Pacific Remote Islands Marine National Monument – Humans and the Ocean

Grade Level

- 7-12

Timeframe

- 2 45-minute classes

Key Words

- Latitude
- Longitude
- Ocean Circulation
- Upwelling

Activity Summary

This lesson seeks to show students how the islands of the Pacific Remote Islands Marine National Monument are integral to interactions between the human and the natural environment. The environment provides us with resources and these resources needs have changed over time. This need for resources is a major reason why islands of the PRIMNM are part of the United States. The historical resource use and the transportation associated with it are used to show how the natural world (i.e. ocean currents and wind patterns) affects humans. Students use the introduction of how sailors traveled to the islands to investigate global wind and currents, and then through a demonstration, understand how global currents can have local effects through processes like upwelling.

Learning Objectives

- Gain a basic understanding of wind patterns in the central Pacific and how that might affect travel decisions
- Understand how wind and temperature differences drive ocean currents
- Draw connections between how the physical processes of the ocean can affect biological systems, including humans

Background Information

Many of the islands of the Pacific Remote Islands Marine National Monument were visited by ancient Polynesian voyageurs, but none of the islands appear to have sustained long

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Outline

ENGAGE – Discovery of the islands of PRIMNM

EXPLORE – Wind patterns of the central Pacific and how that would affect sailing routes

EXPLAIN – Visualization of global wind and ocean currents

ELABORATE – Upwelling demonstration

EVALUATE – Create a voyage plan based upon wind and ocean currents.

Vocabulary

LATITUDE AND LONGITUDE – the lines that divide the globe and run parallel to the equator or prime meridian

OCEAN CIRCULATION – the major patterns of global ocean circulation

UPWELLING – the process by which deep ocean water returns to the surface

term colonization due to lack of available resources. However, one of the resources they do possess, guano, was of great interest in the mid-1800s. The ships traveling to the islands to transport the guano back to the Americas were sailing ships. These square-rigged ships sailed best with the wind at their stern, pushing them from behind. Sailing with, as opposed to against, a dominant ocean current also was in a ship's advantage. Today, as ships plan their routes, they still consider wind and currents even though they may not have as significant effects upon large motor vessels. They use Pilot Charts like the ones used in this lesson to plan the best route. That is just one tool for navigation. Historically, Polynesians and western sailors relied on the sun, stars, wind and currents to navigate. Currently, a Hawaiian voyaging canoe named Hokule'a, is sailing throughout the Pacific using traditional Polynesian navigation. You can read about her voyage at http://www.hokulea.com/.

In addition to affecting how sailors would travel to and from the islands, ocean currents have a great effect on the natural processes of a region as well. Baker, Howland and Jarvis are located within 50 nm of the equator in the central Pacific Ocean and this location puts the islands in the flow of the Equatorial Undercurrent (EUC). The EUC is a cold, nutrient rich subsurface current and when it comes into contact with the underwater volcanoes that form the base of the islands, the result is upwelling. Upwelling is the process by which deep ocean water, often cold and nutrient-rich, returns to the surface. When the nutrient-rich waters rise to the surface, they fuel primary productivity, the energy from which travels up the food web to zooplankton, fish, seabirds, and other upper level predators.

Preparation

- Familiarize yourself with the Pacific Remote Islands on Google Earth.
- Print the Pilot Charts and understand how to read them.
- Make sure the ocean and wind circulation animation is working on your computer.
- Practice the upwelling demonstration.

Learning Procedure

Engage

Either using Google Earth or the map from the images file, show the Pacific with the islands of the PRIMNM. If you did not do Lesson 1 on seabirds, you may want to do the *Engage* part of that lesson to give your students some perspective on the size and locations of these islands.

Instructional Materials and Resources:

- Pilot Charts: 1 of the same month for North Pacific and South Pacific (1 per pair or small group) can be downloaded here: http://www.offshoreblue.com/navigation/pilot-charts.php
- Computer and projector
- Animation of global wind patterns and ocean currents: http://earth.nullschool.net/#current/wind/surface/level/orthographic=-158.83,3.97,608
- For basic upwelling demonstration:
    - Small aquarium or clear, rectangular container roughly 18" x 4" x 4'
    - Room temperature salt water – mix 30-35 grams of salt per liter of water will replicate seawater
    - Aquarium heater or hot water
    - Ziploc bag of ice
    - Binder clip or some method of attaching bag of ice to top edge of container
    - Red and blue food coloring
- For more extensive demonstration of circulation in addition to what is listed above:
    - 2 more similar sized aquariums or containers
    - A fan or hairdryer
    - An additional bag of ice

- Give your students a few minutes to talk in small groups to brainstorm about the discovery of the islands and how they came to be part of the United States.
- Have them share their ideas, making a list of reasons they might be part of the U.S.

Give your students a brief introduction to the fact that a unique feature of these islands (and a few other coastal areas in the world) is that guano accumulates which can then be mined by people and used for fertilizer in agricultural areas. ***You may skip or just do a very quick reminder if you completed the lesson on nutrient cycling.*** The U.S. passed a law called the Guano Islands Act on August 18, 1856 that enables U.S. citizens to claim islands containing guano for the U.S. as long as they are not previously occupied and not already owned by another government.

> *Whenever any citizen of the United States discovers a deposit of guano on any island, rock, or key, not within the lawful jurisdiction of any other Government, and not occupied by the citizens of any other Government, and takes peaceable possession thereof, and occupies the same, such island, rock, or key may, at the discretion of the President, be considered as appertaining to the United States.*
>
> 1. *—first section of Guano Islands Act of 1856*

Over 100 islands were claimed at some point for the U.S. under this act, though only a few remain in its possession. Of those, several are in the PRIMNM including Baker, Howland, Jarvis, Johnston, Kingman Reef, and Palmyra.

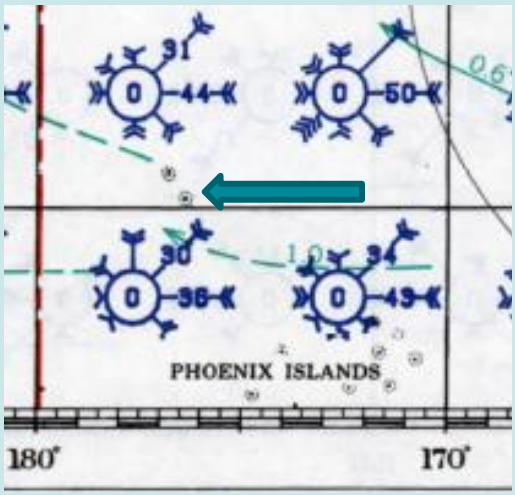
How were the islands discovered and claimed and how was the guano transported back to the mainland U.S.? Ask your students what they know about exploration in general and how their existing knowledge might apply to these islands. These questions are also Part 1 of the associated student worksheet. If your classroom or students have computer access you can give your students the worksheet and have them work in small groups and use the internet to answer the questions. Or you can lead a group discussion and collectively brainstorm and discuss the answers.

