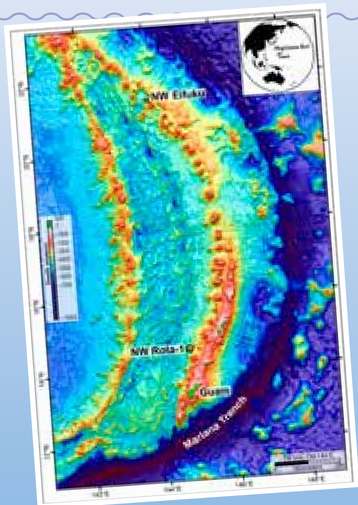
OCEAN EXPLORATION & RESEARCH

Submarine Ring of Fire 2014 – Ironman Expedition

National Treasure



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lesson plan

Focus
Carbon dioxide from deep-ocean volcanoes and its effect on ocean acidity

Grade Level
6-8, with adaptations for 9-12 (Life Science/Earth Science)

Focus Question
What actions should be taken to effectively manage the Marianas Trench Marine National Monument?

Learning Objectives
- Students will evaluate alternative design solutions for maintaining biodiversity and ecosystem services in the Marianas Trench Marine National Monument.
- Students will describe a method for monitoring and minimizing impacts of scientific investigations on the deep ocean environment within the Marianas Trench Marine National Monument

Materials
- ❑ Copies of *Selecting a Management Strategy for the Marianas Trench Marine National Monument Research Guide*, one copy for each student group
- ❑ Copies of *Background on Marine Protected Areas*, one copy for each student group

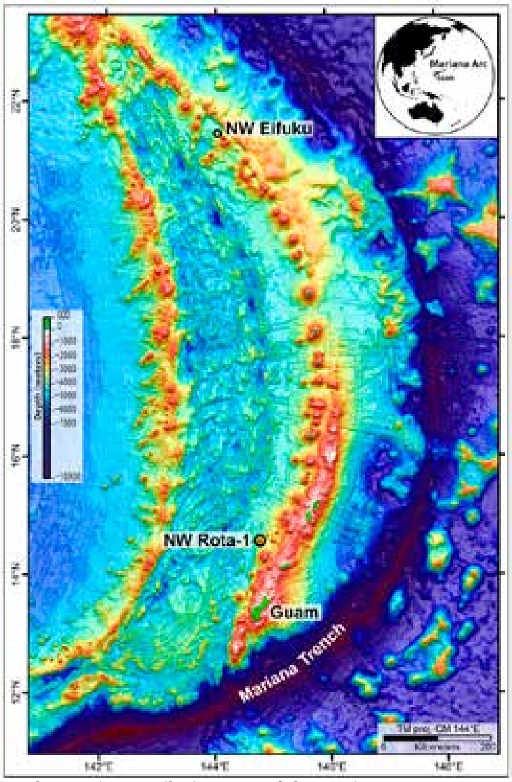
Audio-Visual Materials
- ❑ (Optional) Interactive whiteboard

Teaching Time
Two 45-minute class periods

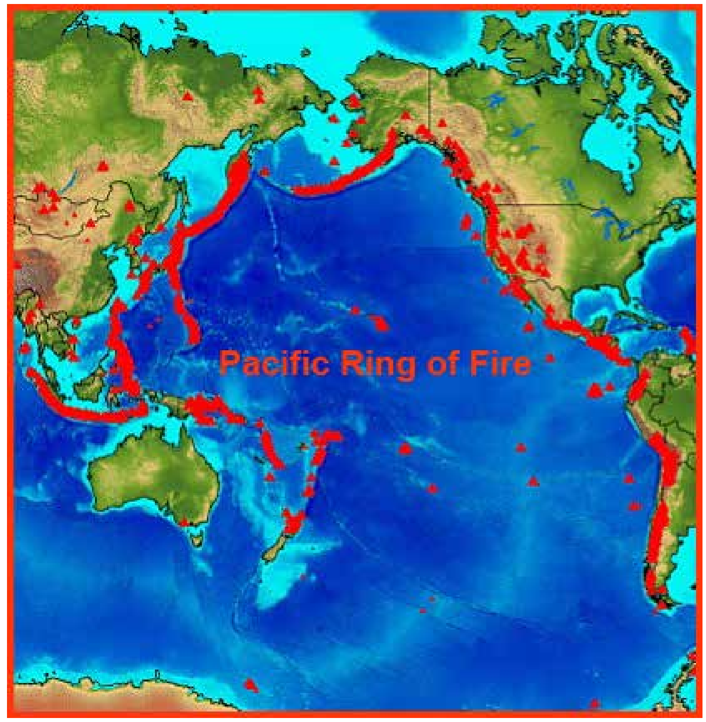
Seating Arrangement
Groups of three or four students

