Papahānaumokuākea Marine National Monument: Marine Debris

Grade Level

- 7-12

Timeframe

- Three 45-minute periods, two 90-minute periods

Key Words

- Nautical Mile
- Marine Debris
- Remote Sensing
- Duplicate Sampling
- Gyre
- Biofouling
- Weathering

Activity Summary

This lesson serves as an introduction to Papahānaumokuākea Marine National Monument (PMNM) and to one of the most difficult management challenges facing the Marine National Monument system, *Marine Debris*. The enormous size of PMNM, its remoteness, and the limited resources available for cleanup make addressing the issue of marine debris in the Monument a difficult one to manage. In this lesson students will explore the distribution, types and impacts of marine debris found in PMNM. That will be followed by an investigation on what types of plastic are likely to end up as marine debris and the possible sources of marine debris to PMNM.

Learning Objectives

Students will be able to:

1. Describe the size and location of PMNM
2. Describe the different scales of marine debris
3. Understand different sizes and types of marine debris.
4. Understand the impacts of marine debris
5. Use replicate testing to determine physical properties of plastic
6. Understand the life cycle of marine debris

Vocabulary

BIOFOULING – the accumulation of microorganisms, plants, or algae on a wetted surface.

GYRE – a large oceanic region of slowly circulating currents, driven by global winds and the Coriolis Effect.

MARINE DEBRIS – NOAA defines as any persistent solid material that is manufactured or processed and is directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes.

NAUTICAL MILE – 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.

REMOTE SENSING- is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Remote sensors collect data by detecting the energy that is reflected from Earth.

REPLICATE SAMPLE – a second (or third, fourth, etc…) sample of the same material collected under the same conditions which is usually used to estimate sample variability.

WEATHERING – the breakdown of material due to prolonged exposure to various environmental conditions (water, salt, sun, ice, wind, wave action, etc).

Background Information

Marine Debris:

The remote location and historically low levels of human visitation have left PMNM in relatively ecologically pristine condition with one major exception, ***marine debris***. NOAA and the USCG define marine debris as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes (33 USC 1951 et seq. as amended by Title VI of Public Law 112-213) (Lippiatt et al, 2013). Huge amounts of consumer plastics, metals, rubber, paper, textiles, derelict fishing gear, vessels, and other lost or discarded items enter the marine environment every day, making marine debris one of the most widespread pollution problems facing the world's ocean and waterways.

This lesson plan focuses on possible sources of marine debris to PMNM, the types of marine debris found on the beaches of Papahānaumokuākea, how density differences among plastics make some more likely to end up as marine debris, and possible impacts of debris to the marine environment in Papahānaumokuākea. Below is some additional background on the sources, types, impacts, and dispersion of marine debris.

Sources of Marine Debris:

Ocean-based Sources

Materials can fall, be dumped, swept, or blown off vessels and stationary platforms at sea. Ocean-based sources of marine debris include:

- **Fishing Vessels** – Fishing gear may be lost from commercial fishing vessels as well as from recreational boats and from shore-based fishing activities.

- **Stationary Platforms** – Offshore oil and gas platforms are surrounded by water, and all items lost from these structures become marine debris. Marine debris generated from these platforms includes plastic drill pipe thread protectors, hard hats, gloves, and 55-gallon storage drums, among others.

- **Cargo Ships and Other Vessels** – Cargo lost overboard from freighters, cruise ships and other vessels poses serious threats to marine navigation. Container vessels caught in rough seas can lose the contents of their containers (plastic resin pellets, sneakers, televisions, plastic toys, etc.), or perhaps even the entire container, a steel box 6 – 12 meters long, 2.4 meters wide and 2.9 meters high. Vessels carrying logs or lumber may lose large bundles or individual pieces of wood.

Land-based Sources

Materials

- Student handout
- Computers with internet access and Google Earth/Atlas
- Six clear beakers or small see through containers per group (9 oz small clear plastic cups work well)
- Paper towels
- Tweezers, enough for one pair per group of two to three students.
- Disks of six different types of plastic (recycle codes 1-6) made with a hole punch. Enough for three each per group.
- Lab glasses and gloves enough for each student.
- Handout for teacher explaining different types of plastic and their recycling codes and density characteristics.
- Six premixed density solutions, enough for 50 ml each per group (see solution mixing chart below)

Outline

ENGAGE – Introduction to Papahānaumokuākea Marine National Monument

EXPLORE – Model dispersion of marine debris, determine types and sizes of marine debris.

