Ocean Exploration and Research

Exploring the Sunken Heritage of Midway Atoll 2017

Atoll Aliens

Image captions/credits on Page 2.

lesson plan

Focus
Invasive species in the northwestern Hawaiian Islands

Grade Level
9-12 (Life Science)

Focus Question
What is the impact of non-native species on marine ecosystems, and how can those impacts be reduced?

Learning Objective
- In this lesson, students will investigate some of these species, then design and evaluate a solution for reducing the impacts of alien species on the marine environment and biodiversity of the Hawaiian Islands.

Materials
- Web access to *Options for managing invasive marine species* and *Guidebook of Introduced Marine Species of Hawaii*, or copies of these materials; see Learning Procedure, Step 1c

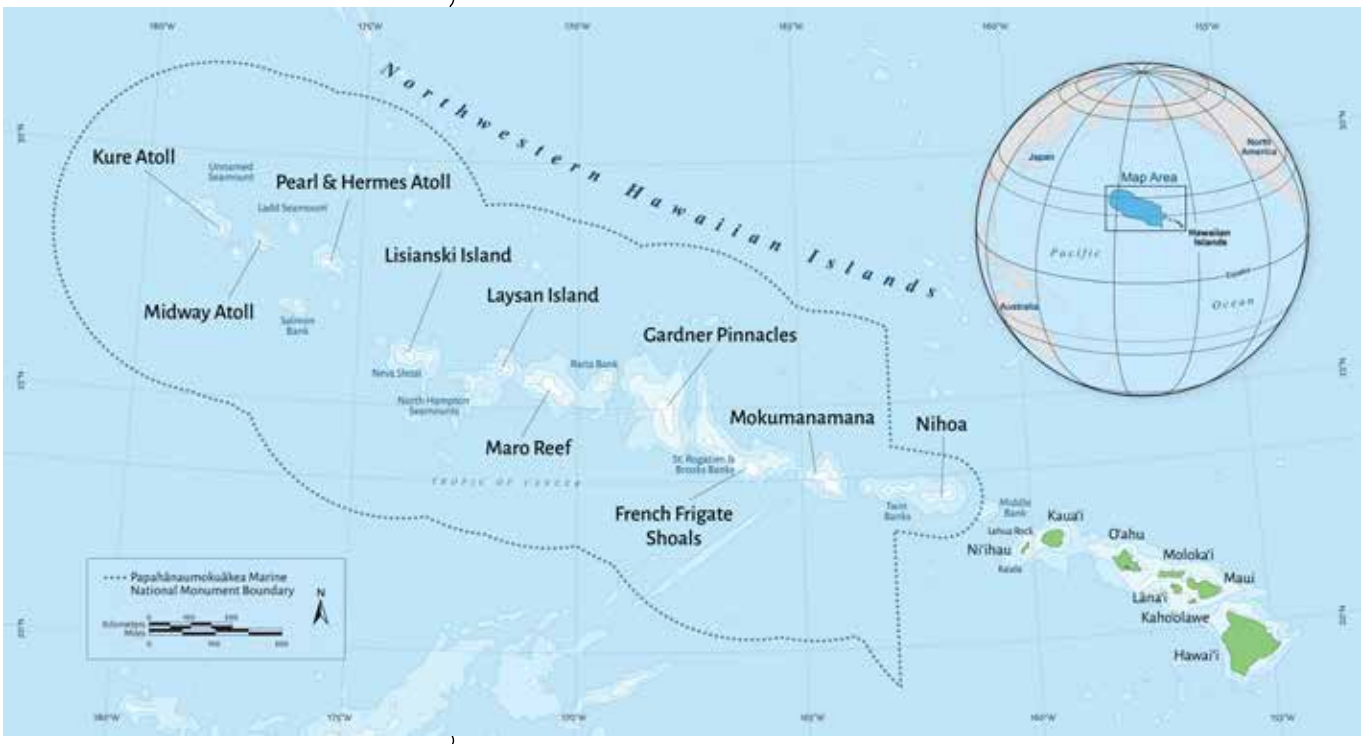
Audio-Visual Materials
- (Optional) Equipment to show images or video from the Exploring the Sunken Heritage of Midway Atoll expedition *http://oceanexplorer.noaa.gov/explorations/17midway/welcome.html*

Teaching Time
One or two 45-minute class periods, plus time for student research

Seating Arrangement
Groups of 2-4 students

Maximum Number of Students
30

Key Words
Midway Atoll
Invasive species
Endemic species
Northwestern Hawaiian Islands



The world's largest MPA (582,578 square miles or 1,508,870 square kilometers) is the Papahānaumokuākea Marine National Monument (PMNM) northwest of the inhabited main Hawaiian Islands. Image courtesy of PMNM.

