Papahānaumokuākea Marine National Monument: Cruise Summary

Cetacean Ecology Survey Underway in the Northwestern Hawaiian Islands

May 7, 2013

A group of rapidly-surfacing Fraser's dolphins, one of many species that may be observed during the Papahānaumokuākea Associated Cetacean Ecology Survey, demonstrate the leaping and splashing that serve as visual cues to observers using high-powered binoculars on the flying bridge of the NOAA Ship *Oscar Elton Sette* (shown in background).

Small boat launches allow closer approaches to cetaceans, so that biopsy samples and photo-identification images can be collected. The notches on the trailing edge of the dorsal fin of the false killer whale on the right form a unique pattern, allowing this individual to be identified each time it is photographed.

Tracklines (green zig-zags) that the NOAA Ship *Oscar Elton Sette* will follow during the Papahānaumokuākea Associated Cetacean Ecology Survey. The yellow line is the boundary of the Papahānaumokuākea Marine National Monument, and the white line encloses the U.S. Exclusive Economic Zone around the Hawaiian Islands.

One of the key missions of NOAA is to improve our understanding of the distribution, abundance, and ecology of whales and dolphins in the central and western Pacific Ocean. Such research informs critical

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decisions on the management of fisheries and other human activities to promote the conservation of these cetacean populations. To advance our understanding or these important marine mammals, the Cetacean Research Program of the Pacific Islands Fisheries Science Center's (PIFSC) Protected Species Division is conducting the Papahānaumokuākea Associated Cetacean Ecology Survey (PACES) from 7 May to 5 June 2013. The goal of PACES is to survey the waters around the Northwestern Hawaiian Islands (NWHI) within the Papahānaumokuākea Marine National Monument (PMNM) in order to learn more about the abundance, stock structure, range, and habitat of whales and dolphins in this region.

PACES will be conducted aboard the NOAA Ship *Oscar Elton Sette* and will involve several operations designed to meet the study objectives. The PACES scientific team consists of researchers from PIFSC and several collaborating institutions. Chief Scientist for the PACES expedition is PIFSC ecologist Dr. Amanda Bradford.

A team of visual and acoustic observers will watch and listen, respectively, for cetaceans while the ship travels along predetermined transect lines that representatively cover cetacean habitat within the PMNM ranging from Nihoa Island in the southeast to Pearl and Hermes Atoll in the northwest part of the monument. Visual observers stationed on the ship's flying bridge will sight cetaceans use high-powered binoculars. Acoustic observers will collect information on cetacean presence using a hydrophone array. The data recorded during this line-transect survey will provide information on cetacean density, distribution, and group size and composition and will be used to estimate the abundance of species observed in the study area. When weather conditions and animal behavior permit, a small boat will be launched from the *Sette* so that groups of some species can be approached more closely by the scientists. During these closer approaches, small tissue samples will be collected from individual cetaceans so that the stock structure and phylogenetic relationships within species can be explored. Photographs will be taken so that marked individuals can be identified and geographic variation in morphology and coloration can be documented. Satellite tags will be attached to some individuals, so that their location can be tracked and their movement patterns and range are better understood. Oceanographic and active acoustic data will be collected along the PACES transects, which will allow for an assessment of the environmental conditions and prey availability encountered by cetaceans in the PMNM.

Focused surveys using a small boat launched from the *Sette* will occur on 3-4 days around some of the NWHI, potentially Nihoa, French Frigate Shoals, Gardner Pinnacles, and Pearl and Hermes. These small-boat surveys will provide scientists greater access to cetaceans in the nearshore waters of selected islands and atolls. Some cetacean species in the main Hawaiian Islands (MHI) are known to exist as separate island-associated and pelagic stocks, and it is possible that this stock structure also occurs in the NWHI. Data provided through biopsy sampling, photo-identification, and satellite tagging of individuals in nearshore waters will offer insight into stock differentiation between the NWHI and pelagic regions, as well as between the NWHI and MHI.

Since 2009, a High-frequency Acoustic Recording Package (HARP) has been deployed with few interruptions in the southeast corner of Pearl and Hermes. The HARP allows for long-term acoustic monitoring of cetacean presence and occupancy in the area. That HARP will be retrieved and a new one deployed during PACES. A new acoustic device, referred to as a Compact Acoustic Recording Buoy (CARB), is being used for the first time in the Pacific Islands Regions during PACES. The CARB will be used for short-term acoustic recording of encountered cetaceans and will be deployed from either the *Sette* or the small boat.

Papahānaumokuākea Marine National Monument: Cruise Summary

Expedition to Establish Long-term Monitoring Sites to Measure Trends on Coral Reefs in the Northwestern Hawaiian Islands

September 3, 2013

A diver searches for locations to deploy monitoring instruments at French Frigate Shoals during the 2010 Pacific RAMP expedition.

Calcification accretion units (CAUs), like this one installed in 2010 on a reef at French Frigate Shoals, are used to monitor rates of net calcium carbonate accretion. CAUs are deployed for 3 years during which time crustose coralline algae and hard corals will colonize the units. Data gathered with the units help scientists measure the effects of ocean acidification on corals and other organisms with carbonate skeletons. NOAA photo by Cristi Richards.

Subsurface temperature recorders will be installed to provide long-term monitoring of environmental conditions on coral reef ecosystems of the Northwestern Hawaiian Islands.

Scientists of the NOAA Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division (CRED) embarked today on a 19-day mission aboard the NOAA Ship *Hiʻialakai* to establish a network of long-term monitoring sites in the Northwestern Hawaiian Islands, a conservation area designated as the Papahānaumokuākea Marine National Monument (PMNM). This expedition is an extension of the coral reef research and monitoring that CRED has been conducting for more than a decade within the Northwestern Hawaiian Islands and is an element of the National Coral Reef Monitoring Plan of NOAA's Coral Reef Conservation Program.

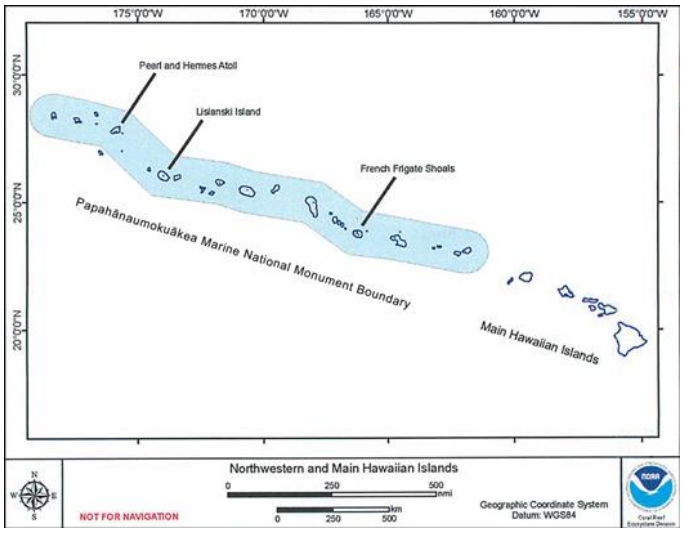
The research expedition is part of the CRED's long-term, integrated Pacific Reef Assessment and Monitoring Program (Pacific RAMP), which is designed to provide a flow of consistent, comparable information to help document and report the status of environmental conditions and living resources of the nation's coral reef ecosystems in the Pacific. Long-term data will enable scientists to study trends in the ecosystems over time and the effects of human activities and natural processes that influence the coral reef environment and biota. The scientific team includes CRED staff who are employees of the Joint Institute for Marine and Atmospheric Research of the University of Hawaiʻi at Mānoa and research partners from San Diego State University, Scripps Institution of Oceanography of the University of California San Diego, the NOAA Diving Center, and the University of Hawaiʻi at Mānoa.

With the *Hiʻialakai* as their base of operations, scientists will conduct scuba dives from small boats to install instruments at 15 long-term monitoring sites around Pearl and Hermes Atoll, Lisianski Island, and French Frigate Shoals. These sites will add to the 5 monitoring sites set up at Kure Atoll earlier this summer by CRED scientists, bringing to 20 the total number of monitoring sites throughout the Northwestern Hawaiian Islands.

The main goal of the research mission is to advance a robust set of methods to be used at these long-term monitoring sites to measure changes in ocean temperature and ocean chemistry as a function of climate change and ocean acidification. Measuring changes in oceanographic parameters over long periods and concurrently monitoring many subsequent biological responses on the reef will allow NOAA scientists to assess the effects of changing ocean chemistry and temperatures on the coral reef ecosystems in the Northwestern Hawaiian Islands.

To achieve a comprehensive understanding of biological, physical, and chemical processes that affect a reef, CRED researchers will use many techniques. Ocean temperatures will be measured with instruments deployed at depths of 1, 5, 15, and 25 m along selected transects on the forereefs surrounding each island or atoll. These instruments are capable of recording subsurface ocean temperatures every 5 min for a period of 3 years. At the site where the temperature sensor is deployed at each island, other instruments will be employed to collect additional measurements. Discrete water samples will be collected and analyzed for salinity, dissolved inorganic carbon, and total alkalinity to evaluate the carbonate chemistry of waters just above the reef. Casts with a conductivity-temperature-depth instrument will be made to profile salinity and temperature of the water column from the sea surface to seafloor. Within the reef matrix, the following monitoring installations will be used: calcification accretion units to assess net rates of calcification, coral recruitment, and algal biomass; bioerosion monitoring units to provide measurements of bioerosion rates across the reef, and autonomous reef monitoring structures to aid in assessment of taxonomic diversity at the species level. Photographic and video mosaic techniques will document the percent cover of corals and algae found on the seafloor.

This 2013 expedition will add to information collected during monitoring and mapping surveys conducted in the Northwestern Hawaiian Islands in 1999, 2000, 2001, 2002, 2003, 2004, 2006, 2008, and 2010. Data collected in these surveys are pivotal to long-term biological and oceanographic monitoring of coral reef ecosystems in the Hawaiian Archipelago. In particular, these data allow scientists to evaluate changes in the condition and integrity of the coral reef ecosystems and enable federal and state resource managers to more effectively manage and conserve reef-associated sea life in the region.



