Office of National Marine Sanctuaries
National Oceanic and Atmospheric Administration
in collaboration with Oikonos Ecosystem Knowledge

Education

WINGED AMBASSADORS

OCEAN LITERACY THROUGH THE EYES OF ALBATROSS

Lesson 4: Bolus Analysis

Grade Level

- 6-8, with options for 9-12

Timeframe

- Two 45-minute class periods

Materials

- Student worksheets
- Color printouts of bolus photographs OR ability for students to work at computer screens or with projections of the photographs
- Lesson 2 Presentation

Key Words

- Bolus
- Gyre
- Marine debris
- Plastic pollution

Activity Summary

Prior to leaving the nest, albatross chicks regurgitate a mass of indigestible material called a bolus. Boluses give us clues as to the types of food and trash eaten by albatross parents at sea. In this lesson, students will use professional photographs of boluses, donated by David Liittschwager, to perform a "virtual dissection" and analysis. They will compare the amounts of prey and non-prey items found in several boluses. They will consider the sources of these non-prey materials and create a model of a bolus, with which they can educate others.

Learning Objectives

Students will be able to:

- Explain that prior to fledging, albatross chicks regurgitate a mass of indigestible material called a bolus.
- This bolus provides a record of the items ingested by chicks.
- Note that nearly all albatross boluses include plastics.
- Calculate the percentage of prey and non-prey items found in boluses.
- Define the term "marine debris" and indicate its sources.
- Create a model of a bolus.

Outline

Engage – Albatross Chicks
Explore – Albatross Boluses
Explain – Class Data Comparisons
Elaborate – Marine Debris
Evaluate – Model Albatross Boluses

Background Information

Raising a chick is a very energy-intensive process for seabird parents. Adult albatross meet on breeding islands in the Northwestern Hawaiian Islands in late summer and fall. During that time, they engage in elaborate mating dances, and then they mate and produce an egg. Albatross pairs often mate for life. In a simple nest on the ground, the parents take turns incubating the egg for about two months, until the chick hatches. The chick remains on or near the nest for five to six months, depending on its parents to provide food from the ocean. The parents have been tracked flying thousands of miles in a matter of days to forage in productive ocean waters for food items like squid, fish eggs, and small fish near the sea surface. The parents produce energy-rich oil from their food, which they deliver in their stomach and regurgitate into the mouth of their chick back at the nest.

Back at the nest, chicks go from fluffy, soft plumage to more adult-like waterproof feathers. When the wind blows, they extend their long wings to exercise their breast muscles. By early summer, they are ready to go to sea for the first time, where they will remain for at least four years before returning to the colony to begin forming pair bonds. In preparation for leaving the nest (called fledging), chicks regurgitate a mass of undigested material collected in their stomach called a **bolus**. Boluses provide a record of the items ingested by the chick, including squid beaks, pumice, and fish bones that came from parents' foraging trips at sea.

Other animals have also evolved similar mechanisms to remove indigestible items from their stomachs. Owl pellets and cat fur balls are familiar examples. Unfortunately, nearly all boluses from Hawaiian albatrosses also include human-made trash such as fishing line and plastics. These floating items concentrate alongside albatross food items, and are scooped up and unintentionally fed to the chicks.

Ingesting trash can harm animals. In particular, scientists are beginning to learn more about how eating plastic can prevent healthy digestion, cause dehydration and increase pollutants in the animal's body. Seabird boluses are dissected to learn what they are eating and to study if the amount of plastic trash is increasing in the ocean. For this reason, albatross and other seabirds are ideal sentinels or bio-indicators of the health of the ocean because they travel across the ocean and sample marine debris along their journeys. By tracking their movements and dissecting their boluses, scientists are learning about albatross plastic ingestion.

What is a Gyre?

The albatross your students are studying inhabit the North Pacific. Their movements and foraging behavior are greatly influenced by the patterns of wind and water in this ocean basin. For example, large circular systems of ocean currents, called **gyres**, are the result of the wind's push on the surface of the ocean. The wind transports the water (and anything else floating on it or drifting in it) around the ocean, following a circular path.

Vocabulary

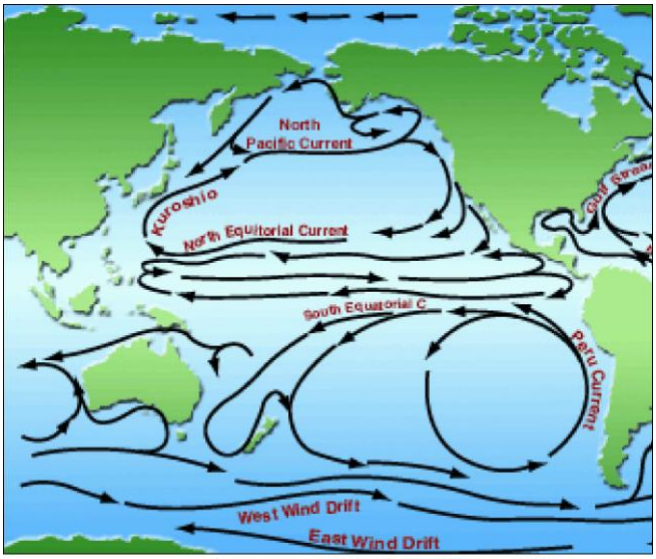
FLEDGLING – chick just about to leave (fledge) the nest