- Who was exploring and what were their motivations?
  The islands discovered and claimed under the Guano Act were discovered by Americans or Europeans in a variety of ways. Many were sighted by whaling or merchant ships and their locations recorded or passed onto companies that would mine and transport guano back to the United States. Those companies would then send their own ships to claim the islands. The

location of some islands was on record because ships had wrecked on the reefs.

- What was their method of traveling and what technologies did they have at their disposal? *Open ocean exploring was conducted in sailboats at that time. Americans and Europeans typically used square-rigged ships for long ocean voyages. These ships had no engine which meant explorers were at the mercy of the wind and currents for how fast and in which directions they could sail. Square-rigged sailboats work by being pushed by the wind; they cannot sail towards the direction that the wind is coming from.*
- How would current technology have changed the exploration process?
  Having an engine would have drastically changed how sailors traveled throughout the Pacific. It would change their speed, the directions they could travel, and how long they could be away from land. Modern navigation equipment also makes it much easier to track where you are on the open ocean.

You should remind your students that although the Guano Act and mining guano was the start of the American and European presence on the islands, that Polynesians had known of their existence for some time. There are lots of videos on the Polynesian Voyaging Society's website about voyages they have been made in the spirit of historical exploration and learning. (http://www.hokulea.com/category/video-2/)



From the North Pacific Pilot Chart. The blue arrow is pointed at Baker Island.

Explore

Show this video of a navigation report from Hokule'a from August, 2014 in which it is discussed how wind direction can affect navigation decisions: http://www.hokulea.com/20140807-navigation-report/
It is slightly less than two minutes.

> When I'm playful I use the meridians of longitude and parallels of latitude for a seine, drag the Atlantic for whales.
>
> -Mark Twain, Life on the Mississippi

Distribute the Pilot Charts and the Pacific Ocean charts and give a brief overview of how to read the Pilot Chart (instructions also on the chart itself). Show the students how to line up the north and south Pacific charts so they have a picture of the whole Pacific Ocean. Baker is not labeled but there is a circle on the chart marking its location. Just northwest of the Phoenix Islands label there are two circles, Baker is the one to the south almost touching the equator line. Ask the students to predict a route in pencil on the Pilot Chart of where the ship that discovered Baker Island may have been traveling to and from. Remind them you cannot sail straight into the wind, draw on the board the

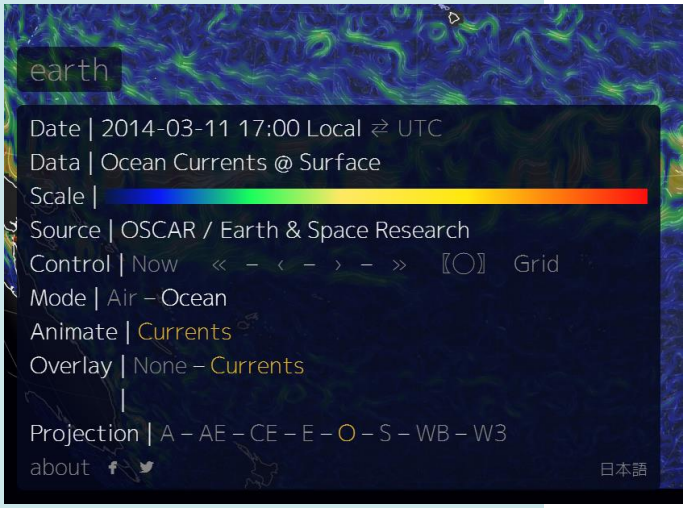
diagram shown below to clarify in which directions a sailboat can sail relative to the wind.

- Things you may stress for them to consider: wind, currents, proximity, destination, transportation infrastructure in the U.S. in the mid 1800's. Depending on time, you may want to remind them the Panama Canal did not yet exist, or give them a chance to predict the route before reminding them of that fact. The Pilot Charts do not show the eastern seaboard of the US. It may be useful to project or display a map that shows the Pacific as well as all of North and South America and have them verbalize the parts of the route they cannot draw.
- Give them the following information and ask them to refine their predictions.
    - The ship that discovered Baker Island was originally from Nantucket Island off the east coast of Massachusetts. It was in the Pacific to hunt whales.
    - The ship, called the *Equator*, was a sailing ship that worked best with the wind behind it. You could also think of it sailing best in the directions that the longest arrows on the Pilot Chart point towards.
- Ask students to talk with their neighbors, share their predictions, and then give them final pieces of information.
    - The *Equator* was in Hawaii in 1819, sometime after discovering Baker.
- Ask students to share their ideas with the class, and then explain that the *Equator*, and other whaling ships from New England, would have gone around Cape Horn and north along the coast of South America. Eventually they would sail offshore to go to Hawaii. Both the wind direction and ocean currents played a role in how they would travel because they did not have engines to move their ships. Show the image of typical whaling routes and currents. The *Equator* would have likely taken a route similar to the pink one.
- Connect this to modern times by explaining the ocean is still used for a great deal of global transportation. On the North Pacific Pilot Chart there are arcs labeled as great circle routes that are typically the routes currently taken by vessels traveling between the two ports. They represent the shortest route between those two places.

Explain

Wind was crucial for the movement of the ships that discovered these islands and were used to transport guano back to the United States. Where does wind really come from?

- Show this animation of global wind and ocean currents: http://earth.nullschool.net/#current/wind/surface/level/orthographic=-158.83,3.97,608
- Reorient the globe so the Pacific is the focus so it's clear what's happening there. By clicking on the Earth and moving the cursor you can move the image however you'd like.
- Earlier in the lesson students learned about how wind had an effect on explorers' travel; ask what other global processes (natural and human) wind effects?
  Ocean currents, wind-generated power, weather



Show the animation again but this time switch it to show ocean currents.

- You can change to ocean currents by clicking on "Earth" in the corner, then click "ocean" option under mode. Show the Atlantic and see if your students recognize the Gulf Stream along the eastern coast of the U.S.
- Switch back to the Pacific. What are some of the major currents in the Pacific Basin? Are the currents that we see on this animation the only currents in the ocean?
  These are just surface currents, subsurface currents exist as well.

Elaborate

In the equatorial Pacific, there is a nutrient-rich subsurface current called the Equatorial Undercurrent (EUC). When this current runs into the underwater volcanoes that form the bases of Howland, Baker and Jarvis, the nutrient-rich water moves up to the surface in a process called upwelling. This is important because the nutrients brought to the surface by upwelling are important for phytoplankton. Phytoplankton need the nutrients and sunlight for food and growth. Phytoplankton are important as they are the base of the oceanic food web providing food for zooplankton and other small organisms that are in turn eaten by seabirds, fish, and other larger marine organisms.