Operating area for the expedition encompasses the waters of the Northwestern Hawaiian Islands.

Papahānaumokuākea Marine National Monument: Cruise Summary

Expedition Focused on Hawaiian Monk Seal Research and Marine Debris Removal in the Northwestern Hawaiian Islands

June 15, 2012

The NOAA Ship *Oscar Elton Sette* sailed from Honolulu on June 15, 2012, for a 30-day mission to the Northwestern Hawaiian Islands to study the endangered Hawaiian monk seal population and to survey and remove derelict fishing gear and other marine debris from beaches and coral reef habitats. The research will support NOAA's efforts to recover the seal population and remove debris that is a threat to monk seals, sea turtles, and other marine life in the coral reef ecosystem. The expedition is staffed by scientists from the University of Hawaii Joint Institute for Marine and Atmospheric Research (JIMAR) working in the Protected Species Division and Coral Reef Ecosystem Division at the Pacific Islands Fisheries Science Center. Chief Scientist responsibilities will be shared by JIMAR researchers Jessie Lopez and Kyle Koyanagi.

Scientists work out of temporary field camps in the Northwestern Hawaiian Islands to monitor the Hawaiian monk seal population and conduct research that will help efforts to recover this highly endangered species.

Each year, scientists in the PIFSC Monk Seal Research Program monitor the status of monk seals at remote locations in the NWHI and conduct research to better understand factors affecting abundance of the seals and ways to enhance the population's recovery. Researchers work out of seasonal field camps at the six major monk seal breeding locations in the NWHI: French Frigate Shoals, Laysan Island, Lisianski Island, Pearl and Hermes Reef, Midway Atoll, and Kure Atoll. During this summer's support

voyage, the *Sette* will deploy researchers and their equipment at the six primary sites and also support seal censuses at Nihoa Island and Necker Island, where no camps will be established.

To help establish monk seal field camps, cruise personnel will transport equipment and supplies from the ship to the islands. Provisions sufficient to sustain teams of 2-4 scientists at each location for 2 months are needed. Included are tents, stoves, solar power arrays, computers, small work boats, and more. Everything brought ashore must be transported by hand and shuttled via small boats from the ship to the islands.

At Necker and Nihoa Islands, scientists will spend a day at each location counting seals, documenting tagged seals, and applying identification tags to weaned seal pups. Identifying seals at these two NWHI locations is an important aspect of the research, as these islands are close to the main Hawaiian Islands (MHI). Subsequent sightings of the tagged seals will provide valuable information on the extent of seal movements between the NWHI and the MHI.

Derelict fishing gear and other kinds of marine debris are a threat to Hawaiian monk seals on the coral reefs where seals feed and on the beaches where they rest and nurse their young. During the research expedition by the NOAA Ship *Oscar Elton Sette*, biologists will remove debris from the reefs and beaches and transport it to Honolulu for safe disposal.

In addition to assisting the Hawaiian monk seal monitoring and research, the Sette will support a team of marine debris specialists to survey and remove marine debris. Derelict fishing gear and other marine debris is collected by ocean currents and swept onto the coral reefs and beaches of the Northwestern Hawaiian Islands where it is a hazard to marine life. Although the debris is a constant threat, the quantity of debris is expected to increase in coming years as a result of the devastating March 2011 tsunami in northeastern Japan, which injected massive amounts of debris into the North Pacific. During the *Sette* cruise, a crew of 17 scientists with specialized dive training will conduct in-water marine debris survey and removal operations at Midway Atoll, Kure Atoll, and Pearl and Hermes Atoll, focusing on areas known to have high densities of derelict fishing gear. Debris survey and removal operations will also be conducted along the shorelines of Midway atoll, Kure Atoll, Pearl and Hermes Atoll, Laysan Island, and

Lisianski Island. Debris removed from the reefs and shorelines will be taken onboard the Sette and transported to Honolulu. Removal of debris from the coral reefs and beaches will reduce the risk of entanglement for protected marine mammals, sea turtles and other wildlife utilizing these habitats. As debris is surveyed and cataloged, researchers will attempt to document any debris that could have originated from the 2011 Japan tsunami.

While the main focus of the expedition is monk seal research and marine debris removal, periodically during the cruise, shipboard personnel will collect oceanographic data on subsurface ocean temperature and conductivity by deploying a CTD instrument. The data will be added to a comprehensive NOAA oceanographic database and used to better understand large-scale phenomena like climate change and the dynamics of local features like oceanic fronts.

The *Sette* cruise will also provide support for several partner agencies working in the NWHI. Supplies and equipment will be transported for the U.S. Fish and Wildlife Service, which maintains field stations at French Frigate Shoals and Midway Island and a permanent field camp at Laysan Island. The cruise will also support a field camp operated by the State of Hawaii Division of Forestry and Wildlife at Kure Atoll.

Papahānaumokuākea Marine National Monument: Cruise Summary

NOAA Expedition Wraps Up Summer of Research on Endangered Hawaiian Monk Seals in the Northwestern Hawaiian Islands

September 11, 2013

The NOAA Ship *Oscar Elton Sette* departed on a 20-day research expedition in the Northwestern Hawaiian Islands (NWHI) to study the endangered Hawaiian monk seal. The information gained will support NOAA's efforts to recover populations of this protected species. As part of the field operations, scientists plan to capture weaned monk seal pups at French Frigate Shoals and relocate them to Laysan Island.

Monk seal research is a primary focus of scientists at NOAA's Pacific Islands Fisheries Science Center. Biologists in the Protected Species Division's Hawaiian Monk Seal Research Program (HMSRP) annually monitor the status of monk seals at remote locations in the NWHI, study factors affecting abundance of the seals, and seek ways to enhance the seal population's recovery. Many HMSRP researchers work out of seasonal field camps at the six major NWHI monk seal breeding locations.

A monk seal research field camp at Pearl and Hermes Reef, NWHI.

During its current voyage, from September 11 through 30, 2013, the *Sette* will retrieve researchers and their equipment from three sites — French Frigate Shoals, Laysan Island, and Pearl and Hermes Reef — where the scientists have been conducting seal studies for several months, working out of field camps established earlier this summer. The ship will also support seal censuses at four other sites, Midway Atoll, Kure Atoll, Nihoa Island and Necker Island (Mokumanamana), where no camps are established. The project will also deploy a temporary field camp at Lisianski Island to conduct monk seal research while the *Sette* is in the area.

Under the direction of the expedition's Chief Scientist Jessica Lopez, mission personnel will use small boats to move equipment and supplies from the field camps to the ship, where the material will be loaded for transport back to Honolulu. Included are tents, stoves, solar power arrays, computers, small boats, and more.

Monk seal moms and their pups at Nihoa Island.

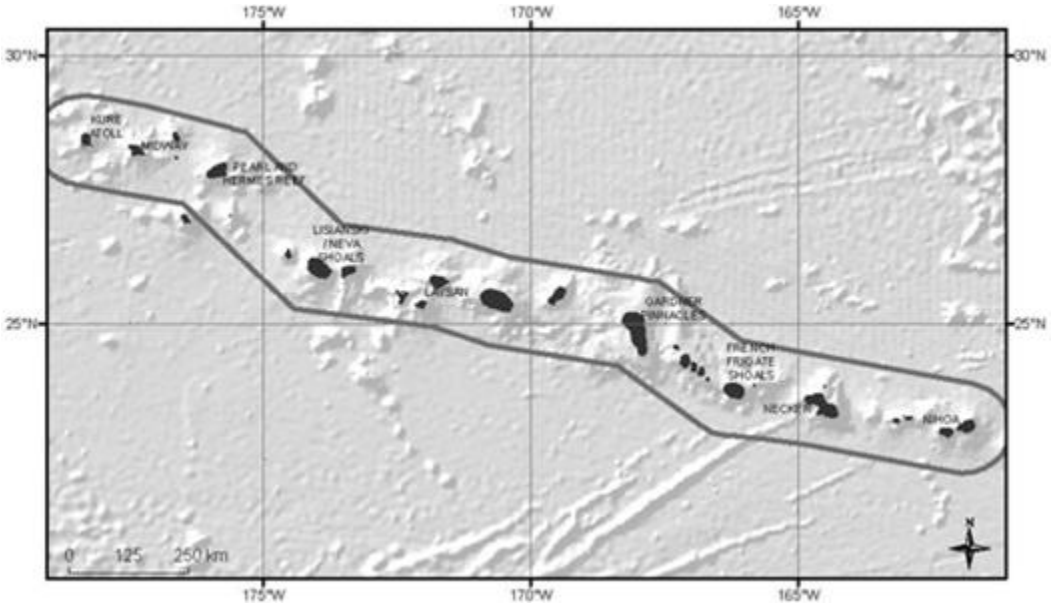
In an earlier expedition this weaned pup was transported to shore at Laysan Island.

At Necker and Nihoa Islands, the scientists will spend a day at each place counting seals, applying identification tags to weaned seal pups, and documenting seals previously tagged. Identifying seals with tags at these two NWHI locations is an important aspect of the research because these islands are close to the main Hawaiian Islands (MHI). Subsequent sightings of the tagged seals will provide valuable information on the extent of seal movements between the NWHI and the MHI, something currently unknown. Scientists will also be deploying two remote digital cameras on Nihoa that will capture photos of seals on the beach throughout the year.

