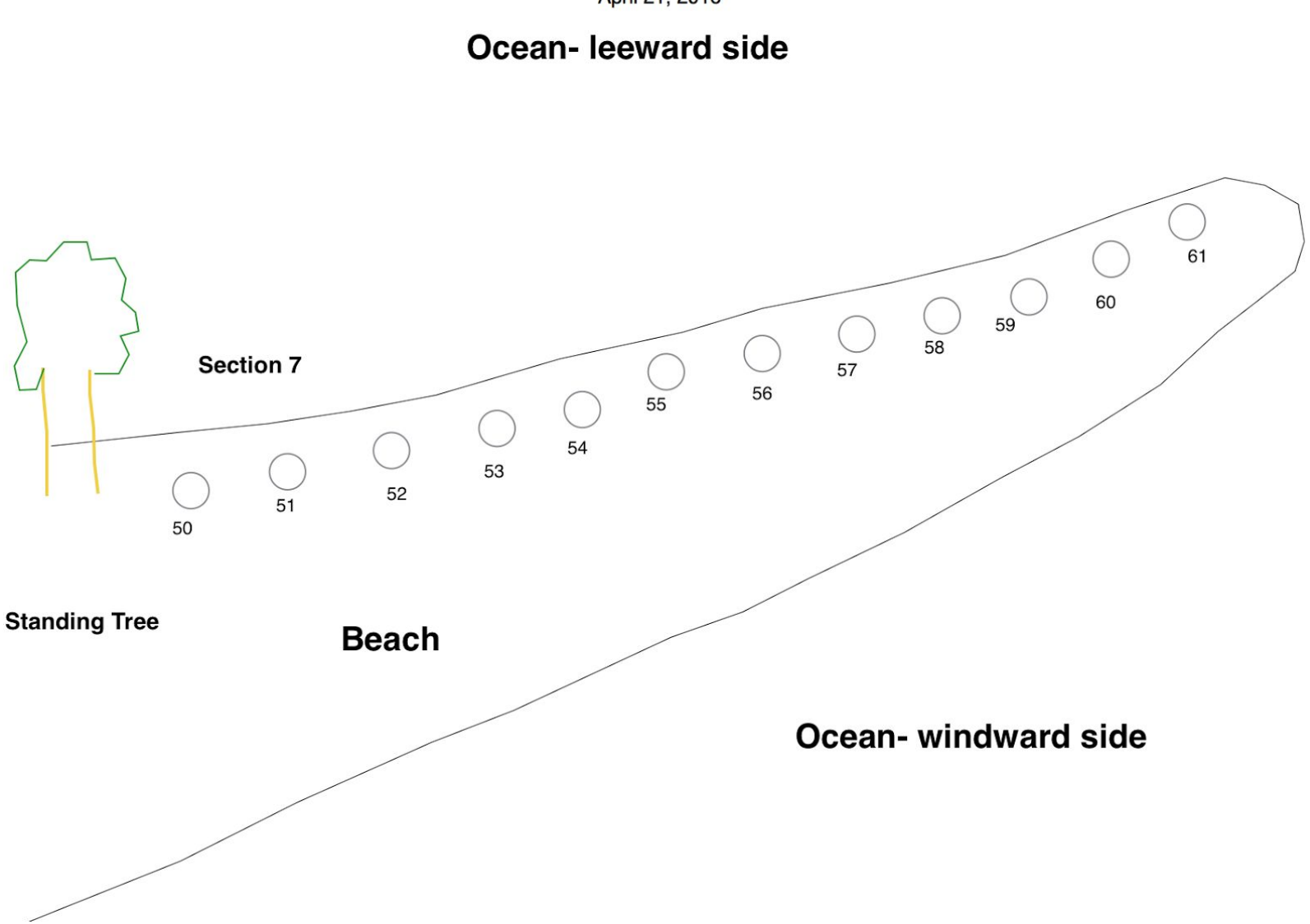
Mangrove Pipe Lab- Creating a Model (Option B)