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.

Marine protected areas (MPAs) are areas of the marine environment where there is legal protection for natural and cultural resources. The world's largest MPA (582,578 square miles or 1,508,870 square kilometers) is the Papahānaumokuākea Marine National Monument (PMNM) northwest of the inhabited main Hawaiian Islands. Besides being the largest, it is also among the world's most remote MPAs. Many of the species found in PMNM are found nowhere else on Earth (species that are found in only one specific location are said to be "endemic" to that location). The marine habitats of PMNM, for example, are home to over 7,000 species, 25% of which are endemic. For additional information about PMNM, please see the essay, *Exploration of the two largest marine protected areas of the United States*, by Daniel Wagner and Samantha Brooke. *http://oceanexplorer.noaa.gov/okeanos/explorations/ex1504/background/mpas/welcome.html*

Midway Atoll is a tiny island near the northwestern boundary of PMNM. This geographic location (as the name suggests,

Images from Page 1 top to bottom:
Satellite image of the Midway Atoll. Image courtesy PMNM.

Brewster F2A-3 'Buffalo' fighter. Image courtesy of PMNM.

Crella Spinulata is an invasive sponge (Porifera) that the team will be surveying for on sunken aircraft sites at Midway Atoll.
http://oceanexplorer.noaa.gov/explorations/15arctic-microbes/background/seaice/seaice.html

WWII aircraft modeled with 3D imagery software. Image courtesy of K. Keogh.

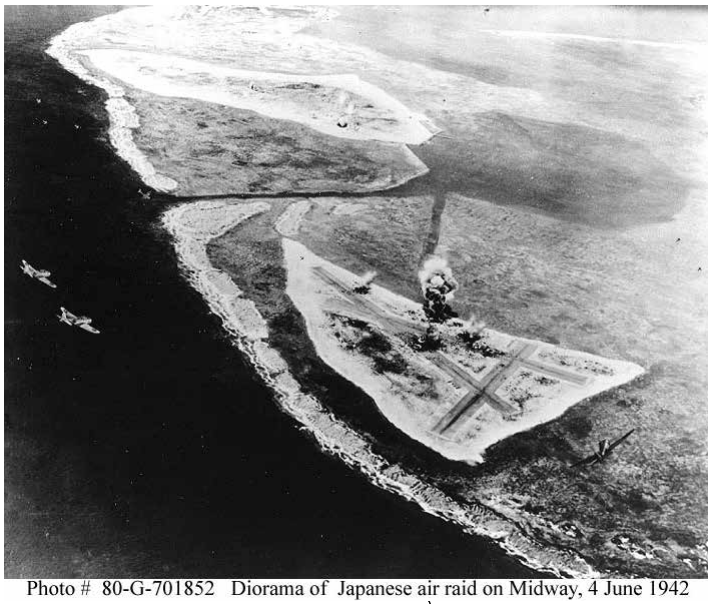


Photo # 80-G-701852 Diorama of Japanese air raid on Midway, 4 June 1942

Top: Diorama of Japanese air raid on Midway, June 4, 1942. Image courtesy of PMNM.

about halfway across the Pacific Ocean) has made Midway the center of a series of dramatic events in history, including a momentous World War II battle that proved to be the turning point of the War in the Pacific. As a result of Midway's importance, human activities have inevitably had an impact on the atoll's natural environment. One of the most significant impacts is the introduction of alien (non-native) species. The problem is that alien species sometimes cause economic and/or environmental harm, or pose threats to human health. When that happens, the species is considered to be invasive. Alien species may arrive on

Crew of Pacific Fleet patrol seaplane which first sighted Japanese fleet approaching Midway on morning of June 3, 1942, and gave alarm that reached island outpost for

Right: Crew of the Patrol Squadron 44 (VP-44) PBY-5A "Catalina" patrol bomber that first sighted the approaching Japanese fleet`s Midway Occupation Force on the morning of 3 June 1942. Image courtesy of PMNM.

natural pathways such as wind, water, or other organisms; but human activities are frequently involved.