Maximum Number of Students
30

Key Words
Marianas Trench Marine National Monument
Biodiversity
Management



Bathymetric compilation map of the Mariana Arc area showing the location of the 2 focus sites on the expedition, NW Eifuku and NW Rota-1 as well as the Marianas Trench. Multibeam bathymetry (120m grid-cell size) is overlaid on satellite altimetry data. Image credit: NOAA/PMEL Submarine Ring of Fire 2014 Expedition.



Map of all of the volcanoes around the Pacific (red triangles), making up the Ring of Fire. Image credit: NOAA/PMEL Submarine Ring of Fire 2014 Expedition.

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

The Ring of Fire is an arc of active volcanoes and earthquake sites that partially encircles the Pacific Ocean Basin. The location of the Ring of Fire coincides with the location of oceanic trenches and volcanic island arcs that result from collisions between large pieces of Earth's crust (tectonic plates) as they move on a hot flowing layer of Earth's mantle (for more about tectonic plate boundaries, please see Appendix A). When two tectonic plates collide more or less head-on, one of the plates usually moves beneath the other in a process called subduction. Subduction produces deep trenches, and earthquakes are common. As the sinking plate moves deeper into the mantle, increasing pressure and heat release fluids from the rock causing the overlying mantle to partially melt. The molten rock (magma) rises and may erupt violently to form volcanoes that in turn may form arcs of islands along the convergent boundary. These island arcs are always landward of the neighboring trenches. The Ring of Fire marks the location of numerous collisions between tectonic plates in the western Pacific Ocean.

Images from Page 1 top to bottom:
Bathymetric compilation map of the Mariana Arc area showing the location of the 2 focus sites on the expedition, NW Eifuku and NW Rota-1 as well as the Marianas Trench. Multibeam bathymetry (120m grid-cell size) is overlaid on satellite altimetry data. Image credit: NOAA/PMEL Submarine Ring of Fire 2014 Expedition.

Mussel bed at NW Eifuku where pH can be as low as 5.3. Image credit: NOAA/PMEL Submarine Ring of Fire 2006 Expedition.
http://oceanexplorer.noaa.gov/explorations/06fire/logs/may8/media/mussel_water_samp.html

Photograph of iron-oxide-encrusted microbial mat collected using ROV (remotely operated vehicle) at Yellow Top Vent, Northwest Eifuku.
http://oceanexplorer.noaa.gov/explorations/04fire/logs/april12/media/yellow_cone.html