BOLUS – a mass of undigested material regurgitated by an albatross chick

MARINE DEBRIS – any persistent and solid material or item created by people and released (intentionally or unintentionally) into an ocean or large lake

CURRENTS – large masses of continuously moving ocean water (e.g., the California Current)

GYRE – a ring-like system of surface ocean currents driven by the wind. When water that is being pushed by the wind encounters a continent, the water flow turns to follow the coastline. This way, water travels around the gyre



Courtesy of Office of Naval Research

Figure of Surface Ocean Currents showing the major Pacific Ocean currents and gyres.

Misconception Note

This map is an *oversimplification* of the *average* ocean currents. There are numerous factors that affect the location, size, and strength of all of these features seasonally and annually. Depicting the dynamic nature of currents on a static map is very difficult.

As you can imagine, marine debris that enters the ocean will be carried by different surface ocean currents, depending on its origin. Scientists use computer models and wind data to predict where floating things (marine debris, floating fish eggs) will be transported by surface ocean currents. One example of a widely-used ocean current model is OSCURS (http://las.pfeg.noaa.gov/oscurs/).

When you and your students study the albatross boluses, you will also observe the movements of individual birds tracked by satellite. Think of the gyres pushing the sea surface (and floating plastics) along with their flow. Also, think about whether albatross routes seem to follow these ocean currents.

Preparation

- Color bolus photographs may be printed (four 8x11 pages per bolus), viewed on computer screens, or projected on a white board or wall paper. Each group of 2-4 students will need at least one photograph to analyze. Ideally, each group will compare one bolus from each species (Black-footed and Laysan albatross).
- If possible review background information on seabirds, and in particular albatross, from Lesson 1.

Learning Procedure

Engage (10 minutes)

Show students the Engage slides and videos.

Discuss what students are seeing, using the following discussion questions:

? Why do you think albatross adults perform a dance?

Accept all answers. Scientists believe that this courtship display is an important part of pair bonding.

? Why might albatross chicks regurgitate a bolus?

Accept all answers. Answers may include—to get rid of indigestible material, to prevent being weighed down as chicks fledge, etc.

Distribute student worksheets and direct students to read the first few paragraphs in the Engage section.

After students read the paragraphs, ask:

? What do you think you might find in a bolus?
Accept all answers as students may have no idea at this point. Possible answers may include:
- *Fish bones*
- *Stones*
- *Plastic*

? Scientists often collect and analyze boluses to examine their contents. Why do you think they do that?
Accept all answers. Possible answers may include:
- *To learn about the diet of albatross*
- *To find out what chicks are regurgitating prior to fledging*

? How might a stomach full of indigestible hard parts affect an animal? Or you?
Large amounts might cause dehydration, take up room for food, cut the stomach

Extension

Show the 5 minute video '360 Punches' of an albatross stomach being dissected on Kure Atoll (video provided for download or online viewing).

Explore

(35 minutes)

Explain to students that they are going to have the opportunity to analyze the contents of boluses through detailed photographs.

Show students the bolus photographs from the presentation and ask them to describe what they see. Note to students that the black, hook-shaped items are squid beaks. Squid use their beaks to break up prey much like teeth. These are not digestible, and therefore are a normal finding in a bolus.

Show students the close-up photograph of the squid beak. They should record a description on their worksheet.

Explain that students will be comparing the number of prey and non-prey items found in boluses.

Divide students into groups of about three. Create heterogeneous groupings if possible.

Provide each group with 1-2 bolus photographs. Make the photographs available to students by printing them out (four 8 x 11 pages taped together make up one bolus), showing them on class computers, or projecting them on wall paper.

See Student Worksheet (Explore)

Each group will fill in the data table for their bolus(es) and calculate the percentage of prey and non-prey items. Adapt the table as needed for your class. To complete the squid beak count in less time, section the bolus into quadrats or have students draw a grid over the image with a ruler. Plastic line cannot be counted so suggest students note presence or absence and if time allows create a method of measuring size. They will also describe any specific items that they can identify.

Students will then answer the worksheet questions.

Differentiation:
1. Have advanced students devise other ways of categorizing the non-prey items (e.g., by color, by size). They should create and complete a new data table. Ask these students to share their findings during the class discussion in the Explain section.
2. Advanced students might also calculate the approximate surface area of the different types of materials found in the boluses and relate that to how the trash would have displaced space (filled up) inside the chick's stomach.