Basic Upwelling Demonstration

1. Fill the aquarium or clear plastic container with room temperature water.

2. Use a binder clip to attach the bag of ice to one of the sides of the container. Make sure the ice is at least mostly below the surface of the water. If you have an aquarium heater, plug it in at this time. Heat additional water; it does not need to boil but should be fairly hot.
3. Ask your students to make predictions about what will happen when you add the dyed hot water.
4. Add a few drops of red food coloring to the warm water and mix. Slowly and gently pour the warm water into the container on the opposite side of the ice. Add a few drops of blue food coloring in the water next to the ice bag. If you are using an aquarium heater add a few drops of red food coloring to the water next to the heater. Add the blue drops next to the ice as previously described.

Explanation

You should see the color on the ice side sink, travel across the bottom of the container, and eventually go back to the surface on the side with heater/warm water. The uneven heating of the Earth, like the temperature change in the container, drives deep circulation of the ocean, called thermohaline circulation. Ask your students to imagine that the sinking process takes place elsewhere in the Pacific and the edge of the container where the water rises back to the surface is the one of the islands you have been discussing. When subsurface currents hit an obstruction like the edge of the container or a submerged volcano, some of the water and everything dissolved in it, like nutrients and gases, rises to the surface. For obstructions the size of a volcano some of the water may also flow around the base and remain deep as opposed to upwelling. Our container more closely resembles a continent where there is no place where the water to go but up. Show the students the images below of the bathymetric images of Baker, Howland, and Jarvis and explain how the islands act like the edge of the container in the demonstration. All of the images are 3-D images of multibeam bathymetry from Pacific Benthic Habitat Mapping Center, part of the School of Earth Science and Technology at the University of Hawaii at Manoa. Purple/blue represents the deepest areas while red is the shallowest. The faster it transitions from cool to warm colors, the steeper the landform.

Extended Upwelling/Circulation Demonstration

1. Fill each of the three containers with room temperature water. For Treatment 3, mix some table salt into the water. Ocean water is typically between 30 – 35 parts per thousand (ppt) so 30 – 35 grams of salt per liter of water will approximate seawater.
2. Attach ice bags to the side of two of the three containers.

3. If using heaters, attach to the other side of all three containers. If using warm water, add red food coloring to warm water and mix well.

Treatment 1 – Demonstration of wind mixing only

1. Add a few drops of red food coloring to the heater side or gently pour your warm colored water into one side.
2. Add a few drops of blue to the other side.
3. Use the fan or hair dryer to blow wind across the surface of the water.

Treatment 2 – Use procedure outlined above in the basic upwelling demonstration.

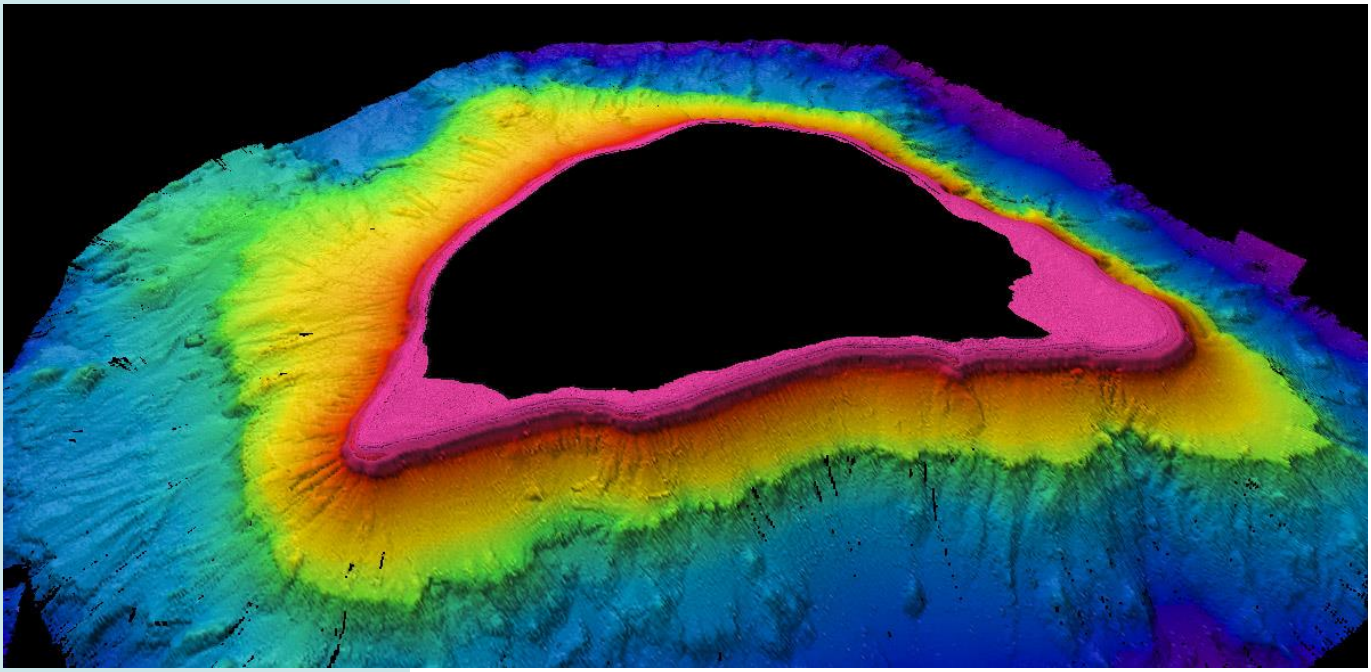
Treatment 3 – Demonstration of fresh water lens

1. Use a fork or other sharp object to poke a few holes in the ice bag. This will allow some cold, fresh water to leak out of the bag. Add a few drops of blue food coloring to that side.
2. Add a few drops of red food coloring to the heater side or gently pour in the warm water.