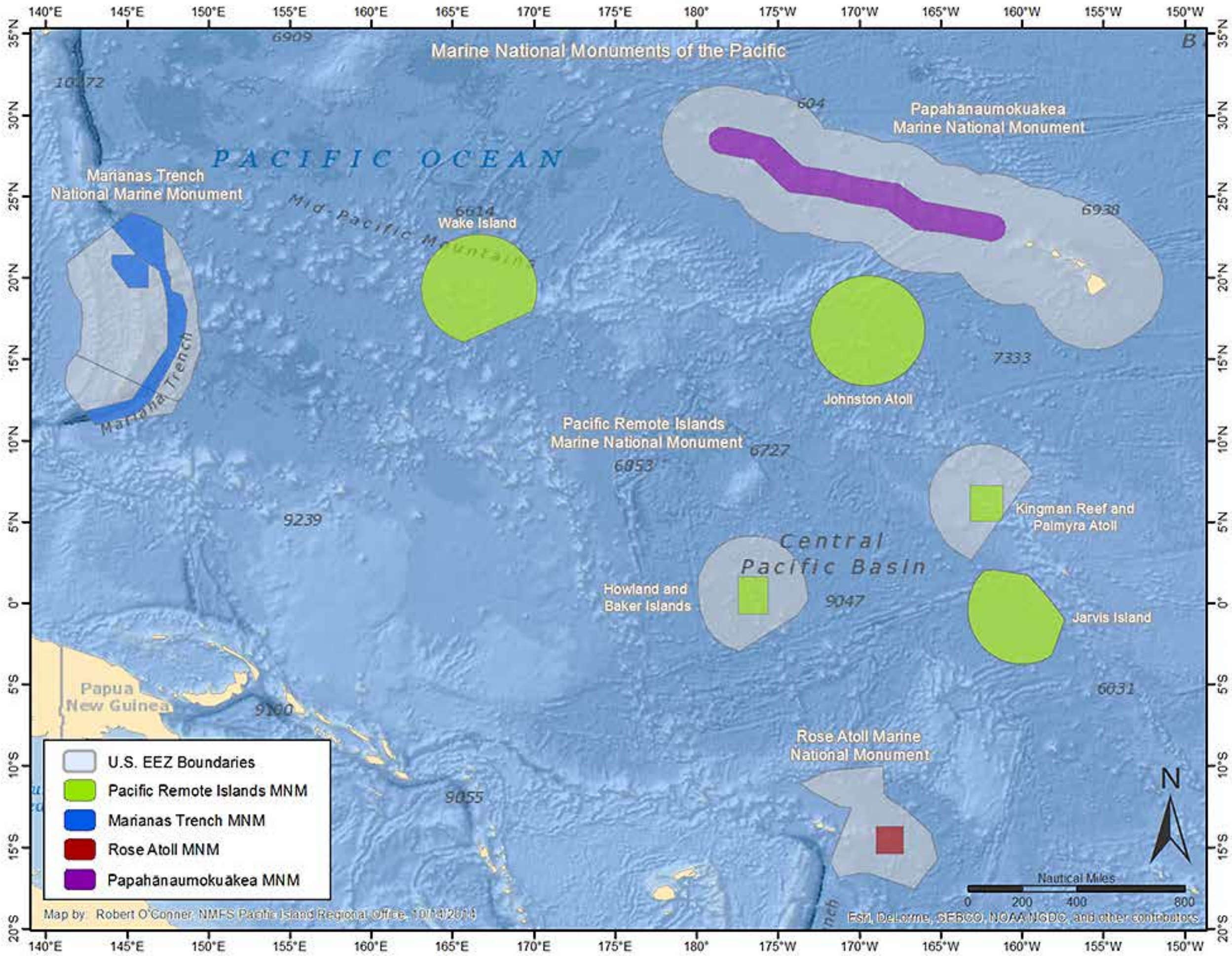
NW Rota-1 seamount has been observed erupting explosively on previous visits. Image credit: Submarine Ring of Fire 2006 Exploration, NOAA/PMEL.
http://oceanexplorer.noaa.gov/explorations/06fire/logs/april29/media/lavabombs.html

The Mariana Arc is part of the Ring of Fire that lies to the north of Guam in the western Pacific. Here, the fast-moving Pacific Plate is subducted beneath the slower-moving Philippine Plate, creating the Marianas Trench (which includes the Challenger Deep, the deepest known area of the Earth's ocean). The Marianas Islands are the result of volcanoes caused by this subduction, which frequently causes earthquakes as well. In 2003, the Ocean Exploration Ring of Fire Expedition surveyed more than 50 volcanoes along the Mariana Arc, and discovered that ten of these had active hydrothermal systems. The 2004 Submarine Ring of Fire Expedition focused specifically on hydrothermal systems of the Mariana Arc volcanoes, and found that these systems are very different from those found along mid-ocean ridges. In 2006, the third Submarine Ring of Fire Expedition visited multiple volcanoes, including the actively erupting NW Rota-1 and Daikoku, which featured a pond of molten sulfur (visit http://oceanexplorer.noaa.gov/explorations/03fire/welcome.html, http://oceanexplorer.noaa.gov/explorations/04fire/welcome.html , and http://oceanexplorer.noaa.gov/explorations/06fire/logs/summary/summary.html for more information on these discoveries).