According to NOAA's Habitat Restoration Center *http://www.habitat.noaa.gov/restoration/programs/invasivespecies.html*, invasive species are considered to be one of the greatest threats to marine and coastal biodiversity world-wide, second only to habitat loss. By reducing the abundance of native

Volunteers pulling the nonnative plant, *Verbesina* from Midway Atoll NWR | Image courtesy of John Klavitter/U.S. Fish and Wildlife Service.
http://refugeassociation.org/2014/04/eradication-of-invasive-species-on-midway-atoll/

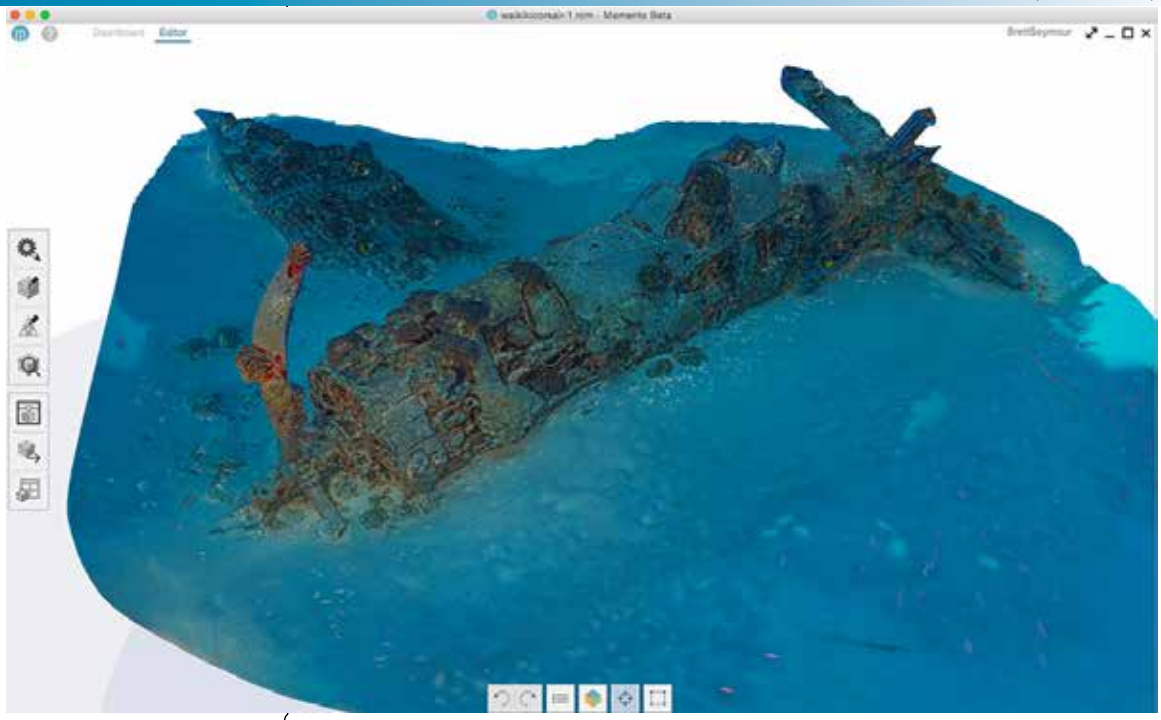
species and altering ecosystem processes, invasive species cause severe and often permanent damage to the habitats they invade. In addition to environmental impacts, invasive species also result in direct economic losses to local communities and industries as well as additional costs for management and control efforts. In the U.S. alone, the costs to control and eradicate invasive species amount to more than $137 billion annually.

On Midway Atoll, the Golden Crown-beard (*Verbesina encelioides*) is the most notorious example of an invasive species. For many years, most of Sand and Eastern islands (the parts of the Atoll that are above sea level) were carpeted with chest-high thickets of *V. encelioides* that made it difficult for albatrosses to reach nesting sites and created oven-like conditions for chicks. In the case of *V. encelioides*, human activities have been able to reverse some of the damage caused by this invasive species. Thanks to a systematic control program by the U.S. Fish and Wildlife Service, *V. encelioides* is no longer a dominant land cover on Eastern and Sand Islands, and the reproductive success rate for Black-footed and Laysan Albatrosses has almost doubled on both Sand and Eastern Islands.