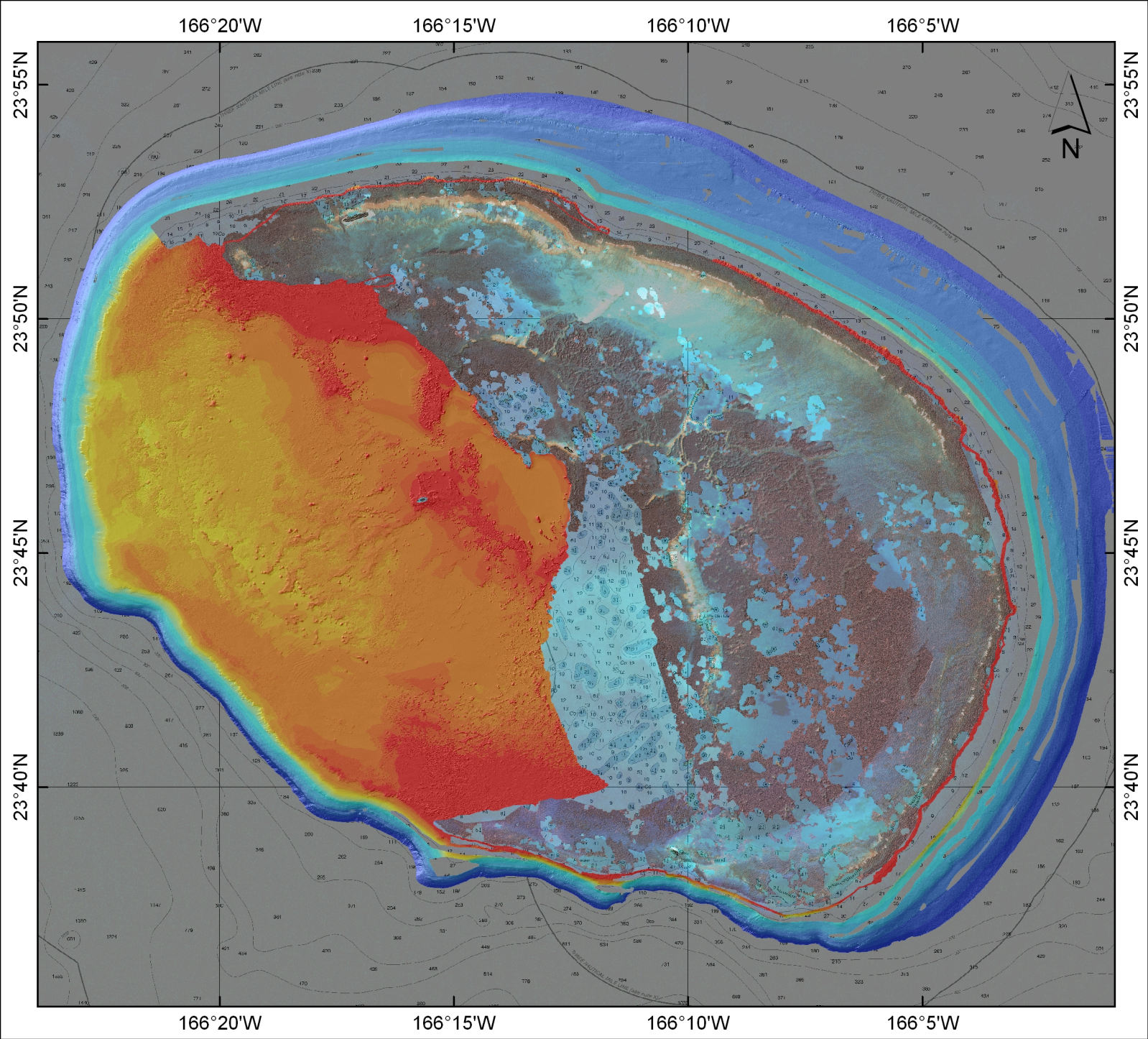
In addition to retrieving field researchers and their equipment, the *Sette* will transport weaned female seals from French Frigate Shoals, where survival of juvenile seals is low, to Laysan Island, where the juvenile survival rate is much higher. Scientists will safely capture the seals at French Frigate Shoals using stretcher nets and carry them to the ship in small boats. Once aboard the ship, the seals will be kept in cages on the deck. A veterinarian, scientists and shipboard personnel will monitor the health and behavior of the seals regularly during transport to ensure the animals arrive at their destination safely and in good health. Before releasing the seals, scientists will attach satellite tags to the animals so they can study where the seals move after they are released at their new island home. Scientists also plan to spend a few days on the island to monitor the seals' post-release behavior.

Periodically during the expedition, shipboard personnel will collect oceanographic data to measure and map subsurface ocean temperature and conductivity in the water column from the sea surface down to greater depths by taking CTD measurements. The data will be added to a comprehensive NOAA oceanographic database and used to better understand large-scale phenomena like climate change and the dynamics of local features like oceanic fronts.

The *Sette* expedition will also provide logistical support for several partner agencies working in the NWHI. The expedition will deliver supplies and personnel to a field camp operated by the State of Hawaii Division of Forestry and Wildlife at Kure Atoll.



Operating area for the expedition in the Northwestern Hawaiian Islands.



French Frigate Shoals Multibeam Bathymetry

NOAA Coral Reef Ecosystem Division

Data include R/V Kilo Moana, NOAA Ship Hiialakai, and R/V AHI multibeam bathymetry

5 m grid cell size

NOT FOR NAVIGATION

Landsat, IKONOS imagery, and NOAA chart No. 19401 also shown

UTM Projection Zone 3N, Ellipsoid WGS84

km

0 10

DEPTH (m)

10 20 30 40 50 100 300

Papahānaumokuākea Marine National Monument: Science Technology

Source: NOAA NMS

Grade Level

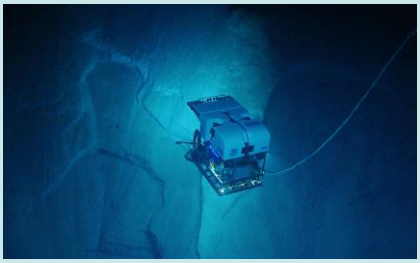
- 7-12

Timeframe

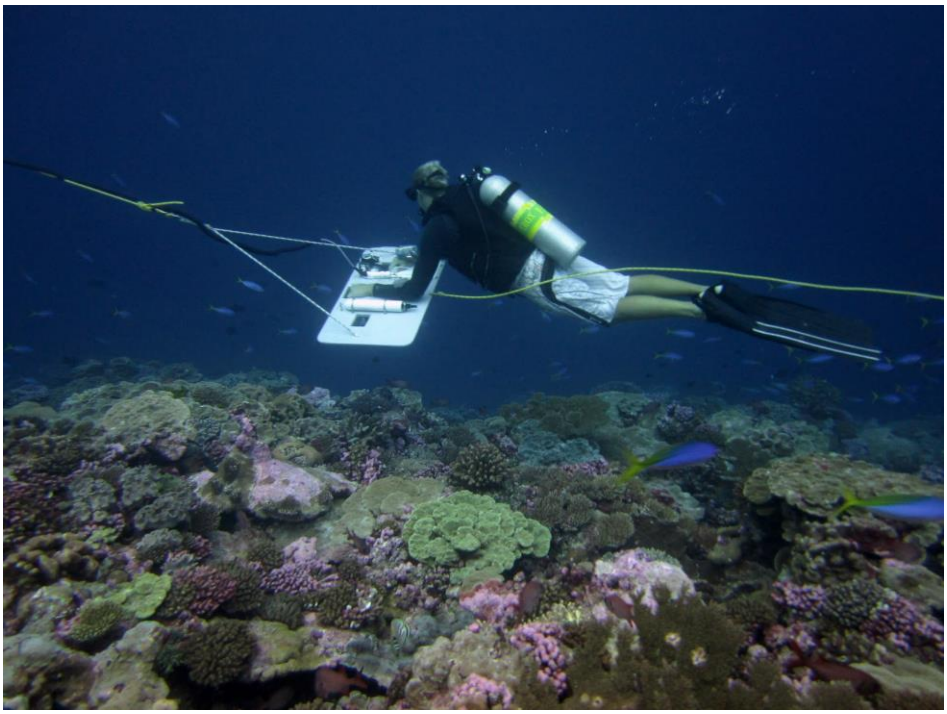
- Four 45-minute periods or two 90-minute periods

Key Words

- Biodiversity
- Deployment
- Mission objectives
- Ocean Exploration
- Photic Zone
- Science mission
- Transect



Source: USGS



Source: NOAA CRED

Activity Summary

This lesson serves as an introduction to Papahānaumokuākea Marine National Monument (PMNM) and scientific tools and techniques that are used to help understand this unique environment. The lesson begins by having students determine some basic statistics about PMNM. Next there is a review of the importance of biodiversity and students are asked to develop some thoughts about how to study biodiversity. The students are then introduced to the idea of a scientific research cruise and develop an understanding of how a scientific mission helps set the strategic objectives of a cruise by reading actual NOAA cruise summaries. After that students do an individual research about scientific equipment and survey techniques used by NOAA scientists to study Papahānaumokuākea Marine National Monument. Building on that base of understanding the students are asked to plan their own research cruise. They are given a mission of understanding biodiversity around French Frigate Shoals and are asked to develop their own a research objectives and to specify what equipment and survey techniques they will use to

Source: NOAA Adopt a Drifter Program

Materials

- Student handout (1 x student)
- Computers with internet access (1 x student/group)

Outline

ENGAGE – Introduction to Papahānaumokuākea and the importance of studying biodiversity

EXPLORE – Exploration of Papahānaumokuākea

EXPLAIN – Science Equipment Research

ELABORATE – Planning a research cruise

EVALUATE – Produce a written summary of a cruise plan

Source: NOAA PMEL

address those objectives. Finally, the students summarize their plan by creating a cruise summary explaining the importance of their scientific mission, their research objectives for the cruise, and which equipment and survey techniques they will use to accomplish their objectives.

Learning Objectives

Students will be able to:

1. Describe the size and location of Papahānaumokuākea Marine National Monument.
2. Be able to explain why it is important to study biodiversity.
3. Understand how research missions are different than research objectives.
4. Develop an understanding of scientific tools or techniques used to carry out research objectives.
5. As a group develop research objectives related to the mission of understanding biodiversity around French Frigate Shoals.
6. Evaluate a suite of tools and techniques and decide which are best suited to accomplishing research objectives around French Frigate Shoals.