Mangrove Restoration-Laughing Bird Caye
April 21, 2016

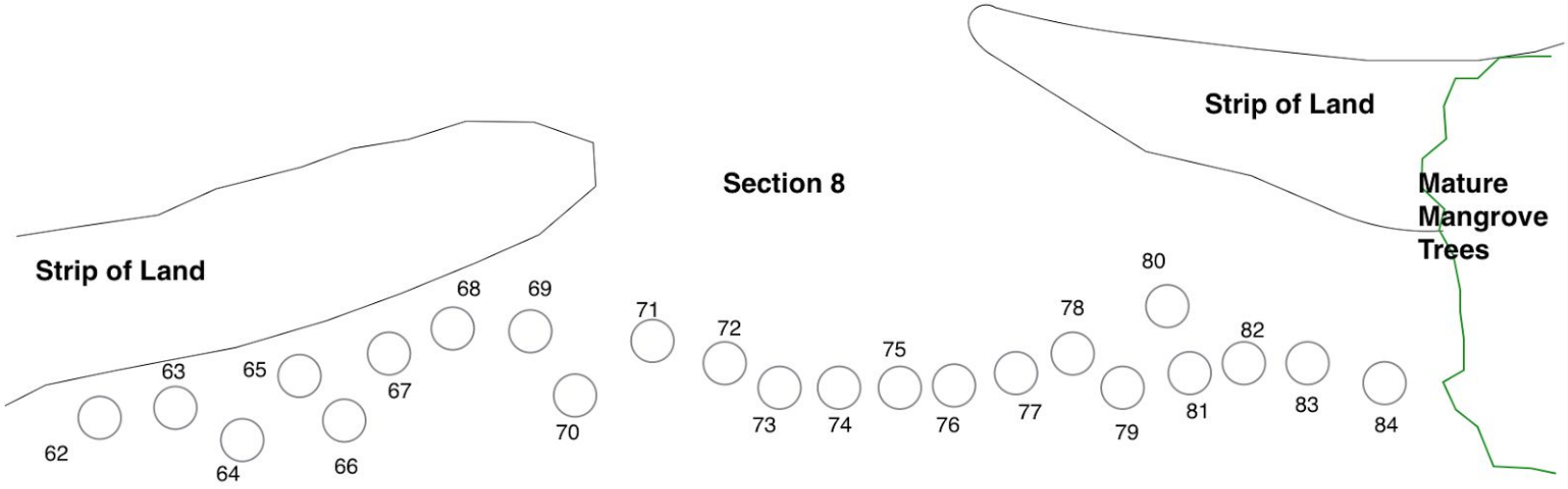


Mangrove Restoration-Laughing Bird Caye
April 21, 2016



Mangrove Restoration-Laughing Bird Caye
April 21, 2016

Ocean- leward side



Ocean- windward side

Mangrove Pipe Lab Chart-For use with Collecting Data, Option A

Pipe Number	# of Seedlings	# Sprouts	Pipe Number	# of Seedlings	# Sprouts
1			43		
2			44		
3			45		
4			46		
5			47		
6			48		
7			49		
8			50		
9			51		
10			52		
11			53		
12			54		
13			55		
14			56		
15			57		
16			58		
17			59		
18			60		
19			61		
20			62		
21			63		
22			64		
23			65		
24			66		
25			67		
26			68		
27			69		
28			70		
29			71		
30			72		
31			73		
32			74		
33			75		
34			76		
35			77		
36			78		
37			79		
38			80		
39			81		
40			82		
41			83		
42			84		

Mangrove Pipe Lab Data Chart- For use with Creating a Model, Option B

Pipe Number	# of Seedlings	# Sprouts	Pipe Number	# of Seedlings	# Sprouts
1	1	0	43	0	0
2	1	1	44	0	0
3	1	1	45	1	0
4	1	0	46	1	0
5	1	0	47	1	0
6	1	0	48	0	0
7	2	1	49	2	1
8	3	1	50	1	1
9	2	0	51	1	0
10	2	1	52	2	0
11	0	0	53	1	1
12	0	0	54	1	1
13	0	0	55	1	1
14	1	0	56	2	1
15	1	0	57	1	1
16	0	0	58	1	1
17	1	1	59	1	0
18	1	0	60	1	0
19	0	0	61	0	0
20	1	0	62	1	0
21	1	0	63	1	0
22	1	1	64	1	0
23	1	1	65	1	0
24	0	0	66	1	0
25	0	0	67	1	0
26	0	0	68	1	0
27	0	0	69	1	0
28	0	0	70	1	1
29	1	1	71	1	1
30	0	0	72	1	0
31	1	1	73	1	1
32	1	1	74	1	1
33	1	1	75	1	0
34	2	1	76	1	0
35	0	0	77	1	0
36	1	0	78	1	0
37	1	1	79	1	0
38	0	0	80	1	0
39	1	1	81	1	0
40	0	0	82	1	0
41	0	0	83	1	0
42	0	0	84	1	0