EXPLAIN – Discussion of type, sizes, and impacts of marine debris

ELABORATE – Investigation of plastic density and how that impacts dispersion potential

EVALUATE – Life cycle of marine debris in PMNM

Debris generated on land can be blown, swept, or washed out to sea. Littering, dumping in rivers and streams, and industrial losses such as spillage of plastic resin pellets during production, transportation, and processing are typical sources for land-based debris.

- **Littering, Dumping, and Poor Waste Management Practices** – Intentional or unintentional disposal of domestic or industrial wastes on land or in rivers and streams can contribute to the marine debris problem if a subsequent action carries the debris to the ocean.

- **Stormwater Discharges** – Stormwater that flows along streets or along the ground as a result of rain or snow can carry street litter into storm drains. Storm drains carry this water and debris to a nearby rivers, streams, canals, or even directly to the ocean. Marine debris from stormwater runoff includes street litter (e.g., cigarette butts and filters, motor oil, tire fragments), medical items (e.g., syringes), food packaging, beverage containers, and other material that might have washed down a storm drain.

- **Extreme Natural Events** – Hurricanes, tornadoes, tsunamis, floods and mudslides have devastating effects on human life and property. The high winds, heavy rains, flooding, and tidal surges associated with extreme events are capable of carrying objects as light as a cigarette butt or as heavy as the roof of a two-story home far out to sea. During storms or other periods of strong winds or high waves, almost any kind of trash (including glass, metal, wood, and medical waste) can be deposited into the ocean.

Types of Marine Debris:

Plastic is one of the dominant materials found in collections of marine debris around the world, though anything man-made, including litter and fishing gear, can become marine debris once lost or thrown into the marine environment. The most common materials that make up marine debris are plastics, glass, metal, paper, cloth, rubber, and wood.

Derelict fishing gear refers to nets, lines, crab/shrimp pots, and other recreational or commercial fishing equipment that has been lost, abandoned, or discarded in the marine environment. Modern gear is generally made of synthetic materials and metal, so lost gear can persist for a very long time.

Glass, metal, and rubber are used for a wide range of products. While they can be worn away and broken down into smaller and smaller fragments, they generally do not biodegrade entirely. As these materials are used commonly in our society, their occurrence as marine debris is overwhelming.

Plastic has been designed to be durable, lightweight, and strong. In addition, many plastics have densities close to or less than the density of water (See *Overview of Plastic Types* included with lesson materials). In combination this means that plastics do not break down quickly in the marine environment and that they are able to disperse over long distances by floating at or near the surface of the water.

Impacts of Marine Debris:

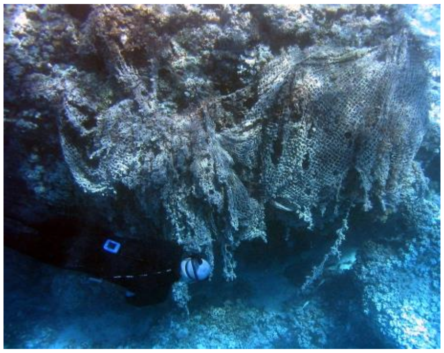
Below are just a few of the ways in which marine debris becomes a significant problem in the marine environment.

Ingestion:
Many animals, such as sea turtles, seabirds, and marine mammals have been known to ingest marine debris. The debris item may be mistaken for food and ingested, an animal's natural food (e.g. fish eggs) may be attached to the debris, or the debris item may have been ingested accidentally with other food. Debris ingestion may lead to loss of nutrition, internal injury, intestinal blockage, starvation, and even death.

Wildlife Entanglement and Ghostfishing:
One of the most notable impacts from marine debris is wildlife entanglement. Derelict nets, ropes, line, or other fishing gear, packing bands, rubber bands, balloon string, six-pack rings, and a variety of marine debris can wrap around marine life. Entanglement can lead to injury, illness, suffocation, starvation, and even death.