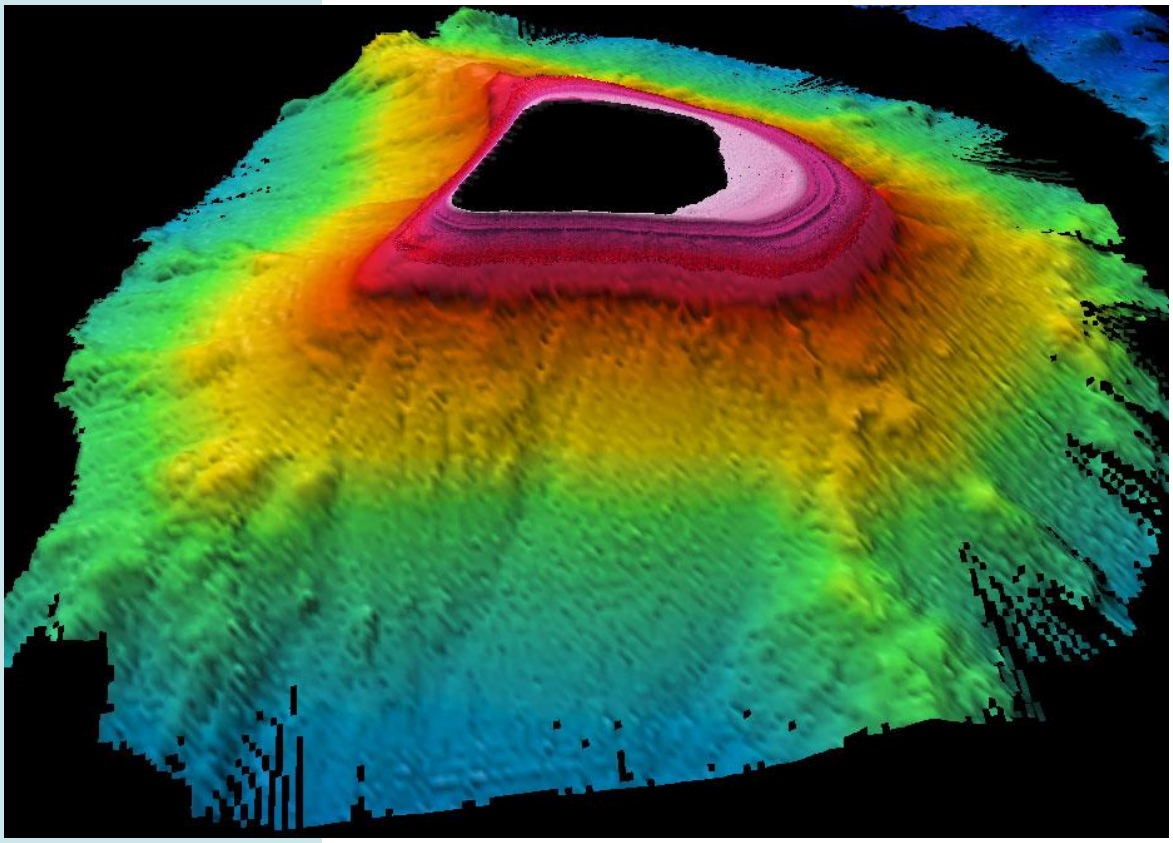
Explanation

Treatment 1 shows the effect of wind mixing. You should see a mix of red and blue, but only at the top of the container. The wind can mix the top layers of the water, but cannot drive those top layers down to the bottom of the container. Treatment 2 shows how the density difference between hot and cold water can cause water to sink and drive deeper circulation that wind alone. Treatment 3 shows how the difference in density between fresh and salt water can prevent circulation. The blue water should sit near the surface since the fresh water is less dense than the salt water. So even though the water is cold and dense it doesn't sink as much as in Treatment 2.

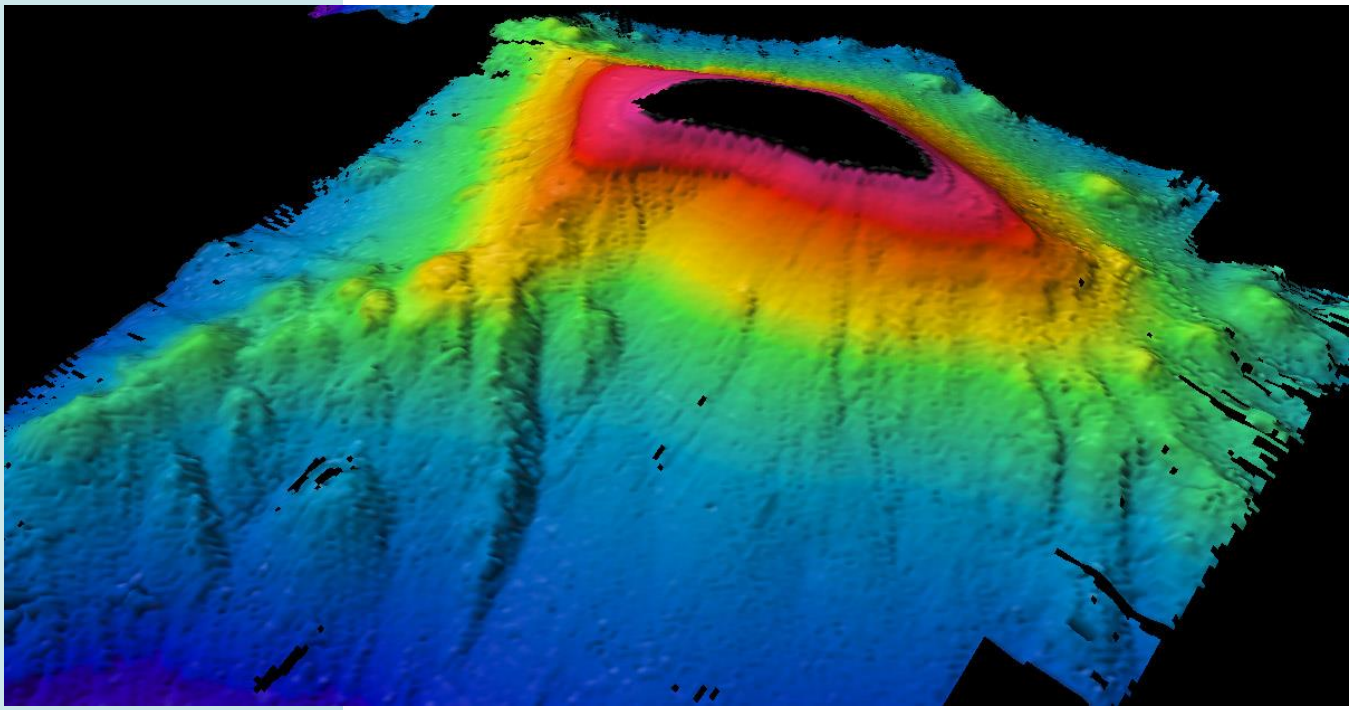
Johnson Atoll



Baker Island



Howland Island



Evaluate

Return to the Pilot Charts used at the beginning of the lesson. Have the students design a voyage based upon what they've learned about ocean currents and how sailboats work. You can give them a starting and finishing location or let them design the whole voyage themselves. Have them fill out the voyage plan worksheet, giving an explanation of why they would travel to those places, being explicit about how the currents and wind affect their directional choices. The worksheet prompts the students to use the Pilot Charts and teacher guidance to plan the voyage; feel free to provide as much or as little direction as you feel your students need. For example, you can give the students options of destinations, stating that they must include at least two continents, or let them decide on their own.