Background Information

Marine Scientific Research:

The ocean is the largest unexplored place on Earth. Though it covers 71 percent of the planet and contains 97 percent of the Earth's water, only about five percent of the world's ocean has been explored. However, our very survival as a species may depend on developing a better understanding of the ocean. The ocean has a major role in regulating weather and climate, both of which have direct impacts on our wellbeing and food supplies. In addition, oceanic phytoplankton are the largest producers of oxygen on the planet, and the ocean is a huge reservoir of biodiversity, which may provide us with new sources of food and medicine. Yet, exploration of the ocean is far from simple. Cold temperatures, vast areas, extreme pressures, lack of light, and exposure to saltwater all make collecting data in the ocean very difficult.

Because of these inherent difficulties, ocean research is one of the great catalysts for innovation and technological development. In the United States, over one-third of the U.S. Gross National Product originates in coastal areas and one in every six jobs is marine-related (NOAA, 1999). The ocean is key to transportation and recreation, and its resources may hold the cures to many diseases. Whether it is green fluorescent proteins (GFP) from jellyfish used to track protein activity in real time, or understanding global plate tectonics, insights and advances in nearly every scientific discipline have developed through the study of the ocean.

Vocabulary

BIODIVERSITY- The degree of variation of life within an area such as an ecosystem, biome, or planet.

BIOME- A large community of plants and animals that occupy a distinct region of the planet (e.g. Tundra).

DEPLOYMENT – In a scientific context, deployment means to organize and put into the environment a scientific observer or a scientific instrument. This can be done from a platform such as a ship or airplane, or can refer to land based operations.

EMERGENT LAND –Land, such as an island, that extends above of the water surface.

ENDEMIC – a plant or animal species that has a highly localized or restricted geographic distribution.

NAUTICAL MILES – a unit of measure commonly used in marine navigation that represents one minute of arc along any meridian of the Earth and by international agreement has been set at 1,852 m.

PHOTIC ZONE – the region of water in the upper part of a lake or ocean where enough light penetrates for photosynthesis to occur. The depth at which light intensity falls to one percent of surface light intensity is considered to be the depth of the photic zone.

TRANSECT – a path along which counts and/or records of data observations are made.

Importance of Marine Biodiversity:
Marine biodiversity refers to the variety of living organisms in the ocean, from bacteria and fungi to invertebrates and fishes, all the way to marine mammals and birds. These biota are intricately connected with the environment where they live and with each other through the flow of energy (food) through the ecosystem. Any changes in the environment or this energy flow can lead to changes in the biodiversity.

Understanding biodiversity is critical to humans from the perspective of ecosystem services such as food, oxygen, a stable climate, and socio-economic benefits that support human livelihoods. This was recognized acknowledged in the U.S. Interagency Ocean Policy Task Force's final recommendations to the President in July 2010, and has become the policy of the United States to "protect, maintain, and restore the health and biological diversity of ocean, coastal, and Great Lakes ecosystems and resources" (United States, 2010). The Census of Marine Life, which concluded in 2010, greatly enhanced our understanding of the status of marine biodiversity (Ausubel *et al.*, 2010). It also made clear the importance of clear-cut, systematic and sustainable approaches to observing and monitoring biodiversity across different levels and at an international scale.

Coral reefs are some of the most diverse and valuable ecosystems on Earth. Coral reefs support more species per unit area than any other marine environment, including about 4,000 species of fish, 800 species of hard corals and hundreds of other species. Scientists estimate that there may be another 1 to 8 million undiscovered species of organisms living in and around reefs (Reaka-Kudla, 1997). This biodiversity is considered key to finding new medicines for the future. Many drugs are now being developed from coral reef animals and plants as possible cures for cancer, arthritis, human bacterial infections, viruses, and other diseases.

http://www.noaa.gov/features/economic_0309/medicines.html

Preparation

Computer Programs

- Make sure there is sufficient computer access for all the students or groups of students.
- Test videos to ensure good playback.
- Spend time becoming familiar with different types of scientific equipment and techniques used by scientist in PMNM. Here are some websites that have information about equipment and technique: http://www.pifsc.noaa.gov/cred/survey_methods.php, http://www.whoi.edu/science/instruments/, http://www.marinebio.net/marinescience/01intro/toindex.htm, http://www.whoi.edu/page.do?pid=96792.

Learning Procedure

Engage: Part 1 – Introduction to Papahānaumokuākea and Studying Biodiversity

Read the introduction to Papahānaumokuākea Marine National Monument (PMNM) as a class and show the students the location of the Monument on a globe or projector. Have them answer ***Part 1 – Introduction of Papahānaumokuākea*** questions in their handout. Note, the questions ask students to think geometrically about the living space in the monument. In order to calculate the habitat space the students will need to convert between standard and metric units. This is an excellent place to have a discussion and some visual aids to illustrate different volume sizes.

Engage: Part 2 –Studying Biodiversity

The goal of this section is to revisit the idea of biodiversity and to have students think about it in the marine context. Ask students to answer questions 1 and 2 on their worksheet in ***Part 2 –Studying Biodiversity***. They should answer these questions based on their previous understanding of biodiversity. Once the students have finished, spend some time talking about the definition of biodiversity and why it is so important to study this subject.

Once you have reestablished the importance of biodiversity, ask the students to spend some time thinking about how to study biodiversity in a marine context and then to answer questions 3 and 4. If useful you can show this TED talk by Paul Snelgrove about the Census of Marine Life (http://www.ted.com/talks/paul_snelgrove_a_census_of_the_ocean), which is a nice recap of how little is known about life in the oceans and different ways in which scientists are trying to study marine biodiversity. The goal of this discussion is to get the students to be thinking about how they might study this biodiversity. Explore:

Explore: Part 3 – Exploration of Papahānaumokuākea

This section gives students a short introduction to research vessels and how an overarching scientific mission guides the development of a research cruise. As a class read through the background information about exploration of Papahānaumokuākea and discuss any questions students have. Once they are comfortable with the differences between “missions” and “objectives” for a research expedition, have them read a recent cruise summary, individually or as a group, and answer the guiding question in their worksheet. Reading about a recent research cruise and picking out the mission, the specific research objectives of the cruise, and the scientific methods used to meet those objectives will help students solidify their understanding of how these elements are related. The questions will help guide students in their reading of the cruise

summaries. They may need help in teasing apart what is the overall mission vs the specific cruise research objectives.

There are four example cruise summaries included with this lesson, but for the most up to date cruise summaries go to http://www.pifsc.noaa.gov/cruise/. Searching the cruise summaries for "Northwest Hawaiian Islands" or "Papahānaumokuākea" should provide plenty of example cruise summaries. The NOAA ships do carry out research cruises in places other than PMNM and any of these summaries will work for the purpose of this exercise.

Additional materials:

Research cruise video about monk seal research in PMNM: https://www.youtube.com/watch?v=cSkZgGY1Bqw&feature=player_embedded

Explain: Part 4 - Science Equipment Research

This section is to help student explore the vast variety of scientific equipment and survey techniques used by oceanographers and other researchers. The list of equipment and survey techniques included with this lesson is a compilation of the scientific equipment on the RV Oscar Elton Sette and survey techniques used by the NOAA Pacific Islands Fisheries Science Center. Write ups of many of the scientific equipment and survey techniques can be found at (http://www.pifsc.noaa.gov/cred/survey_methods.php). Additional information can be found for equipment and survey techniques using simple internet searches. Note: when doing an internet search for survey techniques, focus students on searching for the base technique (i.e. belt transect, line-point-intercept) instead of the complete technique name (belt transect for coral size class). Students should use the questions listed in their handout to help guide their research and to help design their posters.

Provide time for students to present their work in class and to explain the pros and cons of their chosen piece of scientific equipment or survey technique. It is helpful to place the posters in a visible location after the presentations so the students can refer back to when they are trying to figure out which equipment and survey techniques will help them accomplish their research objectives in the next section.

Although these types of equipment and survey techniques may be unfamiliar to teachers, the process of research, poster creation and class presentation are likely very familiar. The following rubric may be helpful in evaluating presentations and the quality of research projects.

	Exceeds Standard	Meets Standard	Emerging	Attempt Made
Subject knowledge	Demonstrates mastery of the topic	Demonstrates accurate knowledge of the topic	Demonstrates some knowledge of the topic	Demonstrates little knowledge of the topic
Organization and coherence	Information well organized and coherently presented	Most information organized and coherently presented	Generally organizes information, presentation occasional strays from topic	Information poorly organized and presentation lacks coherent flow
Physical gestures	Actively engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest	Usually engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest	Occasionally engages the audience by making and maintaining eye contact and using movement (facial expressions, posture, gestures) to focus attention and interest	Neglects to engage the audience because rarely makes and maintains eye contact or uses movement (facial expressions, posture, gestures) to focus attention and interest
Voice	Always speaks clearly/loudly	Usually speaks clearly/loudly	Sometimes speaks clearly/loudly	Does not speak clearly/loudly
Language conventions	Uses appropriate grammar and vocabulary	Uses mostly appropriate grammar and vocabulary	Makes some errors in grammar and vocabulary	Makes many grammatical mistakes
Visual aids	Uses visual aids to enhance presentation of subject matter and is able to knowledgeably discuss components of visual aids	Uses visual aids moderately effectively and/or presents some discussion of visual aids	Moderately ineffective use of visual aids and/or presents some discussion of visual aids	Does not/ineffective use of visual aids and/or does not discuss visual aids
Appearance	Thoroughly demonstrates appropriate appearance	Generally demonstrates appropriate appearance	Demonstrates minimal understanding of appropriate appearance	Fails to demonstrate appropriate appearance

* modified from Seekonk High School Oral Presentation Rubric

Elaborate: Part 5 - Planning a research cruise

Once students have presented their information have them work in groups to answer questions 1 and 2 in ***Part 5 - Planning a research cruise***. This should take a while as the students need to discuss and agree upon research objectives and what equipment will help them best collect data to address both their objectives and the overall mission. See the answer key for the student worksheet for more specific discussion point and tips about how to make this exercise more realistic for the students.