Albatross reclaim nesting space on Midway Atoll National Wildlife Refuge in the Pacific after the U.S. Fish and Wildlife Service beats back an invasion of the plant pest *V. encelioides*. Image courtesy of John Klavitter/USFWS.
https://www.fws.gov/refuges/news/FightingWeedsToSaveSeabirds.html

In the marine environment, more than 400 species of plants and animals have been introduced into Hawaii's coastal and estuarine waters, but only about 10% are established in PMNM. Arthropods have been the most successful marine invaders, followed by molluscs, sponges, cnidarians, polychaetes ascidians, and bryozoans. At present, the most likely source of invasive species in the Northwestern Hawaiian Islands is populations of alien marine species that are already in the main Hawaiian Islands. In PMNM, most of the known alien species are restricted to areas of higher human activity, suggesting that appropriate human interventions may be able to control further spread of these species and introduction of others.

Many anthropogenic substrates have been introduced into the marine environment at Midway Atoll, including ship and



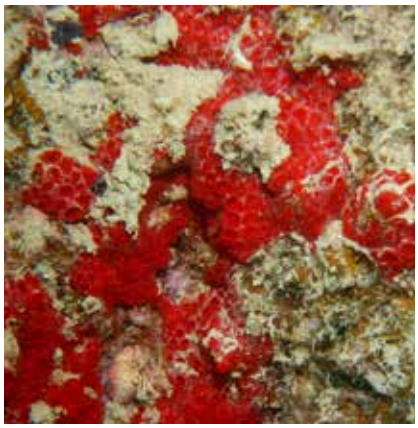
Sunken WWII aircraft modeled with 3D imagery software.
Image courtesy of K. Keogh.

aircraft wreckage, concrete, wood, and many other types of debris. The Exploring the Sunken Heritage of Midway Atoll Expedition to explore for sunken aircraft sites provides an opportunity to investigate the relationships between these substrates and alien marine species. In this lesson, students will investigate some of these species, then design and evaluate a solution for reducing the impacts of alien species on the marine environment and biodiversity of the Hawaiian Islands.

Learning Procedure

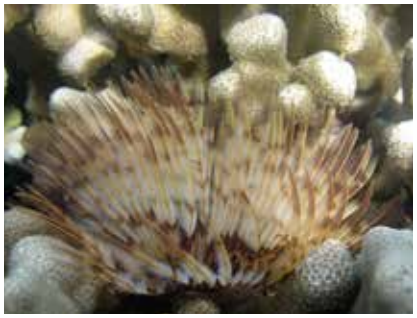
a. Review background information about the Exploring the Sunken Heritage of Midway Atoll expedition *http://oceanexplorer.noaa.gov/explorations/17midway/welcome.html*, and the *Do Sunken Aircraft Create Homes For Non-Native Creatures at Midway Atoll?* essay by Kelly Keogh

Maritime archaeologists Kelly Gleason and Bert Ho examine the propeller blades at the sunken aircraft site. Image courtesy of Stephani Gordon/Open Boat Films.

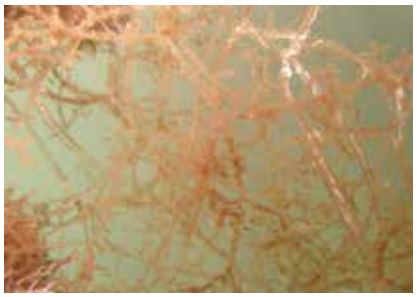


Crella Spinulata is an invasive sponge (Porifera) that the team will be surveying for on sunken aircraft sites at Midway Atoll. Image courtesy of Scott Godwin/NOAA.

Pennaria disticha is an invasive hydroid that the team will be surveying for on sunken aircraft sites at Midway Atoll. Image courtesy of Scott Godwin/NOAA.



Sabellastarte spetabilis is an invasive polychaete worm that the team will be surveying for on sunken aircraft sites at Midway Atoll.Image courtesy of Scott Godwin/NOAA.