Closing

The circulation of the ocean affects the weather patterns, movement of nutrients around islands, and human travel on the ocean. Even far away from the ocean these patterns affect us. Despite our knowledge of the ocean currents there is still a lot to be learned by exploring and learning about historical exploration routes.

Extending the Lesson

- Investigate one way we learn about ocean circulation. ARGO is an international project, in which ships launch ocean observing floats all over the global ocean. Float data and information can be found here: http://www.argo.net/index_flash.html and here http://www.argo.ucsd.edu/.
- Learn more about the Polynesian Voyaging Society and their around the world voyage at http://www.hokulea.com/.
- Learn about what it was like to live on the Pacific Remote Islands. From 1935-1942 the United States sent a handful of young, native Hawaiian men to live there and it is documented in the movie *Under a Jarvis Moon*. It is just under an hour and can be found at http://www.imdb.com/video/imdb/vi3879443993/
- Learn about how people developed a method of being able to figure out the longitude of a ship's location while at sea. Read all or some of the book *Longitude*, by David Sobel or do some internet research. The first chapter of *Longitude* is available free on Google Books.
- Connect lessons learned to your local environment. If you are coastal, there may be some historical connection between the ships that were part of the guano trade. You can also discuss the major local ocean currents. If you are inland, discuss how major wind patterns can affect weather in your area.

Connections To Other Subjects

- Geology
- Ecology
- Biology
- Oceanography
- Physics

Related Links

Hokule'a Polynesian Voyaging Society
NOAA Fisheries Pacific Remote Islands MNM
NOAA Fisheries Pacific Islands Regional Office
NOAA Fisheries Seabird Program
Palmyra Atoll Research Consortium

For More Information

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Acknowledgement

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All images are from NOAA unless otherwise cited.

Thank you to all the reviewers for their feedback and assistance.

Sources

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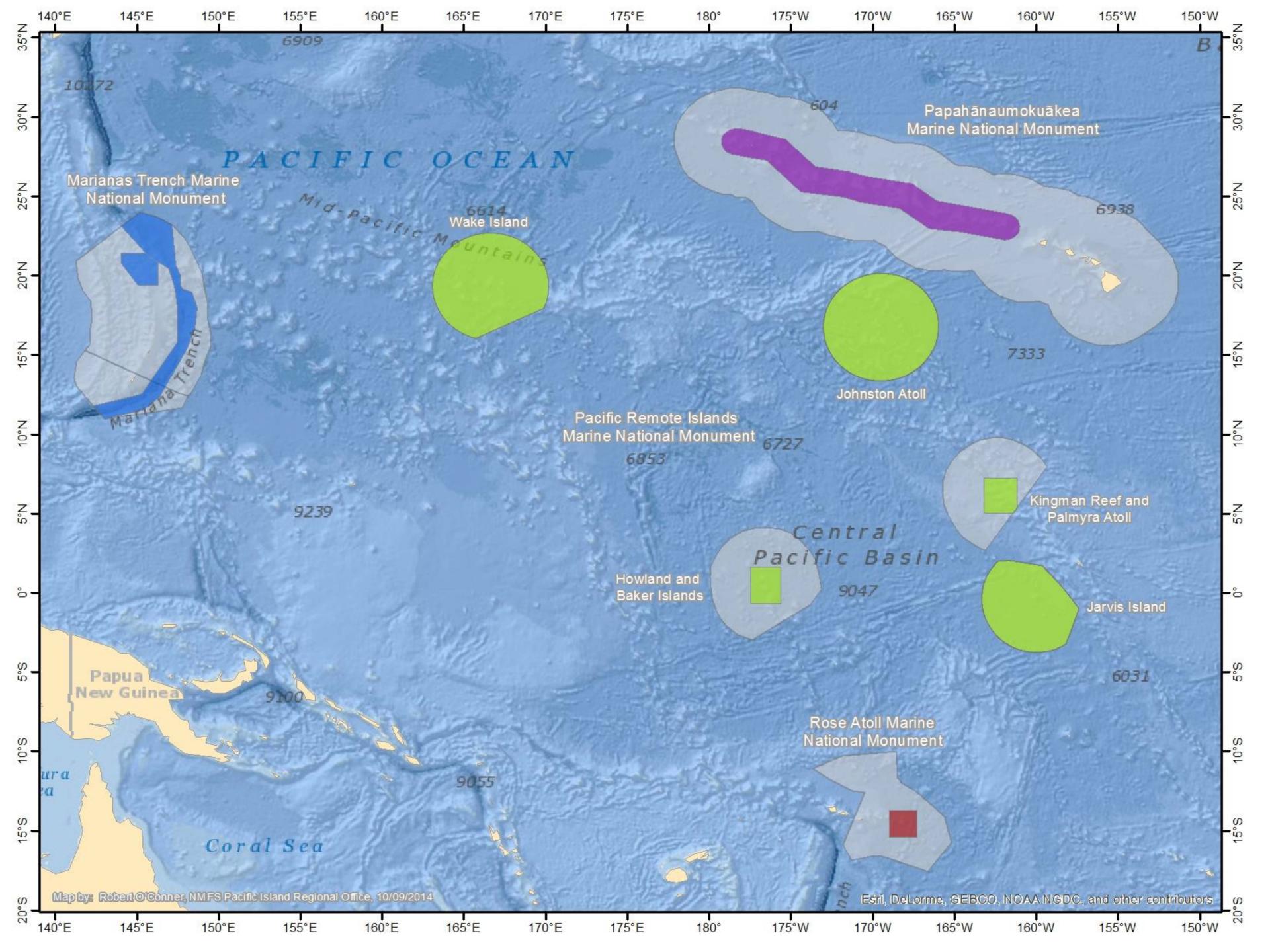
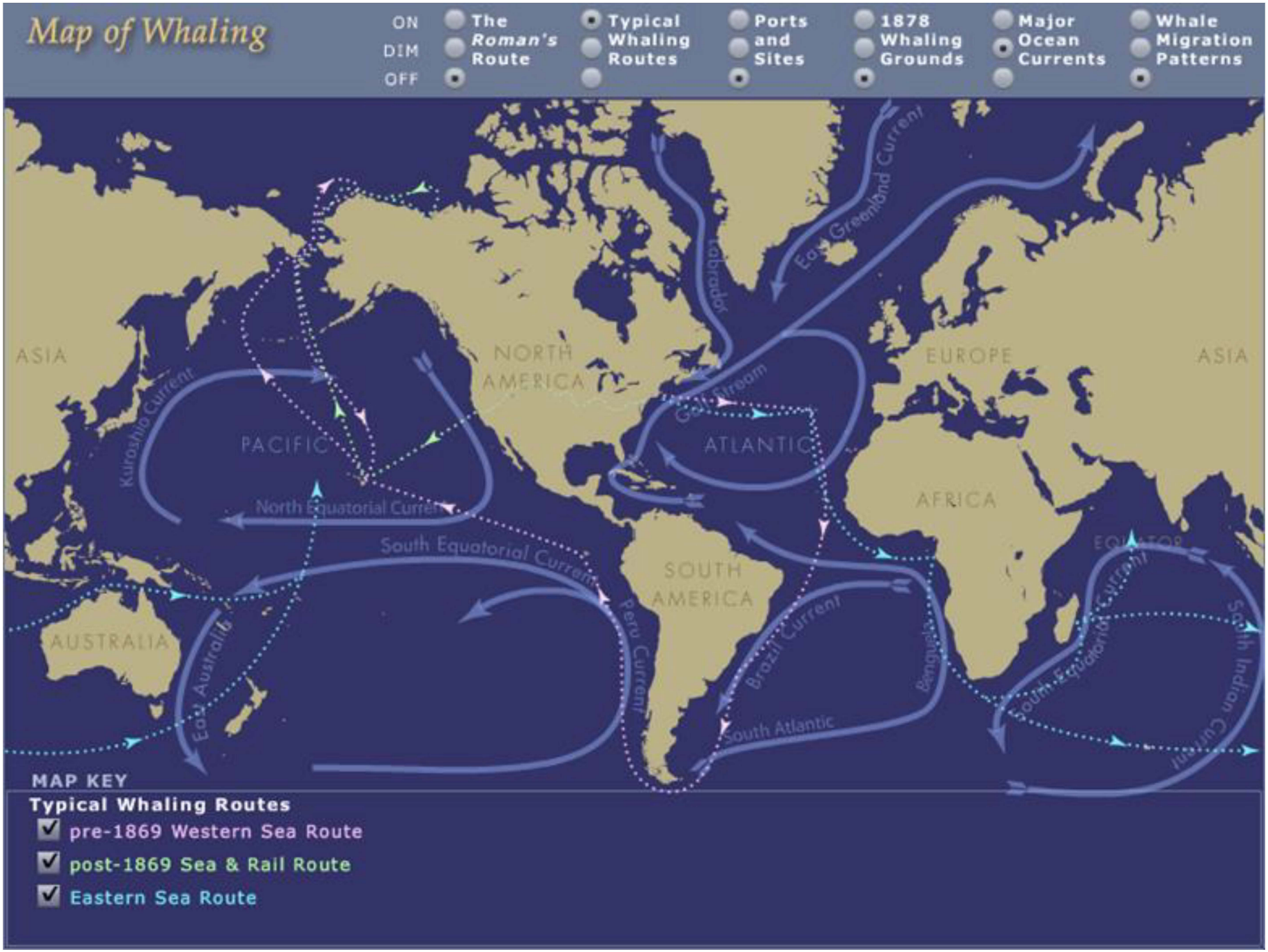
Rauzon, M., D. Forsell, E. Flint, and J. Gove. (2011). Howland, Baker, and Jarvis Islands 25 years after cat eradication: the recovery of birds in a biogeographical context. *Island Invasives: Eradication and Management*. 345-349.