Lesson 6
Map of Belize

APPENDIX 3:

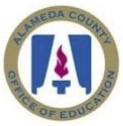
COMMON CORE TECHNIQUES FOR USE IN THE CLASSROOM

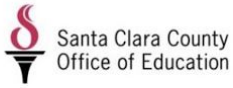
Claims Evidence Reasoning Guide

Claim – Evidence – Reasoning Rubric

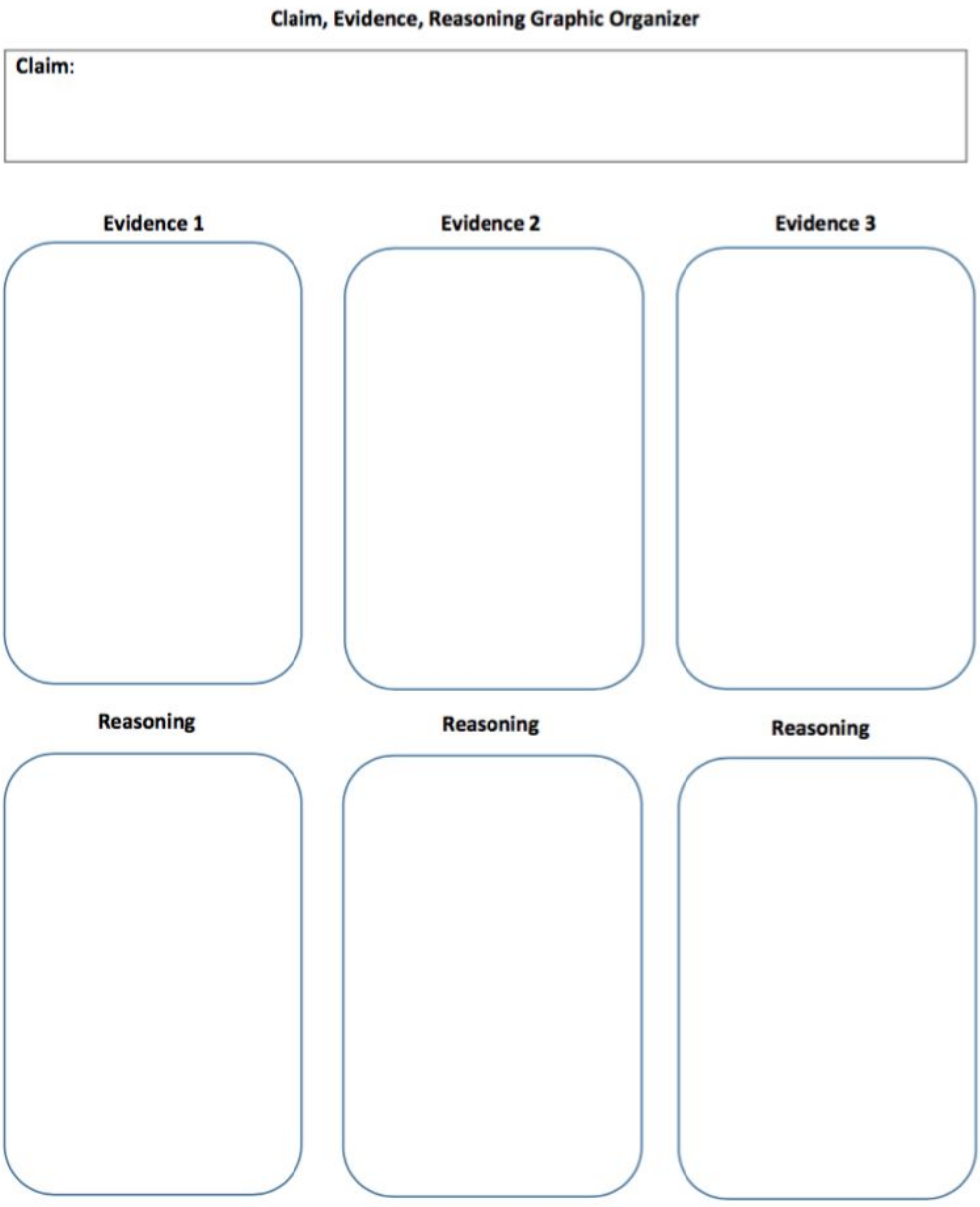
(From NSTA)