Evaluate: Part 6 – Cruise summary

As a summative assessment have the students write their own cruise summary for their proposed cruise. They should refer back to the cruise summaries that they read for examples of how to write this type of document. The questions presented on the student worksheet should help guide the students in the development of their document.

Extending the Lesson

There are numerous ways to extend this lesson depending on the comfort level and understanding of the teacher and students. For example, one extension possibility might be to map out a complete research cruise from port to port. Students can use the specification sheet of the R/V Oscar Elton Sette to help them plan their cruise. Included in the specification sheet is information regarding cruising speed, range,

berthing capacity, personnel, and lab spaces. By using all the individual objectives created by the class, the students can develop a comprehensive research plan for their cruise.

Another extension option would be to tour a research vessel. Most coastal states (and states that have large lakes or rivers) have research vessels of various sizes, and the operators are generally very accommodating about giving tours. If that is not possible bringing a research scientist who plans expeditionary scientific operations in to the classroom to talk about their work is a great way to engage students as well.

Connections to Other Subjects

- Chemistry
- Ecology
- Biology
- Technology
- English
- Mathmatics

Related Links

Census of Marine Life
Pacific Islands Fisheries Science Center
NOAA Marine National Monument Program
NOAA Fisheries Pacific Islands Regional Office
Papahānaumokuākea Marine National Monument
R/V Oscar Elton Sette

For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
1845 Wasp Blvd., Building 176
Honolulu, HI 96818
(808) 725-5000, (808) 725-5215 (fax) pirohonolulu@noaa.gov

Acknowledgement

This lesson is one in a series exploring the geology, biology, oceanography, and ecology of the Pacific Marine National Monuments. It was developed for the NOAA Fisheries Pacific Islands Regional Office.

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http://www.fpir.noaa.gov/MNM/mnm_index.html. If you have any further questions or need additional information, email pirohonolulu@noaa.gov.

All images are from NOAA unless otherwise cited.

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

Sources

Ausubel, J. H., Trew Christ, D., & Waggoner, P. E. (2010). First census of marine life 2010: highlights of a decade of discovery.

M. L. Reaka-Kudla. (1997). The Global Biodiversity of Coral Reefs: A Comparison with Rain Forests. In Biodiversity II, M. L. Reaka-Kudla, D. E. Wilson, E. O. Wilson, Eds. (Joseph Henry Press, Washington, DC, 1997), pp. 83-108.

Ocean. (1999). Retrieved November 26, 2015, from http://www.noaa.gov/ocean.html

United States. Interagency Ocean Policy Task Force & Council on Environmental Quality (U.S.). (2010). *Final recommendations of the Interagency Ocean Policy Task Force*. [Washington, D.C.]: Executive office of the President, White House Council on Environmental Quality.

Education Standards

Next Generation Science Standards	• **MS-ETS1-1.** – Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. • **MS-ETS1-2.** – Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • **HS-PS4-5.** – Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]
Ocean Literacy Principles	• **1A** – The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic. • **7** – The ocean is largely unexplored.

NOAA Ship *Oscar Elton Sette*

Hull Number	R335
Call Sign	WTEE
Home Port	
Ford Island, HI	
Marine Operations Center	
Pacific Islands (MOC-PI)	
Port Office	
None	
Pacific Islands (MOC-PI)	
Regular Area of Operations	
Pacific	
General Classification	
Fishery Research Vessel	
Mailing Address	
NOAA Ship **Oscar Elton Sette** Marine Operations Center, PI 1897 Ranger Loop, Bldg 184 Honolulu, HI 96818-5072	

Contact Information

IN PORT	**AT SEA**
Cellular	VoIP
808-469-0074 (Ship Cell)	N/A
808-306-8550 (CO)	Iridium
808-306-3438 (XO)	808-434-9588
808-306-9456(OOD)	
808-352-7466 (EOW)	
Land Line (Home Port)	
808-725-5790 (VC)	Inmarsat Mini-M:
808-725-5791 (VC)	N/A
808-725-5792 (VC)	Fax or E-Fax
808-725-5793 (Fax)	N/A
	Inmarsat B
Ship's Email	011-870-763-644-039 (Voice 1)
Noaa.Ship.Oscar.Elton.Sette@noaa.gov	011-870-763-644-042 (Voice 2)

Design	
Designer:	Halter Marine
Builder:	Halter Marine, Inc., Moss Point, MS
Launched:	Sep 23, 1987
Delivered:	June 5, 1992
Commissioned:	Jan 23, 2003
Length (LOA - ft.):	224
Breadth (moulded - ft.):	43
Draft, Maximum (ft.):	16.6
Depth to Main Deck (ft.):	22
Hull Description:	Welded steel
Displacement:	2,014 tons

Berthing	
Single Staterooms:	12
Double Staterooms:	10
Other Staterooms:	1 four, 1 six
Total Berths:	**42**

Speed & Endurance	
Emergency Speed (KTS):	11
Cruising Speed (KTS):	10
Range (nm):	17,487
Endurance (days):	60
Endurance Constraint:	Food

Compliment - Maximum	
Commissioned Officers/Mates	5
Engineers, Licensed	3
Engineer, Unlicensed	2
Deck	6
Survey	1
Stewards	3
Electronic Technicians	1
USPHS Medical Officer	1
Total Crew	**22**
Scientists	**20**

Medical Facilities:
One medical treatment room containing one berth for patients. Emergency and first-aid equipment aboard, administered by designated vessel personnel. USPHS medical officer onboard.

Food Service Seating Capacity	
Forward Mess Room:	6
Aft Mess Room:	24

Navigational Equipment (Ship's Use)	**Type (Make / Model / Amount / Location)**
Radars (X and S Band)	Furuno / MU-231CR / 2 / Bridge
GPS and DGPS	Furuno / GP-90 / 2 / Bridge Northstar / 951x / 1 / Bridge
Gyro Compass	Meridian Standard / 2 / Bridge
Deepwater and Shallow Navigational echosounders	Simrad / EK-60, ES-60 / Bridge Furuno / FE-700 / 1 / Bridge
ECDIS	Transas / ES 4 / 2 / Bridge
Other	Coastal Explorer / 1 / Bridge

Navigational Equipment (Access to onboard Scientists)	**Type (Make / Model / Amount / Location)**
GPS and DGPS	Furuno / GP-90 / 2 / Bridge Northstar / 951x / 1 / Bridge
Gyro Compass	Meridian Standard / 2 / Bridge
Deepwater and Shallow Navigational echosounders	EK-60: 38 kHz, 70 kHz, 120 kHz, 200 kHz / 1 / Scientific Computer Lab ES-60 70Khz, 200Khz / 1 / Scientific Computer Lab
Charting Program with Ship's Position	Nobletech / 1 / Scientific Computer Lab

Laboratory Spaces and other Scientific Spaces

Type	**Location**	**ft.^{2}**	**Description: (Available Services and / or Connections, counter space, etc.)**
Dry Lab	01 Deck Aft	100	Computer Lab, Counter Space
Electronics/Computer Lab	01 Deck	100	Location of data acquisition computers
Hydro Lab	01 Deck Aft	50	Flammable Locker, Acids Locker, Storage Closet
Scientific Freezer	Wet Lab/ Bio Chem Lab	50	-20 Deg. Large area for biologic specimens -20 Deg. Small area for chemicals in Hydro-Chem Lab
Store Room	01 Deck STBD Side	50	Scientific Storage Locker, Shelf Space
Wet Lab	Main Deck Aft	150	Sink, Stainless Steel Cutting Table

DATA COLLECTED BY THE SHIP'S SCIENTIFIC COMPUTER SYSTEM (SCS) IN THE STANDARD CONFIGURATION

Description	**Units**	**Data Source**
DPT - Depth of Water with transducer offset	meters	5m offset. EK-60, ES-60
GLL - Geographic Position (Lat/Lon)	Deg.	Northstar GPS
HDG - Heading (Deviation and Variation)	Deg.	Gyro
HDT - Heading (True)	Deg.	Gyro
VTG - Track made good and ground speed	KTS	Northstar GPS
VTG Version 1 (TC, MC, SOG, STW, etc)	KTS	Northstar GPS
VWR - Relative wind speed and angle	KTS, Deg.	RM Young Windbird
ZDA - Time and Date (UTC. d. m, yr, TZ)	hh:mm:ss	Symmetricom time server
Z--DBS - Depth below Surface DBS tag fields	meters	ES-60, EK-60

Scientific Data Collection Systems and Supportable Operations	
Type	**Brief Description (location, type)**
Acoustic Current Doppler Profilier (ADCP)	38 kHz Transducer located on the Transducer Pod located on the hull. Deck unit located in the E-lab.
Automated Underwater Vehicles (AUV) Support	Yes. Wet Lab, Scientific Computer Lab
Conductivity, Temp., Depth (CTD) With Water Samples	Seabird 9-11+. 12 10L bottles for sampling Dual Seabird DO sensors. Seapoint fluorometer. Wet Lab fluorometer
Conductivity, Temp., Depth (CTD) Without Water Samples	Seabird 9-11+. Dual Seabird DO sensors. Seapoint fluorometer. Wet Lab fluorometer
Dive Team Equipped	Yes. 4 NOAA Working Divers
Expendable BathyThermographs (XBT) Capable	Sippican XBT. Launcher on Trawl Deck. Deck unit and data acquisition computer in Wet Lab
Mooring Deployment/Recovery Capable	Yes
Plankton Gear Deployement	Yes. Deployed from Starboard Side J frame
Remote Operated Vehicles (ROVs) Support	Yes. Wet Lab, Scientific Computer Lab
Scientific Computer System Equipped	SCS 4.7.0 Two servers
Scientific Diver Support	Yes
Thermosalinograph	SBE 45 and SBE 21 both installed in the Scientific Seawater System.
Trawl Fishing Capable	Yes. Two trawl winches located on 01 Deck, and net reel located on Trawl Deck
Trawl Sensor Equipped	Netmind system. Temperature and Depth transmitted acoustically during trawl