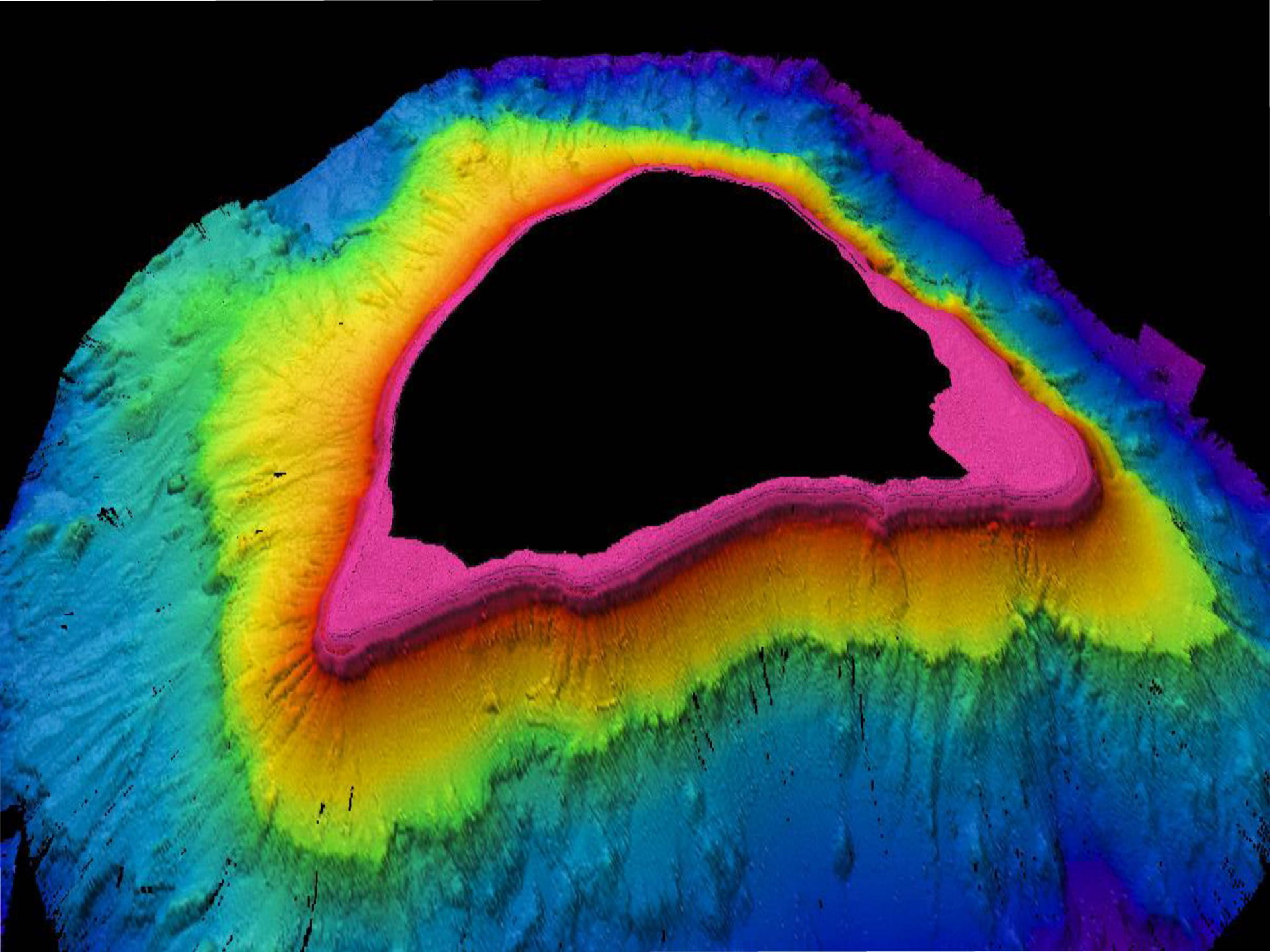
U.S. Fish and Wildlife Service. Baker Island National Wildlife Refuge. http://www.fws.gov/refuges/profiles/index.cfm?id=12511