	Claim *A statement or conclusion that answers the original question/problem.*	**Evidence** *Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	**Reasoning** *A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
4	All aspects of level 3 and is written in a way that engages the reader.	All aspects of level 3, correctly identifies the sources and is written in a way that engages the reader.	All aspects of level 3 and is written in a way that engages the reader.
3	Makes an accurate and complete claim and includes points from the question in the writing.	Provides ***all or most*** of the expected pieces of evidence from the sources used in an appropriate manner.	Provides reasoning components for ***all or most*** of the evidence and explains ***how*** the evidence supports the claim.
2	Makes an accurate and complete claim.	Provides ***some*** of the expected pieces of evidence from the sources used (e.g. data like numbers, observations, etc.) in an appropriate manner.	Provides reasoning components for ***some*** of the evidence and explains ***how*** the evidence supports the claim.
1	Makes an accurate but vague or incomplete claim.	Makes a general statement regarding evidence, but does not include specific details.	Repeats evidence and links it to the claim, but does not explain ***how*** the evidence supports the claim
0	Does not make a claim, or makes an inaccurate claim.	Does not provide evidence, or only provides inappropriate evidence or vague evidence, like “the data shows me it is true”	Does not provide reasoning, or only provides inappropriate reasoning.



CER Graphic Organizer



Lesson Title: Three-Column Vocabulary Worksheet: F*or use with any of the six case studies*

Author: Ryan Keser

Objective: SWBAT identify and sort vocabulary that supports the main idea of the science related text and define unknown words.

Big Idea: Here is a simple strategy to help students navigate vocabulary in a science-based reading in order to uncover the main idea and identify unknown words.

NGSS/MA/CCC Standards Addressed: RI.7.2, RI.7.3, RI.8.4 , RI.8.5, RI.8.10

Science Practices: NOS

Cross-Cutting Concepts: NOS

Getting Started - Setting Up The Lesson :
The purpose of this lesson is to give students a strategy to use while reading a variety of scientific texts. While reading students are asked to record vocabulary words that are unknown to them, vocabulary words that are science related and words from the article which they think most closely relate to the author's main idea.

Once completed students then share their main idea words with their table group and create a master list of the terms the table agrees on. They then work together to create a sentence using these main idea words to encapsulate the authors point.

Materials:

- 3-column vocabulary worksheet
- highlighters
- selected reading*
- mini whiteboards and markers or poster paper

Lesson Progression:

Engage (20 min)
I begin the lesson letting students know that will be practicing a new reading strategy today to help with identify unknown or unfamiliar vocabulary, vocabulary that relates to the scientific information in the reading, and vocabulary that is related to the author's main idea. As I'm explaining this I pass out the *3 Column Vocabulary Recording Sheet* and go over each of the three columns with the students reviewing the directions under each column.

3 Column Vocabulary Recording Sheet

As you read the passage below highlight the following: a) words you do not know, b) science words and c) words that are relad to the main idea of the reading. Add these words to each the columns below. You may use words in more than one column.

Unknown Words	Science Words	Main Idea Words
Any words that are unfamiliar to you (DO NOT look them up YET). Make sure to underline/highlight the sentence that is the source of the unknown word.	Identify a minimum of five words that are subject specific, either different from everyday use or directly related to the scientific content.	Pick a minimum of seven words in the article that YOU think most closely relate to the authors point. More than seven are acceptable but really focus on important words, and try to use words from throughout the article.