DECK EQUIPMENT:			
Winch – CTD (J-Frame)		**Winch – Trawl**	
Quantity:	1	Quantity:	2
Manufacturer:	Markey	Manufacturer:	Marco
Model	DESH-5	Model	Wt202
Drive:	Hydraulic	Drive:	Hydraulic
Max. Pull (lbs.):	14,700	Max. Pull (lbs.):	57,300
Max. Depth (m)	2000	Max. Depth (m)	5000
Drum Capacity:	2000m	Drum Capacity:	5,000m of 5/8" steel wire
Type of Cable Installed:	3/8" conductor cable	Type of Cable Installed:	5/8" steel wire
Length of Cable on the drum (m)	2000	Length of Cable on the drum (m)	5000
Location:	O1 Deck, Starboard Side, Amidships	Location:	O1 Deck, Port and Starboard Side, Amidships

Winch – Oceanographic (J-Frame)	
Quantity:	1
Manufacturer:	Markey
Model	DESH-3
Drive:	Hydraulic
Max. Pull (lbs.):	15,380
Max. Depth (m)	8000
Drum Capacity:	8,000m
Type of Cable Installed:	3/8" conductor cable
Length of Cable on the drum (m)	8000
Location:	Main Deck, Port Side, Amidships

Crane, Articulating	
Quantity:	1
Manufacturer:	Alaska Marine Crane
Model:	MCK-1846
Boom Length (ft.):	46
Lifting Cap. (lbs.):	24,000 max – 6600 at full extension
Location:	Fantail, Starboard Side
Crane, Articulating	
Quantity:	1
Manufacturer:	Alaska Marine Crane
Model:	MCK-1250
Boom Length (ft.):	50
Lifting Cap. (lbs.):	20,000 max – 2100 at full extension
Location:	O2 Deck, Port Side, Amidships

A Frame	
Quantity:	1
Type:	Movable
Clearance over the side (ft.):	10
Horizontal Clearance (ft.):	8
Safe Working Load (lbs.)	10,000
Location:	Trawl Deck, Aft

J Frame	
Quantity:	2
Type:	Movable
Clearance over the side (ft.):	10
Horizontal Clearance (ft.):	6
Safe Working Load (lbs.)	3,500
Location:	Starboard side O1 Deck Amidships, Port side Main Deck Amidships

Boat Davit	
Quantity:	1
Manufacturer:	Schat-Harding
Model:	Gravity
Hoisting Capacity Location	8360 lbs. 02 Deck, Starboard Side
Boat type used	22' Zodiac

Anchor - Bow	
Quantity	2
Type	Stockless
Weight (lbs.)	3,500
Port Anchor Chain Length (fathoms)	120
Starboard Anchor Chain Length (ftm)	105

BOATS (Normally Equipped)				
	Type	Horsepower	Length Over All (ft.)	Max. Persons
1	Rescue Boat (SOLAS Approved)	315	22	6
	Data collection equipment and/or special features.	N/A		
2	Rigid Hull Inflatable Boat (RHIB)	115	17	7
	Data collection equipment and/or special features.	N/A		
3	Inflatable (non RHIB) Boat	50	18	11
	Data collection equipment and/or special features.	N/A		

Additional Capabilities (not previously stated)	
Type	Description
Access to Clean Electrical Power	Yes, Clean Power Generator
Compressed Air	Yes

Papahānaumokuākea Marine National Monument: Equipment and Survey Research Topics

EQUIPMENT	STUDENT NAME(S)
Multibeam sonar	
Acoustic Doppler Current Profilier (ADCP)	
Automated Underwater Vehicles (AUV)	
Conductivity, Temperature and Depth Profiler (CTD)	
Remote Operated Vehicles (ROVs)	
Water Sampling Rosette (10-12L Niskin Bottles)	
Expendable BathyThermographs	
Thermosalinograph	
Fishing trawl	
Plankton Nets	
Towed Optical Assesment Device (TOAD)	
Bottom Camera (BotCam)	
Baited Remote Underwater Video Station (BRUVS)	
Autonomous Reef Monitoring Structures (ARMS)	
Photoquadrat	

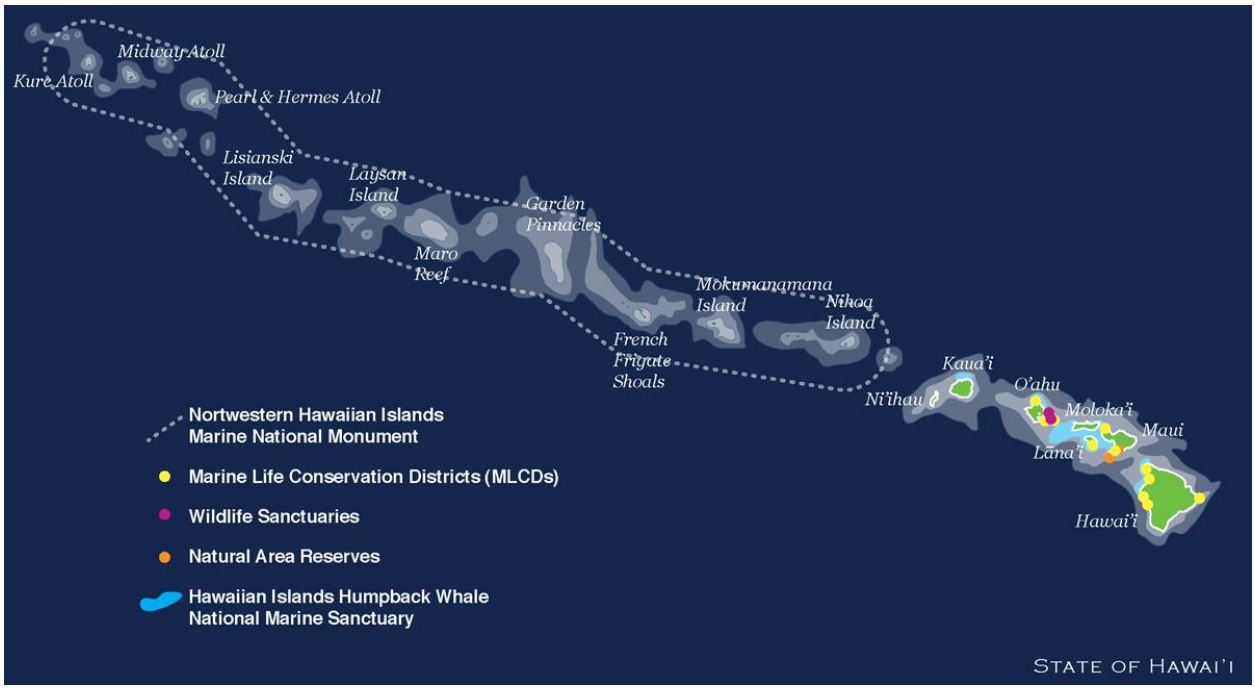
SURVEY TECHNIQUES	STUDENT NAME(S)
Line-point-intercept (for benthic cover)	
Belt transect (for coral size class)	
Belt transect (for coral demographics and condition)	
Towed diver survey (for benthic cover)	
Stationary Point Count Method (for fish)	
Belt transect (for fish)	
Towed diver survey (for fish)	

Papahānaumokuākea Marine National Monument: Science Technology Student Worksheet ANSWER KEY

Name_____ Date_____

Part 1: Introduction to Papahānaumokuākea

Papahānaumokuākea Marine National Monument (PMNM) is the largest conservation area within the United States. It was established in 2006 and in addition to its national monument status has also been declared a natural and cultural World Heritage Site by UNESCO. PMNM encompasses 139,797 square miles and extends northwest for 1,200 nautical miles starting north of the islands of Ni'ihou and Kaua'i, Hawai'i.



As you can see from the map, the majority of PMNM is water. In fact, total **emergent land** only accounts for about 5.15 square miles of PMNM. The rest of the region is covered by water and the water itself is habitat for numerous creatures.

1. Based on what you just read, what percentage of PMNM is dry land? Show your work.

Only about 0.0036% (5.15 square miles/139,797 square miles x 100) of PMNM is dry land. This means the vast majority of PMNM and its inhabitants are found underwater. This has huge implications for how PMNM is managed and studied.

2. Though much of the life in the ocean is concentrated in the **photic zone**, every square meter of the ocean is filled with life. In fact, an estimate 50-80% of life on Earth is found in the ocean. If the average depth of PMNM is 0.5 miles, approximately how many square meters of water habitat are in PMNM? Please show your work.

   The goal of this question is to get the students to think about the three-dimensional living space in the ocean and how, when there is an additional dimension to think about, there is significantly more living space available to organisms.

   $139{,}797 \text{ miles}^2 \times 0.5 \text{ mile} = 69{,}898.5 \text{ miles}^3$

   $69{,}898.5 \text{ miles}^3 \times 4.17 \text{ km}^3/1 \text{ mile}^3 = 291{,}476.745 \text{ km}^3$

   $291{,}476.745 \text{ km}^3 \times 1{,}000{,}000 \text{ m}^3/ 1 \text{ km}^3 = 291{,}476{,}745{,}000 \text{ m}^3$

   Almost 291.5 billion cubic meters of habitat for living organisms!

3. Given the vast size and nature of this Monument, what difficulties might scientists encounter when trying to study in PMNM?

   Answers will vary but reasonable thoughts might include difficulties with access (need ships, scuba gear, etc.), supplies (long way from human habitation), harsh environments (sunlight, salt, waves), pressure and limited light at depth, size of PMNM, need to survey in three-dimensions, movement of organisms, and difficulty of removing organisms from their environments, to name a few….