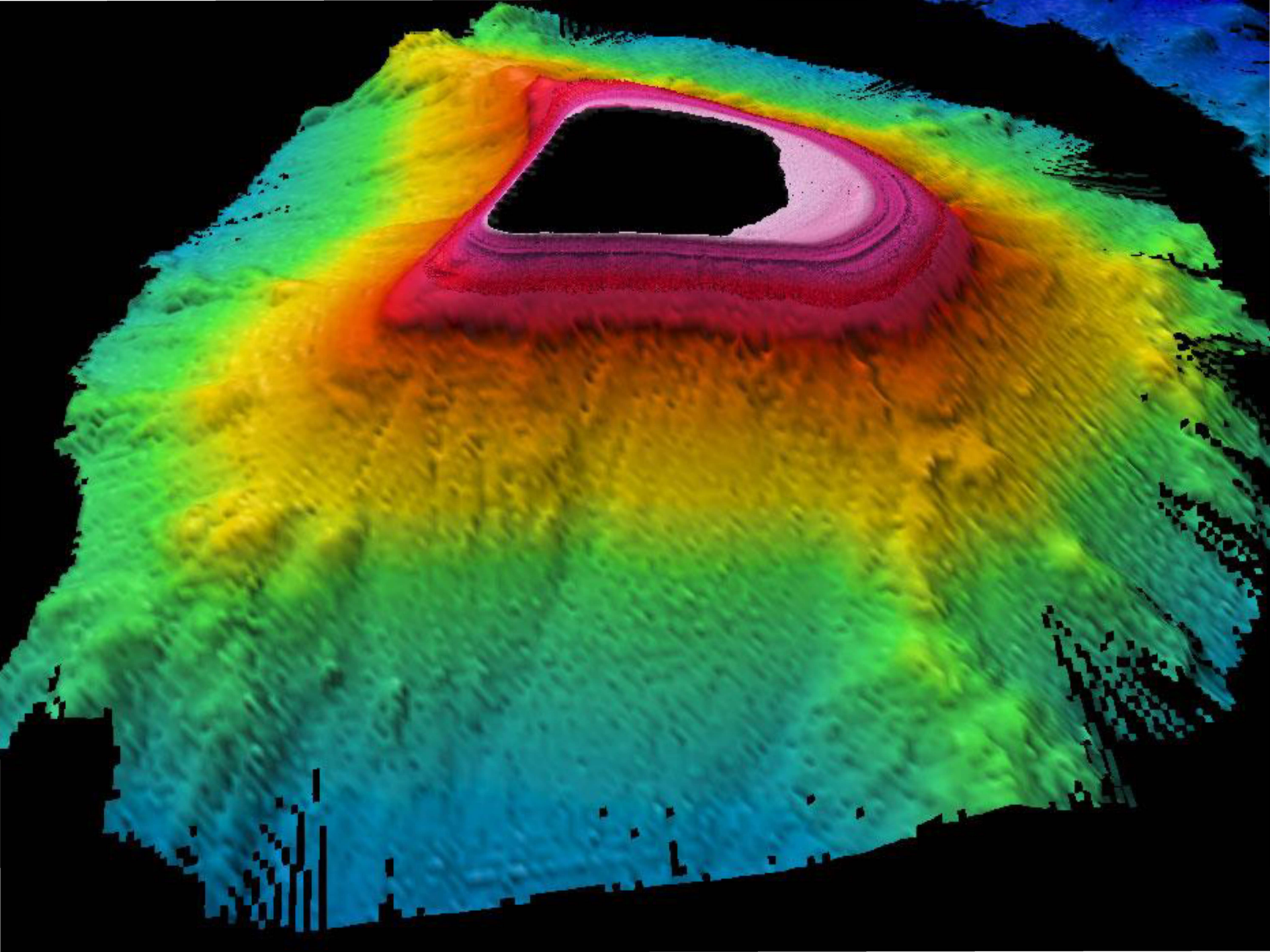
Education Standards

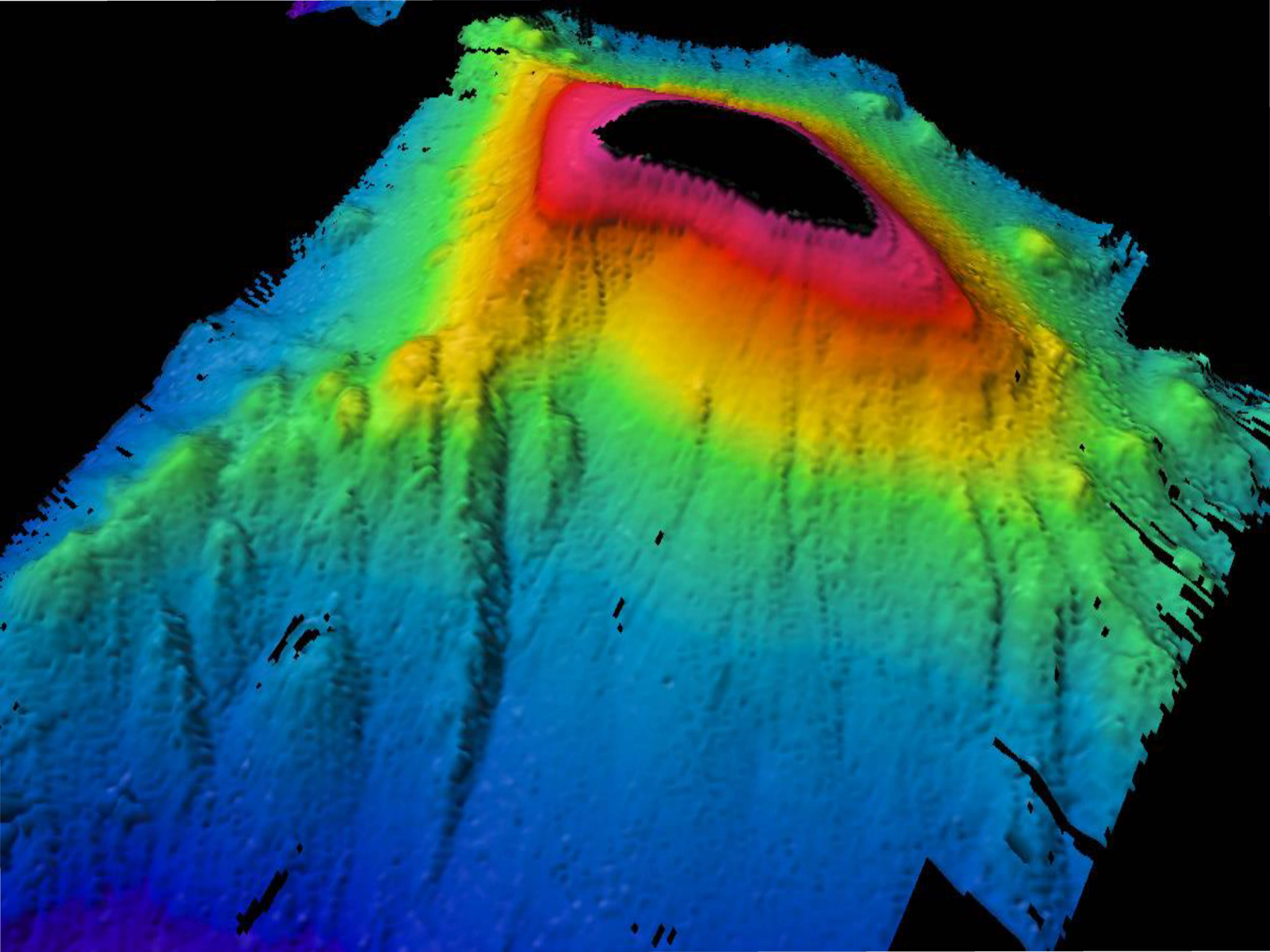
Next Generation Science Standards	• **MS-LS2-2.** – Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems. Examples of types of interactions could include competitive, predatory, and mutually beneficial.] • **MS-LS2-4.** – Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.] • **HS-LS2-2.** – Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. [Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.] [Assessment Boundary: Assessment is limited to provided data.] • **HS-LS2-7.** – Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* [Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.] • **HS-LS4-5.** – Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. [Clarification Statement: Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species.] • **HS-LS4-6.** – Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.* [Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.]
Ocean Literacy Principles	• **5** – The ocean supports a great diversity of life and ecosystems. • **5D** – Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and every transfer) that do not occur on land. • **5F** – Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life. • **6D** - Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean. • **6G** - Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.