Write your main idea sentence below using the terms from column three above.

Define the unknown words from column one below:

7E Article

Expanding the 5E Model

A proposed 7E model emphasizes "transfer of learning" and the importance of eliciting prior understanding

Arthur Eisenkraft

Sometimes a current model must be amended to maintain its value after new information, insights, and knowledge have been gathered. Such is now the case with the highly successful 5E learning cycle and instructional model (Bybee 1997). Research on how people learn and the incorporation of that research into lesson plans and curriculum development demands that the 5E model be expanded to a 7E model.

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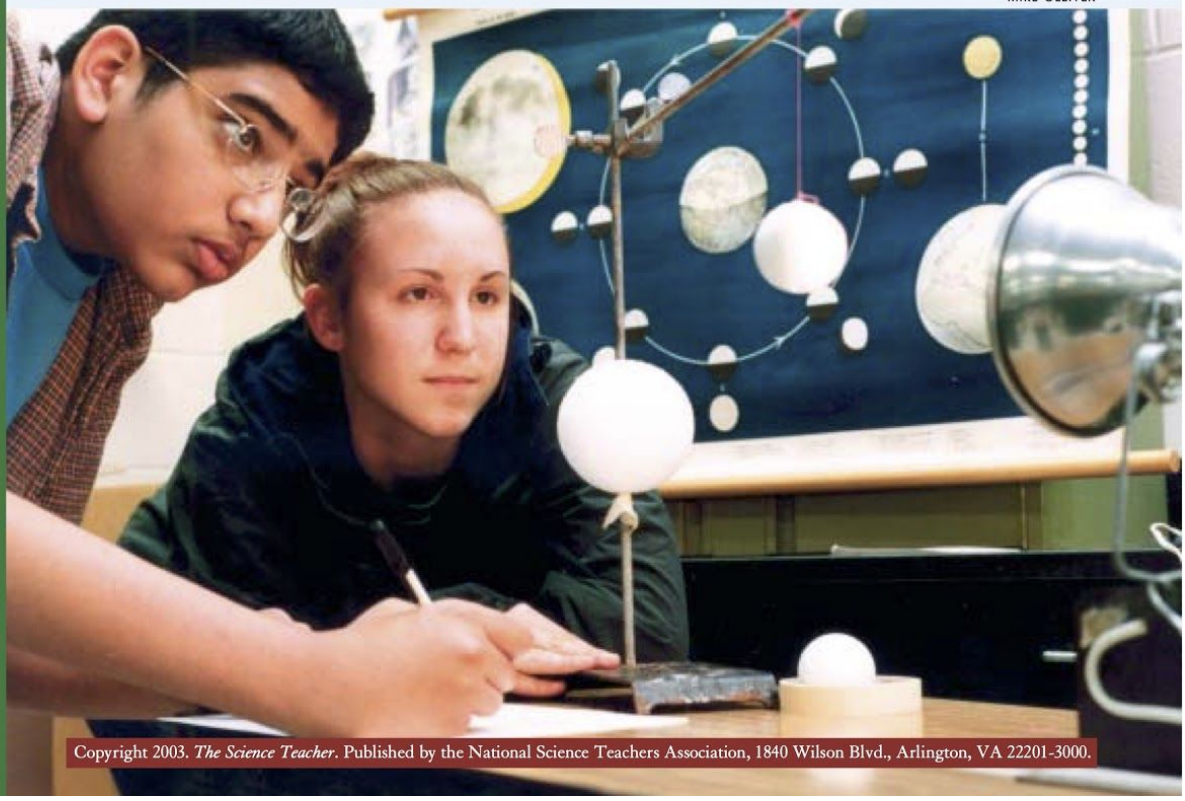

The 5E learning cycle model requires instruction to include the following discrete elements: *engage, explore, explain, elaborate,* and *evaluate*. The proposed 7E model expands the *engage* element into two components—*elicit* and *engage*. Similarly, the 7E model expands the two stages of *elaborate* and *evaluate* into three components—*elaborate, evaluate,* and *extend*. The transition from the 5E model to the 7E model is illustrated in Figure 1.