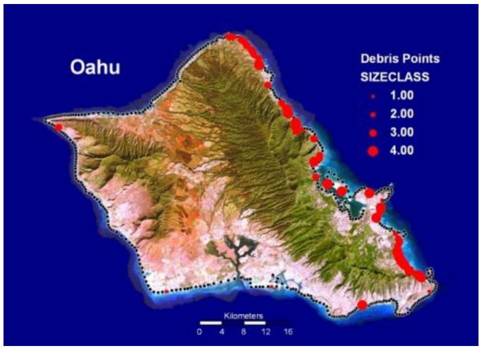

Alien Species Transport:
If a marine organism attaches to debris, it can travel hundreds of miles and land on a shoreline where it is non-native. In addition, un-attached species may use floating debris as shelter and make long distance ocean crossings. These non-native, potentially invasive species can have devastating impacts on fisheries and local ecosystems by out competing native species, and they may be costly to eradicate once established.


Vessel Damage and Navigation Hazards:
Marine debris can be quite large and difficult to see in the ocean, if it's floating at or below the water surface. Vessel encounters with marine debris at sea can result in costly damage, either to the vessel structure or through a tangled propeller or clogged intake.




Habitat Damage:
Marine debris can scour, break, smother, and otherwise damage important marine habitat, such as coral reefs. Beaches, which are essential nesting sites for seabirds, shorebirds, and turtles, are also

impacted by debris that washes up on shore. Many of these habitats serve as the foundation of important marine ecosystems and are critical to the survival of numerous other species.



Economic loss:
Marine debris is an eyesore along shorelines around the world. It degrades the beauty of the coastal environment and, in many cases, may cause economic loss if an area is a popular tourist destination. Would you want to swim at a beach littered in trash? Coastal communities may not have the resources to continually clean up debris.

Dispersion of Marine Debris:
The impacts of marine debris are felt far beyond the point where the debris enters the water. Differing physical characteristics of marine debris will determine how that debris is dispersed. Some marine debris remains localized close to the point it enters the water, but other buoyant debris can be transported long distances and will impact locations far from it source. PMNM is located in the **North Pacific Gyre** (Figure 1), a large area of the ocean bounded by circulating currents. Much of the marine debris found in PMNM is swept into the Monument by these swirling currents from sources far outside the Monument boarders.

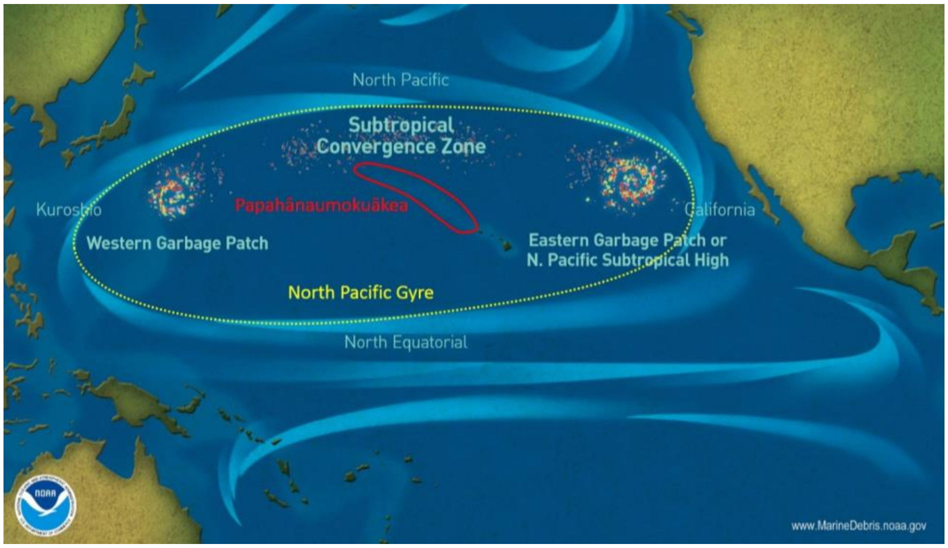


Figure 1. North Pacific Gyre

Preparation

Computer Programs

- If you will be doing the computer portions of this lesson plan, be sure there are sufficient computers with internet access and Google Earth/Map access for each student or group of students.
- Be familiar enough with Google Earth/Maps to be able to assist students.
- Ensure that you are able to access www.adrift.org.au from school computers.

Chemical mixing for plastic density sample testing

- Materials needed: tap water, isopropyl alcohol, and table salt.
- 70% and 91% isopropyl alcohol are the most commonly available formulations at most pharmacies or grocery stores.
- The tables below give amounts of salt and isopropyl alcohol needed to mix solutions for one group of students.