PACIFIC OCEAN
Marianas Trench Marine National Monument
Mid-Pacific Mountains
Wake Island
Papahānaumokuākea Marine National Monument
Johnston Atoll
Pacific Remote Islands Marine National Monument
Kingman Reef and Palmyra Atoll
Central Pacific Basin
Howland and Baker Islands
Jarvis Island
Papua New Guinea
Rose Atoll Marine National Monument
Coral Sea
Map by: Robert O'Conner, NMFS Pacific Island Regional Office, 10/09/2014
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors


Map of Whaling
ON
DIM
OFF
The Roman's Route
Typical Whaling Routes
Ports and Sites
1878 Whaling Grounds
Major Ocean Currents
Whale Migration Patterns
ASIA
NORTH AMERICA
EUROPE
ASIA
PACIFIC
ATLANTIC
AFRICA
SOUTH AMERICA
AUSTRALIA
Kuroshio Current
North Equatorial Current
South Equatorial Current
Peru Current
East Australia
Brazil Current
South Atlantic
Benguela
South Equatorial Current
South Indian Current
Labrador
East Greenland Current
Gulf Stream
MAP KEY
Typical Whaling Routes
pre-1869 Western Sea Route
post-1869 Sea & Rail Route
Eastern Sea Route







Pacific Remote Islands Marine National Monument: Student Voyage Plan

Name_____ Date_____

Part 1: Exploring the Pacific

1. Who was exploring the Pacific Ocean and what were their motivations?

2. How did these explorers travel and what technologies did they have at their disposal to help them find their way?

3. How would current technology have changed the exploration process if it were available to the early explorers?

Name_____ Date_____

Part 2: Route finding

Use the Pilot Charts used at the beginning of class and guidance provided by your teacher to plan a voyage aboard a sailing ship.

1. What are the starting and final destinations of your voyage?

2. Describe and provide a rough sketch of your route below.

3. How did ocean currents and wind patterns affect your choice of route?

4. If you were going to sail your voyage in reverse and sail from your destination to your starting point, would you take the same route or would you sail another way? Refer to currents and wind in your answer.

Pacific Remote Islands Marine National Monument: Student Voyage Plan ANSWER KEY

Name_____ Date_____

Part 1: Exploring the Pacific

1. Who was exploring the Pacific Ocean and what were their motivations?

   The islands claimed under the Guano Act were found by Americans and Europeans, some on voyages specifically looking for islands with guano mining potential. Many were sighted by whaling or merchant ships and their locations recorded or passed onto companies that would mine and transport guano back to the United States. Those companies would then send their own ships to claim the islands. The location of some islands was on record because ships had wrecked on the reefs.

2. How did these explorers travel and what technologies did they have at their disposal to help them find their way?

   Open ocean exploring was conducted in sailboats at that time. Americans and Europeans typically used square-rigged ships for long ocean voyages. These ships had no engine which meant explorers were at the mercy of the wind and currents for how fast and in which directions they could sail. Square-rigged sailboats work by being pushed by the wind; they cannot sail towards the direction that the wind is coming from.

3. How would current technology have changed the exploration process if it were available to the early explorers?

   Having an engine would have drastically changed how sailors traveled throughout the Pacific. It would change their speed, the directions they could travel, and how long they could be away

from land. Modern navigation equipment also makes it much easier to track where you are on the open ocean.

Name_____ Date_____

Part 2: Route finding

Use the Pilot Charts used at the beginning of class and guidance provided by your teacher to plan a voyage aboard a sailing ship.

1. What are the starting and final destinations of your voyage?

Students can pick any places, just should be two places you can travel between by sea.

2. Describe and provide a rough sketch of your route below.

This should align with what they answered in #1. Their route should use the wind and currents to their advantage; they shouldn't have their ship sailing directly against wind or against prevailing currents. They should use the information from the Pilot Charts to plan the route.

3. How did ocean currents and wind patterns affect your choice of route?

This should be a basic explanation of how they used the Pilot Chart to analyze the wind and currents that would affect their travel. Students should demonstrate that they can read the Pilot Chart and understand that traveling directly into the wind or against the current would make the voyage difficult.

4. If you were going to sail your voyage in reverse and sail from your destination to your starting point, would you take the same route or would you sail another way? Refer to currents and wind in your answer.

If the student has correctly planned their original voyage and had the wind and currents behind their boat, the return voyage will likely follow a different path to take advantage of different winds and currents. How different this return voyage is will depend on factors like their destinations and their first voyage. Again, look for a demonstrated understanding of how winds and currents vary geographically and that just retracing their steps may not be the most efficient option.