These changes are not suggested to add complexity, but rather to ensure instructors do not omit crucial elements for learning from their lessons while under the incorrect assumption they are meeting the requirements of the learning cycle.

Eliciting prior understandings

Current research in cognitive science has shown that eliciting prior understandings is a necessary component of the learning process. Research also has shown that expert learners are much more adept at the transfer of learning than novices and that practice in the transfer of learning is required in good instruction (Bransford, Brown, and Cocking 2000).

The *engage* component in the 5E model is intended to capture students' attention, get students thinking about the subject matter, raise questions in students' minds, stimulate thinking, and access prior knowledge. For example, teachers may engage students by creating surprise or doubt through a demonstration that shows a piece of steel sinking and a steel toy boat floating. Similarly, a teacher may place an ice cube into a glass of water and have the class observe it float while the same ice cube placed in a second glass of liquid sinks. The corresponding conversation with the students may access their prior learning. The students should have the opportunity to ask and attempt to answer, "Why is it that the toy boat does not sink?"

The engage component includes both accessing prior knowledge and generating enthusiasm for the subject matter. Teachers may excite students, get them interested and ready to learn, and believe they are fulfilling the engage phase of the learning cycle, while ignoring the need to find out what prior knowledge students bring to the topic. The importance of *eliciting* prior understandings in ascertaining what students know prior to a lesson is imperative. Recognizing that students construct knowledge from existing knowledge, teachers need to find out what existing knowledge their students possess. Failure to do so may result in students developing concepts very different from the ones the teacher intends (Bransford, Brown, and Cocking 2000).

A straightforward means by which teachers may elicit prior understandings is by framing a "what do you think" question at the outset of the lesson as is done consistently in some current curricula. For example, a common physics lesson on seat belts might begin with a question about designing seat belts for a racecar traveling at a high rate of speed (Figure 2, p. 58). "How would they be different from ones available on passenger cars?" Students responding to this question communicate what they know about seat belts and inform themselves, their classmates, and the teacher about their prior conceptions and understandings. There is no need to arrive at consensus or closure at this point. Students do not assume the teacher will tell them the "right" answer. The "what do you think" question is intended to begin the conversation.

The proposed expansion of the 5E model does not exchange the *engage* component for the *elicit* component; the engage component is still a necessary element in good instruction. The goal is to continue to excite and interest students in whatever ways possible and to identify prior conceptions. Therefore the elicit component should stand alone as a reminder of its importance in learning and constructing meaning.

Explore and explain

The *explore* phase of the learning cycle provides an opportunity for students to observe, record data, isolate variables, design and plan experiments, create graphs, interpret results, develop hypotheses, and organize their findings. Teachers may frame questions, suggest approaches, provide feedback, and assess understandings. An excellent example of teaching a lesson on the metabolic rate of water fleas (Lawson 2001) illustrates the

FIGURE 1

The proposed 7E learning cycle and instructional model.

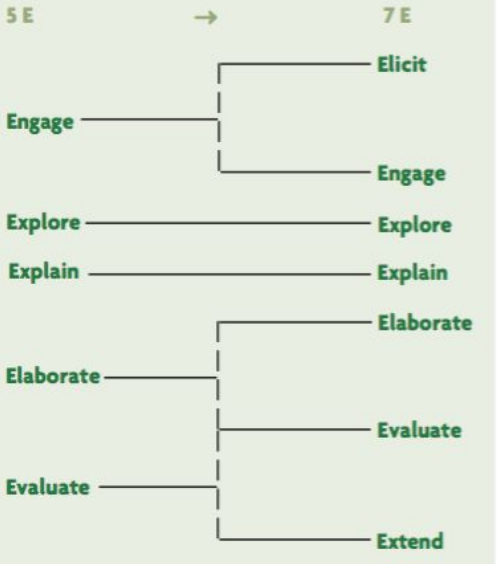

FIGURE 2

Seatbelt lesson using the 7E model.

Elicit prior understandings
- Students are asked, "Suppose you had to design seat belts for a racecar traveling at high speeds. How would they be different from ones available on passenger cars?" The students are required to write a brief response to this "What do you think?" question in their logs and then share with the person sitting next to them. The class then listens to some of the responses. This requires a few minutes of class time.