On April 10, 2004, scientists exploring the NW Eifuku Seamount in the northern Mariana Arc saw small white chimneys emitting a cloudy white fluid near the volcano's summit, as well as masses of bubbles rising from the sediment around the chimneys. The bubbles were composed of some type of fluid, and were so abundant that the scientists named the site "Champagne." Further investigation revealed that the fluid was saturated with carbon dioxide, and that the bubbles were liquid carbon dioxide. The concentration of carbon dioxide in the vent fluid was an order of magnitude higher than in previously studied hydrothermal vents. In addition, ocean explorers found dense populations of mussel, crustaceans, and other organisms associated with the hydrothermal vents.

The Marianas Arc region contains unique geological features found nowhere else in the world, one of only a few places in the world where photosynthetic and chemosynthetic communities of life coexist, and which have the greatest diversity of seamount and hydrothermal vent life yet discovered. In 2009, the Marianas Trench Marine National Monument was established to protect the region's unique and important natural resources.

In this lesson, students will investigate management strategies that may be applied within the Marianas Trench Marine National Monument.



Marine National Monument Program
The Marine National Monument Program implements the January 2009 Presidential Proclamations that established three Pacific Marine National Monuments, the Marianas Trench, Pacific Remote Islands and Rose Atoll, and also co-manages the Papahanaumokuakea Marine National Monument, created in 2006. The Marine National Monument Program coordinates the development of management plans, scientific exploration and research programs within the Marine National Monuments in the Pacific Islands Region. Under NOAA's existing authorities and the Antiquities Act, the Marine National Monument Program works with federal and regional partners and stakeholders to conserve and protect the marine resources in these large marine protected areas. Image credit: Robert O'Conner, NMFS Pacific Island Regional Office. http://www.fpir.noaa.gov/Graphics/MNM/Pacific_MNM_DRAFT_10_14_2014.jpg

Learning Procedure

1. To prepare for this lesson, review background information about the 2014 Submarine Ring of Fire – Ironman Expedition (http://oceanexplorer.noaa.gov/explorations/14fire/welcome.html). Download the *Our Deepest Water* video from (http://oceanexplorer.noaa.gov/explorations/14fire/background/edu/mariana-video.html), or bookmark this URL. You may also want to download additional images or videos from the expedition website to help introduce the expedition to students.

2. Show students the *Our Deepest Water* video, and briefly introduce the 2014 Submarine Ring of Fire – Ironman Expedition. Tell students that their assignment is to find out more about the Marianas Trench Marine National Monument, and how this kind of Marine Protected Area (MPA) may be managed.

3. Provide each student group with copies of *Selecting a Management Strategy for the Marianas Trench Marine National Monument Research Guide* and *Background on Marine Protected Areas*. You may also want to provide some of the links listed in the Other Resources section, or allow students to discover their own sources for answers to questions

9 through 12 on the *Research Guide*. Depending upon available time and curriculum objectives, you may want to have each group provide a brief report on one of the features to be listed for Question 9.

4. Lead a discussion of student groups' answers to *Research Guide* questions. Answers to Questions 1 – 8 are provided below:
   1. MPA
   2. Great Lakes
   3. Ecosystems
   4. No take
   5. conservation
   6. Cultural Heritage
   7. Natural Heritage
   8. Sustainable Production

   Unusual or unique features that justify designation of the Marianas Arc region as a Marine National Monument include:
   - The Champagne vent on NW Eifuku Seamount
   - Liquid sulfur cauldron on Daikoku Seamount
   - Life around deep hydrothermal vents
   - Adjacent photosynthetic and chemosynthetic environments at Maug Caldera
   - Biodiversity on reefs around the islands of Farallon de Pajaros (Uracas), Maug, and Asuncion
   - Adaptation to low pH around the Maug Caldera
   - The Sirena Deep

   Ecosystem services provided by natural resources in the Marianas Arc region include biodiversity, cycling of numerous substances at vents and volcanoes, potential for novel pharmaceuticals and other biological products, and scientific research opportunities.