Part 2: Studying Biodiversity

One of the reasons that Papahānaumokuākea was designated as a Marine National Monument was due to the amazing biodiversity found within the waters of the Northwest Hawaiian Islands. Over 7,000 species are known to exist within PMNM, a quarter of which are **endemic**, and scientists are discovering new species regularly.

4. In your own words, describe *what* biodiversity means and why it is important.

   Answer will vary, but students should be able to come up with a definition of biodiversity similar to "the degree of variation of life (genetic, species, and ecosystem) within an area such as a biome, or planet".

   As to why biodiversity is important, again answer will vary. Here are some good discussion points for why it is important:

   - *Our lifestyle as humans would not exist without high levels of biodiversity.*
   - *Most of our air, food, medicine, and raw materials come directly from the great variety of organisms we interact with.*
   - *As we lose biodiversity we are less and less able to adapt to changes and thus potentially reduce our own long-term survival possibilities.*
   - *High genetic diversity slows down the spread of diseases and harmful pathogens.*
   - *The world becomes less interesting and less fulfilling without the huge variety of life.*

5. Why is it important to study biodiversity?

   Answers will vary, but here are some discussion points.

   - *We are very unlikely to protect what we do not know about or understand.*
   - *A better understanding of the biodiversity helps humans better understand their possibilities for survival long-term.*
   - *Until we know how our actions are impacting other species, we cannot alter our own behavior.*
   - *The discovery of new species will lead to medical and other scientific advances that directly benefit us.*
   - *Studying biodiversity helps us to better understand ourselves. For example, insights from sea lampreys are helping scientists better understand spinal nerve regeneration.*
   - *The world is full of fascinating and amazing creatures and the more we know, the more enriched our lives can be.*

6. As a scientist, how might you go about studying biodiversity? What techniques would you use to quantify biodiversity?

   Answers will vary. Studying biodiversity is complex and so there are many different ways to approach these studies. Biological collections, such as those gathered by Charles Darwin and or the Challenger expedition, are one of the oldest ways to study biodiversity. This technique removes organisms from their natural environment and holds them in an artificial environment where they are easier to study, or more commonly, kills the organisms and preserves the specimens for further identification and analysis. Visual surveys, which count organisms in situ, are another technique that has been employed with great success. Other ways to study biodiversity include genetic analysis, photographic documentation, spatial analysis, statistics, and remote sensing, to name a few. As with any scientific techniques, each of these was of studying biodiversity has its limitations. The goal with this question is to get students thinking about what kinds of things it might be possible to accomplish it they were tasked with studying the biodiversity in the ocean. Here are a few additional points for discussion:

   - *There is great variation in the size of life in the ocean, everything from blue whales to virus particles, and all sizes in between. Different sized organisms may require different methods of collection and/or study.*
   - *Life stages and/or forms have very different strategies, some stay fixed throughout their life, some are on the move all the time. These also may require different methods of collection and/or study.*
   - *The ocean habitat is three-dimensional.*
   - *Organisms accustomed to life in the ocean may not adapt well to being removed and placed in artificial study environments. For particularly sensitive species, study in their natural habitat may be the only realistic method for learning more about these organisms.*

7. If you were trying to study biodiversity in PMNM, which methods/techniques of studying biodiversity might be most useful? Remember that the majority of habitat for living organisms in PMNM will be water and sediments below the water surface.

   Answers will vary but here are some ideas that might help students get started

   - *Net tows: Pros – provides physical samples, can sample at different depths, relatively rapid sampling, can be done from a boat. Cons – smallest organisms collected determined by mesh size, can't separate exactly where each organism came from.*
   - *Human visual surveys: Pro – fairly simple, quick, can be done from deck of ship for some organisms. Cons – no physical sample, requires scuba gear or other gear for underwater surveys, covers only small areas, requires underwater lights for surveys below of the photic zone or at night.*

- *Photographic surveys: Pros – fast, permanent records, data collection requires no experience identifying organisms Cons – covers small area relative to other methods (ie sonar, satellites, etc.), no physical samples, requires light source for deep ocean, need specialized gear for underwater photos.*
- *Remotely Operated /Autonomous Underwater Vehicles/Submersibles: Pros – access to deep ocean (6000+ m), can be operated at a distance, multiple tools and sensors available Cons – expensive, range is limited by battery life or tether length, covers only a small area.*
- *Sonar (Sound waves): Pros – very fast, cover large areas, can reach great depths. Cons- hard to tell what species the sound waves are detecting, data can be difficult to interpret.*
- *Satellite data: Pros- cover very large areas, lots of data, very fast Cons – may not be able to identify species without human and species interactions (e.g. satellite tracking tags), restricted mostly to ocean surface, data limited by satellite resolution.*
- *Genetic analysis: Pros- very detailed information about organisms, can establish relationships between organisms. Cons – expensive, time consuming, hard to do in the field.*
- *Unmanned Aerial Systems (UAS): Pros –can capture images of difficult to access places and collected data with little disturbance of animals. Cons – expensive, requires specific training, range limited by battery power or fuel capacity.*

Part 3: Exploration of Papahānaumokuākea

Exploration of Papahānaumokuākea is far from straight forward. The vast majority of PMNM is water and even that land that is emergent has limited access (only a few islands have runways). So, how do scientists and explorers study a region like this? Early Polynesian explorers came in long distance voyaging canoes, and though not common today, a few of these canoes are still used for exploration. For example, the Hokule'a, meaning "Star of Gladness" is a replica of one of those early double hulled sailing canoes and has made several voyages to Papahānaumokuākea to study the biological and cultural wonders of PMNM.

In addition, the US maintains a fleet of modern research vessels which make expeditions to PMNM. These ships, which are specifically designed and equipped to carry out research at sea, allow scientists to access to remote parts of the oceans. One vessel that spends significant time in PMNM is the NOAA research vessel R/V Oscar Elton Sette, named after one of the modern fathers of fisheries oceanography.

Regardless of whether the platform is old or new, each trip to PMNM begins long before the ships leave port. Months and sometimes years of planning go into each expedition and the first step in that planning is to define what the *mission* will be. This mission while general, helps scientists outline the *research objective* of the research cruise. For example, if the mission is to better understand cetaceans (whales, dolphins, etc) in the Pacific Ocean, individual research objectives of the cruise might be to survey the number of cetacean numbers within Papahānaumokuākea, and to collect genetic data to determine how closely the populations are related. Once specific research objective have been determined, then scientists can develop plans about how to meet those objectives. In this example, perhaps the survey will consist of both visual and auditory observations along **transects** through PMNM, while the genetic analysis will consist of collecting tissue samples from as many animals as possible. Both of the research objectives in this example fit within the mission of better understanding cetaceans, but will require very different equipment and scientists to complete.

To give you a better sense of how these missions and research objectives actually are related please read a recent cruise summary for a research cruise to PMNM and answer the following questions:

Note: answers will depend on which cruise summary students read. Example answers here are from the cruise summary "Expedition to Establish Long-term Monitoring Sites to Measure Trends on Coral Reefs in the Northwestern Hawaiian Islands" included with lesson materials

1. Where did the research cruise take place and what research vessel was used?

   Scientists of the NOAA Pacific Islands Fisheries Science Center's Coral Reef Ecosystem Division (CRED) embarked today on a 19-day mission aboard the NOAA Ship Hi'ialakai to establish a network of long-term monitoring sites in the Northwestern Hawaiian Islands, a conservation area designated as the Papahānaumokuākea Marine National Monument (PMNM).

2. What was the *mission* of the research cruise?

   … to establish a network of long-term monitoring sites in the Northwestern Hawaiian Islands…

   The research expedition is part of the CRED's long-term, integrated Pacific Reef Assessment and Monitoring Program (Pacific RAMP), which is designed to provide a flow of consistent, comparable information to help document and report the status of environmental conditions and living resources of the nation's coral reef ecosystems in the Pacific.

3. What were some of the *research objectives* of the cruise?

   With the Hi'ialakai as their base of operations, scientists will conduct scuba dives from small boats to install instruments at 15 long-term monitoring sites around Pearl and Hermes Atoll, Lisianski Island, and French Frigate Shoals.

   The main goal of the research mission is to advance a robust set of methods to be used at these long-term monitoring sites to measure changes in ocean temperature and ocean chemistry as a function of climate change and ocean acidification. Measuring changes in oceanographic parameters over long periods and concurrently monitoring many subsequent biological responses on the reef will allow NOAA scientists to assess the effects of changing ocean chemistry and temperatures on the coral reef ecosystems in the Northwestern Hawaiian Islands.

4. What equipment (if any) did the scientists use to accomplish their *research objectives*?

   Ocean temperatures will be measured with instruments deployed at depths of 1, 5, 15, and 25 m along selected transects on the forereefs surrounding each island or atoll. These instruments are capable of recording subsurface ocean temperatures every 5 min for a period of 3 years. At the site where the temperature sensor is deployed at each island, other instruments will be employed to collect additional measurements. Discrete water samples will be collected and analyzed for salinity, dissolved inorganic carbon, and total alkalinity to evaluate the carbonate chemistry of waters just above the reef. Casts with a conductivity-temperature-depth instrument will be made to profile salinity and temperature of the water column from the sea surface to seafloor. Within the reef matrix, the following monitoring installations will be used: calcification accretion units to assess net rates of calcification, coral recruitment, and algal biomass; bioerosion monitoring units to provide measurements of bioerosion rates across the reef, and autonomous reef monitoring structures to aid in assessment of taxonomic diversity at the species level.

5. What survey techniques (if any) did the scientist employ to accomplish their *research objectives*?

Photographic and video mosaic techniques will document the percent cover of corals and algae found on the seafloor.