Engage
- Students relate car accidents they have witnessed in movies or in real life.

Explore
- The first part of the exploration requires students to construct a clay figure they can sit on a cart. The cart is then crashed into a wall. The clay figure hits the wall.

Explain
- Students are given a name for their observations. Newton's first law states, "Objects at rest stay at rest; objects in motion stay in motion unless acted upon by a force."

Engage
- Students view videos of crash test dummies during automobile crashes.

Explore
- Students are asked how they could save the clay figure from injury during the crash into the wall. The suggestion that the clay figure will require a seat belt leads to another experiment. A thin wire is used as a seat belt. The students construct a seat belt from the wire and ram the cart and figure into the wall again. The wire seat belt keeps the clay figure from hitting the wall, but the wire slices halfway through the midsection.

Explain
- Students recognize that a wider seatbelt is needed. The relationship of pressure, force, and area is introduced.

Elaborate
- Students then construct better seat belts and explain their value in terms of Newton's first law and forces.

Evaluate
- Students are asked to design a seat belt for a racing car that travels at 250 km/h. They compare their designs with actual safety belts used by NASCAR.

Extend
- Students are challenged to explore how airbags work and to compare and contrast airbags with seat belts. One of the questions explored is, "How does the airbag get triggered? Why does the airbag not inflate during a small fender-bender but does inflate when the car hits a tree?"

effectiveness of the learning cycle with varying amounts of teacher and learner ownership and control (Gil 2002).

Students are introduced to models, laws, and theories during the *explain* phase of the learning cycle. Students summarize results in terms of these new theories and models. The teacher guides students toward coherent and consistent generalizations, helps students with distinct scientific vocabulary, and provides questions that help students use this vocabulary to explain the results of their explorations. The distinction between the explore and explain components ensures that concepts precede terminology.

Applying knowledge

The *elaborate* phase of the learning cycle provides an opportunity for students to apply their knowledge to new domains, which may include raising new questions and hypotheses to explore. This phase may also include related numerical problems for students to solve. When students explore the heating curve of water and the related heats of fusion and vaporization, they can then perform a similar experiment with another liquid or, using data from a reference table, compare and contrast materials with respect to freezing and boiling points. A further elaboration may ask students to consider the specific heats of metals in comparison to water and to explain why pizza from the oven remains hot but aluminum foil beneath the pizza cools so rapidly.

The elaboration phase ties directly to the psychological construct called "transfer of learning" (Thorndike 1923). Schools are created and supported with the expectation that more general uses of knowledge will be found outside of school and beyond the school years (Hilgard and Bower 1975). Transfer of learning can range from transfer of one concept to another (e.g., Newton's law of gravitation and Coulomb's law of electrostatics); one school subject to another (e.g., math skills applied in scientific investigations); one year to another (e.g., significant figures, graphing, chemistry concepts in physics); and school to nonschool activities (e.g., using a graph to calculate whether it is cost

effective to join a video club or pay a higher rate on rentals) (Bransford, Brown, and Cocking 2000).

Too often, the elaboration phase has come to mean an elaboration of the specific concepts. Teachers may provide the specific heat of a second substance and have students perform identical calculations. This practice in transfer of learning seems limited to near transfer as opposed to far or distant transfer (Mayer 1979). Even though teachers expect wonderful results when they limit themselves to near transfer with large similarities between the original task and the transfer task, they know students often find elaborations difficult. And as difficult as near transfer is for students, the distant transfer is usually a much harder road to traverse. Students who are quite able to discuss phase changes of substances and their related freezing points, melting points, and heats of fusion and vaporization may find it exceedingly difficult to transfer the concept of phase change as a means of explaining traffic congestion.

Practicing the transfer of learning

The addition of the *extend* phase to the *elaborate* phase is intended to explicitly remind teachers of the importance for students to practice the transfer of learning. Teachers need to make sure that knowledge is applied in a new context and is not limited to simple elaboration. For instance, in another common activity students may be required to invent a sport that can be played on the moon. An activity on friction informs students that friction increases with weight. Because objects weigh less on the moon, frictional forces are expected to be less on the moon. That elaboration is useful. Students must go one step further and extend this friction concept to the unique sports and corresponding play they are developing for the moon environment.