   Management objectives of the Marianas Trench Marine National Monument include:
   - Public education and outreach
   - Maintaining traditional access to the Monument by indigenous persons for culturally significant subsistence and other cultural and religious uses
   - Scientific exploration and research, tourism, and recreational and economic activities and opportunities
   - Process for permitting recreational fishing permits in certain areas
   - Programs for monitoring and enforcement necessary to ensure that scientific exploration and research, tourism, and recreational and commercial activities do not degrade the Monument's coral reef ecosystem or related marine resources or species, or diminish the Monument's natural character

Make sure students understand the distinctions between "natural heritage," "cultural heritage," and "sustainable production" MPAs.

In natural heritage and cultural heritage MPAs, the primary mission is to protect natural and/or cultural resources. Varying types and degrees of human uses may be allowed, but these activities are secondary to the primary purpose of resource protection.

In contrast, allowing certain uses as well as protecting resources are both part of the primary purpose of sustainable production MPAs. These MPAs allow resources to be used, as long as the resources can also be maintained and conserved. For example, in an area where local fishing has traditionally provided an important food supply to coastal communities a sustainable production MPA might allow local fishermen to continue to use fishery resources, but might limit fishing by non-residents. Or, in an area where recreational fishing by visitors is important to the local economy, a sustainable production MPA might allow recreational uses to continue as long as fishery resources are not depleted. A common misconception is that protected areas are synonymous with severely restricted use, but this is not true of many MPAs.

Given the management objectives of the Marianas Trench Marine National Monument, the most appropriate strategy would be primarily focused on natural heritage.

Some scientific activities (such as collecting biological samples) could adversely affect deep ocean ecosystems. In addition, in areas such as the Marianas Trench Marine National Monument where only a limited number of sites are known and scientists from a wide variety of disciplines frequently work at single locations, there is the potential for conflicts among scientists, at sites where scientific activity is intense. To address these issues, an international research organization has developed a statement of commitment to responsible research practices at deep-sea hydrothermal vents. This is a voluntary code of practice, but does not have a formal mechanism for enforcement. Enforcement, however, can be included in management plans for Marine National Monuments which may also use the statement of commitment as a guide for acceptable scientific practices (for more information, please see http://www.interridge.org/IRStatement).

The BRIDGE Connection

www.vims.edu/bridge/ – In the menu on the left, scroll over "Ocean Science Topics," click on "Geology" and scroll down to resources about the NeMO program for activities based on scientific investigations of active volcanoes on the deep ocean floor.

The "Me" Connection

Have students write a brief essay discussing how the Marianas Trench Marine National Monument could be of personal importance or benefit.

Connections to Other Subjects

English Language Arts

Assessment

Group assignments and class discussions provide opportunities for assessment.

Adaptations to Other Grade Levels

Grades 9-12: Extend the lesson to emphasize biodiversity, a frequent objective of marine protected areas. For a suitable lesson, please see **"Protect This!"** (http://oceanservice.noaa.gov/education/classroom/lessons/03_mpa_protect.pdf).

Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/14fire/welcome.html for daily logs and updates about discoveries being made by the Submarine Ring of Fire 2014 – Ironman Expedition.
2. Prepare a report on one or more of the unusual or unique features found within the Marianas Trench Marine National Monument.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Lessons 1, 4, and 5 for interactive multimedia presentations and Learning Activities on Plate Tectonics, Subduction Zones and Chemosynthesis and Hydrothermal Vent Life.