Zoobotryon verticillatum is an invasive bryozoan that the team will be surveying for on sunken aircraft sites at Midway Atoll.Image courtesy of Scott Godwin/NOAA.

http://oceanexplorer.noaa.gov/explorations/17midway/background/invasive-species/invasive-species.html.

b. Review the Multimedia Discovery Mission, Seamounts (Lesson 14) *http://oceanexplorer.noaa.gov/edu/learning/welcome.html#lesson14*. Decide whether your students will be able to understand these presentations on their own, or whether you want to use the videos with your own narration and explanations. You may also want to keep track of new vocabulary to discuss with your students.

c. Review *Options for managing invasive marine species* (Thresher and Kuris, 2004), and *Guidebook of Introduced Marine Species of Hawaii* (Hawaii Biological Survey and Bishop Museum, 2002). If students will not have online access to these resources, make sufficient copies for students to complete Step 4, below. Decide whether you want to have students read the entire paper by Thresher and Kuris, or selected portions of the paper. Decide whether you want to assign specific species from the *Guidebook*, or allow students to make their own selections. Also decide whether to have students work individually or in groups. Group work is usually preferred, since the design of remedial measures often benefits from multiple perspectives, and actual design projects of this sort are typically team efforts.

2. Briefly review the mission of the *Exploring the Sunken Heritage of Midway Atoll expedition*. Highlight:
- Papahänaumokuäkea Marine National Monument as the largest marine protected area in the world;
- The definition of an atoll;
- Midway Atoll is at the northwestern end of the Hawaiian Archipelago (literally about midway across the Pacific Ocean); and
- This remote location predisposes to a relatively large number of endemic species.

Depending upon available time and learning objectives, you may also want to review events surrounding the Battle of Midway. See additional resources on page 9.

3. Introduce the concept of alien and invasive species. Be sure students understand the distinctions between these terms: An alien species is not native to its surrounding environment; an invasive species is one that causes economic and/or environmental harm, or poses threats

to human health. Discuss how alien species may be introduced to a marine environment, and the kinds of damage that may result if alien species become invasive.

4. Tell students that their assignment is to investigate three alien invertebrate species found in Hawaiian marine environments, then design and evaluate a solution for reducing the impacts of one of these species on the marine environment and biodiversity. Say that to prepare for this assignment they should read some or all (your decision) of Thresher and Kuris (2004).

   Have students choose three alien invertebrate species from the Guidebook, or assign species that you have previously selected. For each of these species, students should prepare a brief report that includes:
   - Distribution in the Hawaiian Islands;
   - Probable mechanism of introduction to the Hawaiian Islands;
   - Habitat type (*e.g.*, burrowing in sediment, sessile and living on hard substate, etc.);
   - Feeding type (*e.g.*, suspension feeder, detritivore, carnivore, etc.); and
   - Known ecological impacts.

   Students should prepare a fourth brief report in which they describe their design for a solution to reduce the impacts of one of these species, and an evaluation of this solution considering factors described by Thresher and Kuris (level of risk, probability of success, and public acceptability). If students find that none of their species are known to present a serious environmental threat, ask them to assume that one of these species has been recently found to be a host for a parasitic organism that can be carcinogenic in humans. Emphasize that possible solution designs are not confined to those discussed by Thresher and Kuris, since this paper was written in 2004 and there have been many technological advances since then. Encourage students to research other remediation ideas before deciding on their own solutions.

5. Lead a discussion of students' reports, solution designs, and evaluations. This discussion should include:
   - Many of the species listed in the *Guidebook* are fouling organisms that were probably introduced on the hulls of ships.

- The environmental impact of most organisms in the *Guidebook* has not been studied, and is assumed to be confined to possible competition for space with native species. The two exceptions are the stomatopod (mantis shrimp) *Gonodactylaceus falcatus* which has largely replaced the native species in some areas, and the oyster *Crassostrea virginica* which had overgrown some benthic habitats until a die-off event in the 1970's.

- Even though serious problems with invasive species are not reported in the *Guidebook*, the difficulty of eradicating such species once they are established is a strong argument for avoiding the introduction of alien species. Prevention, early detection and eradication are key strategies. In PMNM, prevention is the primary activity related to invasive species, and includes mandatory hull inspections and cleaning, marine debris removal, quarantines for most islands, and monitoring programs.

- According to Thresher and Kuris, some options that have the highest probability of successfully managing invasive species may not be publicly acceptable (*i.e.*, when "the cure is seen to be worse than the disease"). This is particularly likely when invasive species do not have a well-established negative impact on the natural environment, as is the case with many of the species included in the *Guidebook*.

- New technologies may expand the range of options described by Thresher and Kuris. A good example is an experimental deep learning machine vision algorithm developed at Lamar University that allows an underwater remotely operated vehicle to locate, identify and track lionfish without human interaction *https://engineering.lamar.edu/electrical/research/aquatic-robot-lionfish-remediation.html*.