Table 1 (91% isopropyl alcohol)

Solution	ml of H_2O	ml of isopropyl alcohol (91%)	Grams of Salt	Density (g/mL)
A	50	0	17.5	1.35
B	50	0	5	1.1
C	50	0	0	1
D	37	13	0	0.945
E	30	20	0	0.915
F	21	29	0	0.876

Table 2 (70% isopropyl alcohol)

Solution	ml of H_2O	ml of isopropyl alcohol (70%)	Grams of Salt	Density (g/mL)
A	50	0	17.5	1.35
B	50	0	5	1.1
C	50	0	0	1
D	31	19	0	0.945
E	20	30	0	0.915
F	6	44	0	0.876

- When mixing the salt solutions, be sure that the salt completely dissolves.
- Should you care to change the density solutions to some other range of densities, the volume of alcohol needed for each density was determined from the following equations:

$$Vol_{alcohol} = \frac{(\rho_{total} * Vol_{total}) - (\rho_{water} * Vol_{total})}{\rho_{alcohol} - \rho_{water}}$$

The volume of water needed was calculated from:

$$Vol_{water} = Vol_{total} - Vol_{alcohol}$$

The density of the final solution will be:

$$\rho_{solution} = \frac{(Vol_{alcohol} * \rho_{alcohol}) + (Vol_{water} * \rho_{water})}{Vol_{total}}$$

For all these equations we assume these densities:

$$\rho_{water} = 1 \frac{g}{ml}$$
$$\rho_{alcohol\,(70\%)} = 0.858 \frac{g}{ml}$$
$$\rho_{alcohol\,(91\%)} = 0.786 \frac{g}{ml}$$

- The amount of salt needed to get salt solutions of known density is determined by:

$$\rho_{solution} = \frac{(Mass_{water} + Mass_{salt})}{Vol_{total}}$$

Learning Procedure

Engage: Part 1 – Size of a Monument

For this activity the students will need access to an atlas or computers with internet and mapping programs.

Read Part 1 of the Marine Debris Student Worksheet as a class.

Have the students work in pairs to calculate the size of Papahānaumokuākea and to find a land-based comparable distance.

Next ask groups of students to share what locations they discovered and the number or state/countries that this area covers. Follow this up with a discussion on the issues related to managing a region the size of Papahānaumokuākea.

Explore: Part 2 – Marine debris on the move

For classrooms that have access to computer and internet resources have students do the following modelling activity for themselves. For classrooms not equipped with student computer resources, the following activity can be done with projected simulations or by using the model results included in the accompanying PowerPoint. Note that the static image does not show the changing distribution of marine debris with time and so may not highlight possible source countries as well as the dynamic model run.

Have the students navigate to www.adrift.org.au and locate where Papahānaumokuākea would be on the map. Have students run simulations of the distribution patterns of plastic marine debris by clicking on any ocean area. Note, the simulations can be run both forward in time and backward in time (click on button "showing where plastics end up" to change). Both simulation methods should allow students to answer the subsequent questions on the worksheet.

The last question in this section of the student worksheet is an opportunity to reconnect students with how their own actions might contribute to the issue of marine debris. See the *Extending The Lesson* section at the end of this document for some additional ideas about how to engage students to local pollution issues.

Explore: Part 3 – Beach walk

For classrooms that have access to computer and internet resources have students do the following beach walk activity for themselves. For classrooms not equipped with student computer resources, the activity can be done using individual photographs from the accompanying PowerPoint.

The following page has links to each individual island in Papahānaumokuākea that has Google Street View imagery: (http://www.papahanaumokuakea.gov/news/google_streetview.html). Follow these links to look at the beaches of the Papahānaumokuākea in Google Street View and ask the students to explore and to see if they find any visible marine debris.

After some exploration time ask the students to focus on these locations on Lisianski (Papaāpoho) Island (26.056477, -173.961058), and Laysan Island (25.781036, -171.727775). In order to access these locations they should be able type the latitude/longitude coordinates into the Google Maps/Earth search bar and then zoom in until in Street View.

Once in Street View give them 10 minutes or so to identify as many pieces of marine debris as they can (there are milk crates, buoys, laundry baskets, bottles tires, etc) and to record these on their datasheets. They may need to move around while in Street View in order to identify different types of marine debris.