Other Relevant Lessons from NOAA's Ocean Exploration Program

It Looks Like Champagne

(from the New Zealand American Submarine Ring of Fire 2005 Expedition)

http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_champagne.pdf

Focus: Deep ocean carbon dioxide and global climate change (Chemistry/Earth Science)

Students will be able to interpret phase diagrams, explain the meaning of "critical point" and "triple point", define "supercritical fluid," describe two practical uses of supercritical carbon dioxide, and discuss the concept of carbon dioxide sequestration.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov - Web site for NOAA's Ocean Exploration program

http://oceanexplorer.noaa.gov/explorations/14fire/background/edu/mariana-video.html –*Our Deepest Water* video

http://www.fpir.noaa.gov/MNM/mnm_index.html – NOAA web page for the Marine National Monument Program

http://www.deepseachallenge.com/the-science/marianas-trench-marine-national-monument/ – National Geographic web page about the Marianas Trench Marine National Monument

http://www.fws.gov/refuge/mariana_trench_marine_national_monument/ – U.S. Fish and Wildlife Service web page about the Marianas Trench Marine National Monument

http://www.interridge.org/IRStatement – InterRidge statement of commitment to responsible research practices at deep-sea hydrothermal vents

http://www.regulations.gov/#!documentDetail;D=NOAA-NMFS-2012-0035-0001 – Notice of Intent to prepare Monument Management Plan, Comprehensive Conservation Plans, and Environmental Assessment for the Marianas Trench Marine National Monument

marineprotectedareas.noaa.gov/pdf/fac/wahle_definitions_final0703.pdf – A User's Guide to Marine Protected Area Terms and Types

Next Generation Science Standards

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Performance Expectation MS-LS2-5.

Evaluate competing design solutions for maintaining biodiversity and ecosystem services. [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

Science and Engineering Practices

Engaging in Argument from Evidence

Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans

- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Crosscutting Concepts

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- Individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Connections to Nature of Science

Science Addresses Questions About the Natural and Material World

- Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

MS-ESS3 Earth and Human Activity

Performance Expectation MS-ESS3-3.

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

[Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Science and Engineering Practices

Constructing Explanations and Designing Solutions

- Apply scientific principles to design an object, tool, process or system.

Disciplinary Core Ideas

ESS3.C: Human Impacts on Earth Systems

- Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.

Crosscutting Concepts

Cause and Effect

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

Essential Principle 3.

The ocean is a major influence on weather and climate.

Fundamental Concept f. . The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.

The ocean and humans are inextricably interconnected.

Fundamental Concept g. 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.

Essential Principle 7.

The ocean is largely unexplored.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Design/layout: Coastal Images Graphic Design, Mt. Pleasant, SC.

Credit

Selecting a Management Strategy for the Marianas Trench Marine National Monument Research Guide

1. ______________________________ is an area of the marine environment that has been reserved by laws or regulations to protect natural or cultural resources

2. ______________________________ are large freshwater areas that are included in the term "marine protected areas."

3. MPAs protect entire ________________________, rather than just one animal.

4. A _________________________________ zone is a zone in which fishing is not allowed.

5. The primary goal of all MPAs in the United States is ______________________.

6. ______________ _____________________ is a MPA whose primary purpose is to protect resources that reflect maritime history .(2 words)

7. ______________ _____________________ is a MPA whose primary purpose is to protect biological communities, habitats, and ecosystems. (2 words)

8. ______________ _____________________ is a MPA whose primary purpose is to support the long-term use of renewable living resources. (2 words)

9. What are five unusual or unique features that justify designation of the Marianas Arc region as a Marine National Monument?

10. What are three ecosystem services provided by natural resources in the Marianas Arc region?

11. What are the objectives of the Marianas Trench Marine National Monument?

12. Evaluate the three alternative management solutions (Questions 6, 7, and 8) in terms of their suitability for meeting the management objectives of the Marianas Trench Marine National Monument.

13. Discuss why it might be necessary to consider the impacts of scientific investigations on the deep ocean environment within the Marianas Trench Marine National Monument, and describe an approach that might be used to monitor and minimize these impacts.

Background on Marine Protected Areas

(adapted from A User's Guide to Marine Protected Area Terms and Types,
marineprotectedareas.noaa.gov/pdf/fac/wahle_definitions_final0703.pdf)

What is an MPA?