6. Lesson connections to Next Generation Science Standards HS-LS2-7: Students' reports on solution designs should include reference to relevant scientific knowledge about the species to be managed, as well as explicit consideration of tradeoffs involved with adopting their designs. While catastrophic impacts have not been associated with invasive species in Hawaiian marine environments, be sure students understand that introduction of alien species is just one of many anthropogenic changes in these environments, and that while a single change may not cause serious disruption

of an ecosystem, multiple changes may have significant cumulative effects. Students should also consider the potential for collateral impacts when an alien species replaces a native species in an ecosystem. While the actual biodiversity may remain the same (or even increase, if the native species are still present in much-reduced numbers) the resilience of the ecosystem to future change may be impacted if, for example, the alien species cannot be consumed by predators of the native species, or if the alien species is susceptible to diseases that did not affect the native species.

The BRIDGE Connection

www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then "Biology," then click on "Exotics" for links to information and activities about invasive species.

The "Me" Connection

Have students write a short essay about how they might be personally affected by an invasive species.

Connections to Other Subjects

English/Language Arts

Assessment

Student reports and participation in class discussions provide opportunities for assessment.

Extensions

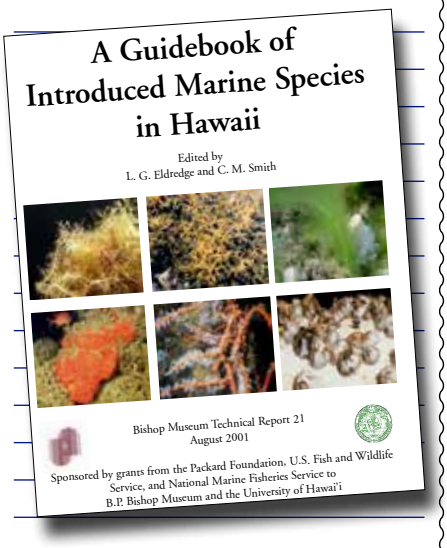
Visit *http://www.iiseagrant.org/NabInvader/* for an interactive resource to introduce students to invasive, nonindigenous species.

Other Relevant Lessons from NOAA's Ocean Exploration Program

Aliens on the Reef! (grades 6-8)
from the Coral Ecosystem Connectivity 2013 expedition
http://oceanexplorer.noaa.gov/explorations/13pulleyridge/background/edu/media/pr_13_aliens_68.pdf

Focus: Impacts of invasive species on coral reefs (Life Science)

Students explain interactions between native coral reef species and invasive lionfish, and construct explanations that predict how these interactions may affect other ecosystems.



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/explorations/17midway/welcome.html Web page for the Exploring the Sunken Heritage of Midway Atoll Expedition

Hawaii Biological Survey and Bishop Museum. 2002. *Guidebook of Introduced Marine Species of Hawaii*. Available online: *http://www2.bishopmuseum.org/HBS/invertguide/index.htm*.

Thresher, R. and A. Kuris. 2004. Options for managing invasive marine species. Biological Invasions 6: 295–300. Available online: *reviverestore.org/wp-content/uploads/2015/03/ThresherKuris.pdf*

Remembering the Battle of Midway, Commemorating June 4-7, 1942, A presentation of Panahanaumokuakea Marine National Monument
http://www.pmnmims.org/battlemidway/#0

The 2017 Battle of Midway 75th Commemoration
www.midway75.org

Next Generation Science Standards

The primary purpose of this lesson is to assist educators with incorporating information about invasive species and the Exploring the Sunken Heritage of Midway Atoll expedition into their instructional program. While they are not intended to target specific Next Generation Science Standards, activities in this lesson may be used to address specific NGSS elements as described below.

HS-LS2 Ecosystems: Interactions, Energy and Dynamics

Performance Expectation

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
[Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.]

Science and Engineering Practices

Constructing Explanations and Designing Solutions

- Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations

Disciplinary Core Ideas

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

- Anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.

Crosscutting Concepts

Stability and Change

- Much of science deals with constructing explanations of how things change and how they remain stable.

Common Core State Standards Connections:

ELA/Literacy –

RST.9-10.8 Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.

RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (*e.g.*, quantitative data, video, multimedia) in order to address a question or solve a problem.

WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.

The ocean supports a great diversity of life and ecosystems.

Fundamental Concept f. Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure,

substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept d. Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

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 b. Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

Fundamental Concept c. Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.

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 f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

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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Credit