Part 4: Science Equipment Research

Since scientists want their data to be comparable to data collected in other places, they typically use standardized equipment and techniques to study different types of organisms. Spend some time researching equipment or survey techniques commonly used by NOAA scientists aboard the R/V Oscar Elton Sette and at the Pacific Islands Fisheries Science Center to study Papahānaumokuākea. After doing your research create a poster to help you present your information to rest of the class. Be sure to address the following questions when creating your poster:

Equipment:

1. Name of Equipment
2. Describe the equipment and include a visual of the equipment.
3. Explain what kind of data the equipment is designed to collect.
4. Explain how the equipment collects data (ie, does it bounce sound off various surface, does it use variations in electrical fields to determine conductivity, etc)
5. Describe where this equipment can collect data (ie, surface data collection only, bottom collection only, etc).
6. Describe how this equipment can be **deployed** and recovered (from large ship, from a small boat, by scientific diver, etc).

Survey methods:

1. Name of survey method
2. Description of survey methodology
3. Visual of survey methodology
4. What kind of data will be collected by this survey method?
5. What are the benefits of this survey method?
6. What are the limitations of this survey method?

Part 5: Planning a research cruise

Now that you are familiar with relationship between the *mission* and the *research objectives* of a research cruise, as well as some of the equipment and techniques used by scientists, it is time for you and your classmates to plan a research expedition to PMNM. The *mission* of this research cruise, aboard one of NOAA's research vessels, will be to better understand the **biodiversity** within one nautical mile of French Frigate Shoals.

1. Now that you know the *mission* of the cruise, as a group, decide on one *research objective* for the cruise and explain how that will help you address your *mission*.

   Push the students here to develop a realistic research objective, and be sure to review that with the students before they move on to selecting equipment and techniques. To define biodiversity is a very broad mission with lots of room for more specific studies. For example, students could choose as a research objective to better understand the benthic reef communities around French Frigate Shoals, and they might choose to accomplish that objective by conducting a series of benthic surveys using a Line-Point-Intercept technique. If they chose instead to focus their research objective on better understanding the water column communities, perhaps they would chose to tow a series of nets to sample that community. Maybe it is mostly the fish communities around French Frigate Shoals are what really interest the students. Perhaps they would choose to deploy a baited camera (BotCam) to photodocument different types of fish. All of these research objectives will help address the broader mission of better understanding biodiversity around French frigate shoals, but are tangible and doable.

2. Based on the presentations of your classmates, what equipment and survey techniques would help you accomplish your *research objective*? Refer back to the posters if you need a refresher on available equipment or techniques.

   Once the research objectives are established, have the students pick out what equipment and techniques they think will best help them accomplish their research objectives. Direct students to refer back to the posters and to pay attention to things like how long it takes to accomplish the survey/tow/deployment. Get them to really think about the logistics of trying to accomplish their research objectives. Have them ask the original presenters for additional information if they are not sure about a piece of equipment or survey technique. Use the map of French Frigate Shoals as a visual to have them plan where they might conduct their science. How deep is the water? Will a large ship be able to get into that water or do they need a small boat and divers? Use the ship specification sheet and look at the range of the ship and carrying capacity. These are the kinds of questions that all scientists address before undertaking field work and having students really address those questions will help make the exercise more real.

Part 6: Cruise Summary

Based on the research objective of your research group, please produce a written cruise summary that addresses the following:

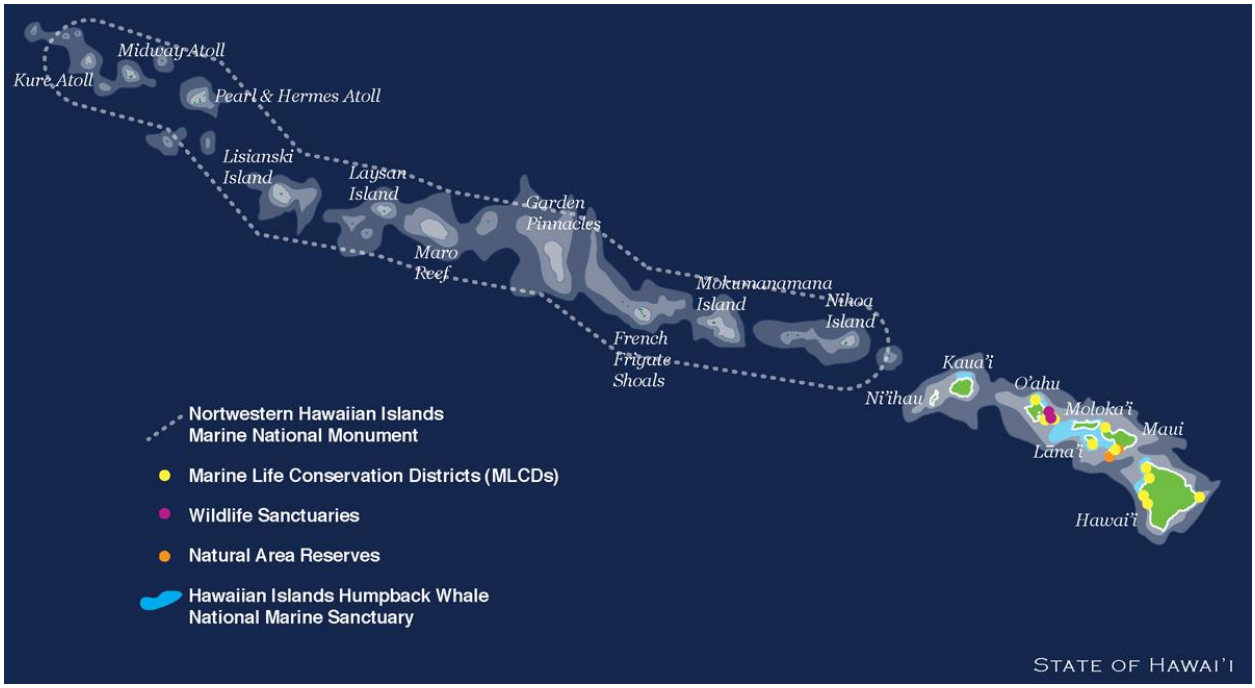
1. What is the overall mission of the research cruise?
2. Why is that mission important?
3. What research objective did your group come up to help address the mission?
4. How does your research objective address the mission of the cruise?
5. What equipment will you use to help you accomplish your research objective?
6. What survey techniques will you use to help accomplish your research objective?

Papahānaumokuākea Marine National Monument: Science Technology Student Worksheet

Name_____ Date_____

Part 1: Introduction to Papahānaumokuākea

Papahānaumokuākea Marine National Monument (PMNM) is the largest conservation area within the United States. It was established in 2006 and in addition to its national monument status has also been declared a natural and cultural World Heritage Site by UNESCO. PMNM encompasses 139,797 square miles and extends northwest for 1,200 nautical miles starting north of the islands of Ni'ihou and Kaua'i, Hawai'i.



As you can see from the map, the majority of PMNM is water. In fact, total **emergent land** only accounts for about 5.15 square miles of PMNM. The rest of the region is covered by water and the water itself is habitat for numerous creatures.

1. Based on what you just read, what percentage of PMNM is dry land? Show your work.

2. Though much of the life in the ocean is concentrated in the **photic zone**, every square meter of the ocean is filled with life. In fact, an estimate 50-80% of life on earth is found in the oceans. If the average depth of PMNM is 0.5 miles, approximately how many square meters of water habitat are in PMNM? Please show your work.

3. Given the vast size and watery nature of this monument, what difficulties might scientists encounter when trying to study in PMNM?

Part 2: Studying Biodiversity

One of the reasons that Papahānaumokuākea was designated as a Marine National Monument was due to the amazing biodiversity found within the waters of the Northwest Hawaiian Islands. Over 7,000 species are known to exist within PMNM, a quarter of which are **endemic**, and scientists are discovering new species regularly.

1. In your own words, describe *what* biodiversity means and why it is important.

2. Why is it important to study biodiversity?

3. As a scientist, how might you go about studying biodiversity? What techniques would you use to quantify biodiversity?

4. If you were trying to study biodiversity in PMNM, which methods/techniques of studying biodiversity might be most useful? Remember that the majority of habitat for living organisms in PMNM will be water and sediments below the water surface.

Part 3: Exploration of Papahānaumokuākea

Exploration of Papahānaumokuākea is far from straight forward. The vast majority of PMNM is water and even that land that is emergent has limited access (only a few islands have runways). So, how do scientists and explorers study a region like this? Early Polynesian explorers came in long distance voyaging canoes, and though not common today, a few of these canoes are still used for exploration. For example, the Hokule'a, meaning "Star of Gladness" is a replica of one of those early double hulled sailing canoes and has made several voyages to Papahānaumokuākea to study the biological and cultural wonders of PMNM.

In addition, the US maintains a fleet of modern research vessels which make expeditions to PMNM. These ships, which are specifically designed and equipped to carry out research at sea, allow scientists to access to remote parts of the oceans. One vessel that spends significant time in PMNM is the NOAA research vessel R/V Oscar Elton Sette, named after one of the modern fathers of fisheries oceanography.

Regardless of whether the platform is old or new, each trip to PMNM begins long before the ships leave port. Months and sometimes years of planning go into each expedition and the first step in that planning is to define what the *mission* will be. This mission while general, helps scientists outline the *research objective* of the research cruise. For example, if the mission is to better understand cetaceans (whales, dolphins, etc) in the Pacific Ocean, individual research objectives of the cruise might be to survey the number of cetacean numbers within Papahānaumokuākea, and to collect genetic data to determine how closely the populations are related. Once specific research objective have been determined, then scientists can develop plans about how to meet those objectives. In this example, perhaps the survey will consist of both visual and auditory observations along **transects** through PMNM, while the genetic analysis will consist of collecting tissue samples from as many animals as possible. Both of the research objectives in this example fit within the mission of better understanding cetaceans, but will require very different equipment and scientists to complete.

To give you a better sense of how these missions and research objectives actually are related please read a recent cruise summary for a research cruise to PMNM and answer the following questions:

1. Where did the research cruise take place and what research vessel was used?

2. What was the *mission* of the research cruise?

3. What were some of the *research objectives* of the research cruise?

4. What equipment (if any) did the scientists use to accomplish their *research objectives*?

5. What survey techniques (if any) did the scientist employ to accomplish their *research objectives*?

Part 4: Science Equipment Research

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