"Marine protected area" is a broad umbrella term that encompasses a wide variety of approaches to place-based management in the U.S. The official federal definition of an MPA is: "any area of the marine environment that has been reserved by Federal, State, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein". Areas that restrict access for purposes other than conservation (e.g. security zones), and areas that are inaccessible logistically are not considered to be "marine protected areas", although they may confer some conservation value. In practice, MPAs are specific places in the ocean and the Great Lakes within which the natural and/or cultural resources are afforded a higher-level protection than in surrounding waters. Familiar examples of MPAs in the U.S. include national marine sanctuaries, parks, monuments and refuges, fisheries closures, endangered species' critical habitat, and a variety of state parks, conservation areas and reserves. MPAs in the U.S. span a surprising range of habitats including areas in the open ocean, in coastal areas, in the inter-tidal zone, in estuaries and in the Great Lakes waters. U.S. MPAs also vary widely in their purpose, legal authorities, agencies and management approaches, level of protection and restrictions on human uses. This diversity of MPA types and names severely complicates the ongoing national dialogue about how, when and where to use this tool to conserve and manage important habitats and species.

A Simple Way to Describe any MPA

MPAs can be defined by two key characteristics:

- Primary Conservation Goal – why the MPA was created and what it seeks to achieve; and
- Level Of Protection – the types of human activity the MPA restricts and the nature of the protection afforded to its natural and cultural resources When these characteristics are combined for any given MPA, the resulting intuitive description can be used by any interested party to understand, describe and evaluate both existing and proposed MPAs. Moreover, by highlighting goals and protection, the definition addresses many of the issues underlying the current policy discussions about how, when and where to use MPAs for conservation and management of marine ecosystems in the U.S.

Primary Conservation Goal

While many MPAs in the U.S. have multiple objectives, most are established to achieve a primary overarching conservation goal that reflects their statutory mandates, implementing regulations and management plans. The primary conservation goal also determines many fundamental aspects of the site's design, location, size, scale and management strategies. Most MPAs in the U.S. fall into one of the following goal categories.

- Natural Heritage MPAs – established principally to sustain the protected area's natural biological communities, habitats, ecosystems and processes, and the ecological services, uses and values they provide to this and future generations.
  Applications: most national marine sanctuaries, national parks, national wildlife refuges, and many state MPAs.

- Cultural Heritage MPAs – established principally to protect, understand and interpret submerged cultural resources that reflect the nation's maritime history and traditional cultural connections to the sea.
  Applications: some marine sanctuaries, national and state parks and national historic monuments.

- Sustainable Production MPAs – established and managed principally to support the continued sustainable extraction of renewable living resources (e.g. fish, shellfish, plants, birds or mammals) within or outside the MPA by protecting important habitat and spawning, mating or nursery grounds; or providing harvest refugia for by-catch species.
  Applications: most federal and state fisheries MPAs and many national wildlife refuges.

Level of Protection

The degree to which an MPA restricts human uses influences its impacts on both the ecosystem and the people who use it. MPAs in the U.S. vary widely in the level and type of protection provided by their legal authorities to the natural and cultural resources they contain and to the ecosystems and natural processes that sustain them. There are two primary approaches to protection found in U.S. MPAs.

- Multiple Use MPAs – MPAs that allow a variety of human activities that are managed comprehensively to support compatible uses while protecting key habitats and resources. Protections may be uniform across the MPA or allocated spatially or temporally through marine zoning to reduce user conflicts and minimize adverse impacts.
  Applications: presently the most common type of MPA in the U.S., multiple use sites include most marine sanctuaries, national and state parks, and many fisheries and cultural resource MPAs.

- No Take MPAs – MPAs that prohibit the extraction or destruction of natural or cultural resources within the MPA boundaries. Some may also restrict access and/or other activities that may adversely impact resources, processes, and qualities, or the ecological or cultural services they provide.
  Applications: rare in the U.S., occurring mainly in state MPAs and in some areas closed for either fisheries management or the protection of endangered species. No take MPAs are sometimes referred to as marine reserves or ecological reserves.