Once the students have a list of marine debris items, ask them to sort those according to the size classes listed in their worksheet and to indicate what materials they think each item is made of. Finally, when they are done recording data, have them answer the associated questions in their worksheet.

Explain: Part 4 – Characteristics of marine debris

After a few minutes to compare data from Part 3 between groups, have the students answer the questions about characteristics of marine debris. Discuss these answers as a class.

To help the students understand the scale of the problem in Papahānaumokuākea, you may want to show this short video about marine debris http://www.youtube.com/watch?v=wJo-DAcXtzo.

More information on marine debris clean ups in Papahānaumokuākea can be found at:
https://pifscblog.wordpress.com/2013/05/29/final-marine-debris-midway/

Elaborate: Part 5 – Float test

As the students investigated above, marine debris is a very significant problem in Papahānaumokuākea, and most other ocean environments and inland water ways. Some of the most persistent types of marine debris are made of pre- and post-consumer plastics. However, not all plastic that enters the marine environment will be dispersed over long distances. Which plastics persist in the marine environment depends on many things, including the type of plastic, what form the plastics take (are they pellet shaped, bottle shaped, etc.), how weathered the plastic is, and so on. The goal of this elaboration section is to investigate how plastic density affects plastics' ability to disperse in the marine environment.

Procedure:

1. Break students into groups. Groups of two to three are ideal.
2. Each group of students should have:
    a. 6 x 50 ml clear containers containing density solutions A thru F
    b. Tweezers
    c. Paper towels
    d. Gloves and goggles
    e. One worksheet per student.
3. Begin by stressing to all the students proper use of gloves and goggles for these investigations.
4. Give each student group two different types of plastic disks (so not all the groups have the same plastics to test).
5. Demonstrate how to test plastic disk in different density solutions. Plastic disks should be clean and dry. Use tweezers to hold plastic disks and avoid touching the disks with your fingers. Oils from your hands can change the apparent properties of the plastic. Using the tweezers place the disk into the density solutions close to the bottom of the container. Shake *gently* to dislodge any air bubbles. Release disk and wait until it stops

moving. Record the behavior of the plastic disk. Does it float, sink or is it neutrally buoyant?

6. Be very careful to stress that they should NOT mix the solutions and that they are careful to clean and dry the pieces of plastic between testing in each solution.
7. Ask the students to test their plastic disks in the different solutions and to record their data on their worksheets. They should do three replicates of each type of plastic.
8. Have each group contribute to a group graph on the board. By the time all groups are finished, all the different plastic types (recycle codes) should be represented on the board.

Give students time either in class or as homework to complete the elaboration questions.

Evaluate: Part 6 – Marine debris life cycle

Have the students create a life-cycle model for a piece of marine-debris that they found in Papahānaumokuākea. This could be either a written or creative assignment depending on needs, time and resources. Questions that the students should address with their life cycle model include: Where did the object enter the environment? How was the object transported to Papahānaumokuākea? What processes impacted the object during its travels? What are potential impacts of that marine debris to the environment? How was the object removed from the marine environment? What is the likely fate of this marine debris? What potential impact could this marine debris have on me? What potential impact can I have on marine debris?

Closing

This may seem like an overwhelming problem, but there are things you can do in your local community to help. Talk to your students about the concepts of reduce, reuse, and recycle. It is much easier to prevent plastic from going in the ocean in the first place than to clean it up later.

Extending the Lesson

- Participate in a beach or park clean-up near your community
- Reuse is a particularly important method of limiting our trash generation. One way to empower students to take action might be to have them keep a log for a week of the things that can be reused that they ordinarily throw away. This is a great discussion and brainstorming tool, as well as an opportunity for peer support around forming low-impact habits.
- Plastic is not the only pollution that ends up in the ocean, have a conversation with your students about chemical run-off, increased CO_2, and other materials that also end up in the ocean.
- Check out some of the other education materials from NOAA's marine debris program. http://marinedebris.noaa.gov/educational-materials

Connections to Other Subjects

- Chemistry
- Ecology
- Biology
- Technology

Related Links

Adrift
NOAA Marine Debris Program
NOAA Marine National Monument Program
NOAA Fisheries Pacific Islands Regional Office
Papahānaumokuākea Marine National Monument

For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
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Acknowledgement

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Education Standards

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