The *evaluate* phase of the learning cycle continues to include both formative and summative evaluations of student learning. If teachers truly value the learning cycle and experiments that students conduct in the classroom, then teachers should be sure to include aspects of these investigations on tests. Tests should include questions from the lab and should ask students questions about the laboratory activities. Students should be asked to interpret data from a lab similar to the one they completed. Students should also be asked to design experiments as part of their assessment (Colburn and Clough 1997).

Formative evaluation should not be limited to a particular phase of the cycle. The cycle should not be linear. Formative evaluation must take place during all interactions with students. The *elicit* phase is a formative evaluation. The *explore* phase and *explain* phase must always be accompanied by techniques whereby the teacher checks for student understanding.

Replacing *elaborate* and *evaluate* with *elaborate, extend,* and *evaluate* as shown in Figure 1, p. 57, is a way to emphasize that the transfer of learning, as required in the extend phase, may also be used as part of the evaluation phase in the learning cycle.

Enhancing the instructional model

Adopting a 7E model ensures that eliciting prior understandings and opportunities for transfer of learning are not omitted. With a 7E model, teachers will *engage* and *elicit* and students will *elaborate* and *extend.* This is not the first enhancement of instructional models, nor will it be the last. Readers should not reject the enhancement because they are used to the traditional 5E model, or worse yet, because they hold the 5E model sacred. The 5E model is itself an enhancement of the three-phrase learning cycle that included exploration, invention, and discovery (Karplus and Thier 1967.) In the 5E model, these phases were initially referred to as explore, explain, and expand. In another learning cycle, they are referred to as exploration, term introduction, and concept application (Lawson 1995).

The 5E learning cycle has been shown to be an extremely effective approach to learning (Lawson 1995; Guzzetti et al. 1993). The goal of the 7E learning model is to emphasize the increasing importance of eliciting prior understandings and the extending, or transfer, of concepts. With this new model, teachers should no longer overlook these essential requirements for student learning. ■

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7E Learning Cycle

7E Learning Cycle in Science (Instructional Design Model recommended by the NSTA)			
Phase	**Description**	**Examples/Suggestions for Classroom Instruction**	**Research**
Elicit	▪ extract or draw attention to prior understandings and knowledge ▪ new knowledge is built on existing knowledge ▪ assists in transferring knowledge	▪ K of the KWL Chart (K= Know) ▪ Think-Pair-Share ▪ Draw-What-You-Know	▪ *Doing Good Science in Middle School*
Engage	▪ focus student thinking on content ▪ provide conversation opportunities for all students, not a select few	▪ **Students ask open-ended questions*** ▪ **Students develop and use models *** ▪ Think-Pair-Share to provide conversation opportunities as response to question prompts ▪ Demonstration by teacher with written observations by students ▪ Lesson hook ▪ Foldables for creating visual representations of content and/or vocabulary ▪ Menu Choice Boards – students select optional learning activities ▪ Student created skits to explain or represent knowledge ▪ One-to-one technologies (ie: graphing calculators, interactive white boards, interactive Websites) ▪ Graphic Organizers ▪ Inquiry-Based Learning Stations: discovery, student-centered	▪ *Doing Good Science in Middle School* ▪ *Research-Based Strategies (#5)* * ***Next Generation: Scientific and Engineering Practices***
Explore	▪ observations, ▪ record data, isolate variables, ▪ design experiments, create graphs, ▪ interpret results, organize findings ▪ accompanied by teacher's check for students' understanding	▪ **Students plan and carry out investigations *** ▪ **Students analyze and interpret data *** ▪ Students make predictions from demonstrations. ▪ Question prompts by the teacher ▪ Data collection during lab activities and in science experiments ▪ Cooperative group learning activities ▪ Jigsaw groups where student become group experts and then travel to other groups to share their specific components ▪ Student created graphs	▪ *Expanding the 5E Model* ▪ *GaDOE Instructional Framework for SBC* * ***Next Generation: Scientific and Engineering Practices***