Explain (25 minutes)

Create a class table on the board and ask each group to add their data.

See Student Worksheet (Explain)

Direct students to calculate a class average of prey vs. non-prey items, and to complete the questions.

Discuss the answers to the worksheet questions as a class. Be sure to have student groups share items they identified.

Ask students:

? What were the most common non-prey items that you observed?
Plastic pieces and fishing line.

? Where are the chicks getting the plastics and fishing line?
The adult birds are picking up these items at sea, along with food. Albatross do not eat on land or the beach.

? Where are these items coming from?
Some plastics come from ships, but most are land-based and enter the ocean through drain pipes, rivers, and bays.

? Who is responsible for this pollution?
We all are!

? Are you surprised by the amount of plastic found in the boluses?
Allow students to share their ideas.

Discuss the presence of plastic line with students.

? Where does this line come from?
From humans—the line we see in boluses is mostly frayed and broken down fishing nets and ropes.

Explain to students that the nets and line may have been lost by accident, or intentionally released, e.g., when tangled or unusable.

Extension

Describe any obvious differences between Kure Atoll and Tern Island chick boluses. See four "advanced slides" presenting researcher results from the same boluses the students analyzed. Also look at the foraging tracks from both islands (available in Lesson 2).

Elaborate (20 minutes)

Ask students whether they have ever heard of the "garbage patches" in the Pacific Ocean and other ocean basins. Explain that there are misconceptions about the garbage patches, and that you will clarify this information for them.

Using the presentation, introduce students to the idea of ocean gyres, the term marine debris and garbage concentrations at sea. Use this presentation to clarify these concepts.

On the map, assist students in identifying features, e.g., Alaska and Baja California, in order to better understand the geography of what they are observing.

Ask students what they think are the sources of marine debris. Be aware that many students don't make the connection that most debris comes from land. If you will be doing the next lesson, explain that the class will be looking at litter on their school campus.

Show students the slide of satellite tracks of albatross movements, and ocean winds that create the large gyre systems in the North Pacific and the world.

Discuss:

? Do you know other animals that naturally throw up things they can't digest?
Examples include owl pellets, cat fur balls.

? Why don't humans produce boluses?
Our digestive systems are different from albatross. We do a good job of "passing" indigestible material. We usually do not put indigestible items such as large bones and seeds in our mouths.

On average, chicks are fed 25 grams of plastic in the 4 months before they fledge (on Kure Atoll, Oikonos-HPU data). If scaled to the size of a high school senior, that is the equivalent of 150 bottle caps inside your stomach – see Lesson 5 for activity.

Adult albatross also have the ability to regurgitate and may throw up undigested material at sea, where they spend the great majority of their time. At sea, however, this behavior is nearly impossible to observe.

? What if you ate plastic but couldn't throw it up or pass it?
Our systems might become very full of plastic, impeding our abilities to process real nutrients.

? How does this idea relate to seabirds?
Some bird species have no way (no adaptation) of getting rid of plastic in their systems. Therefore, the debris can interfere with their nutrition and digestion.

Extension

Plastics are known to contain and absorb toxic chemicals, threatening organisms that ingest them. Use the *Ecotoxicology of Marine Debris* lesson at http://www.oikonos.org/education to investigate potential toxicity of ingesting plastic.

Misconception Note

When people hear the term "garbage patch," they often picture large mats of floating plastic atop the ocean. While once popular in the media, this term is no longer encouraged to help change this misconception. Concentrations of garbage (microscopic plastics to large plastics) can be found on the ocean surface as well as in deeper waters. Concentrations of plastic are being found in mid depth waters where fish are ingesting it and on the ocean floor. Where wind and currents concentrate marine animals and plants, you will also find concentrations of human garbage.

See Student Worksheets (Elaborate)

Direct students to work with a partner to answer the questions about marine debris patches. Then, discuss their answers as a class.

Next, discuss the scale of the problem and the size of the ocean basins. As a class, determine that the best way to address the issue of marine debris is through *prevention* because clean up is so difficult. Discuss the value of cooperation, *laulima*, in protecting our ocean. This idea is the focus of the next lesson.

Extension

Students can practice graphing their results with Excel using the file Bolus Analysis.xls:
http://www.oikonos.org/education

Learn the route of trash in the ocean using this online model based on real wind and current data: OSCURS:
https://www.pfeg.noaa.gov/products/las.html

Show students videos about marine debris such as the one at this link:
http://marinedebris.noaa.gov/outreach/video.html

Evaluate (Homework)

See Student Worksheets (Evaluate)

For homework, assign the Evaluate task. Students can then display their boluses and placards around the classroom.

Resources

- More information about Ocean Currents: http://oceanservice.noaa.gov/education/lessons/ocean_motion.html
- Ocean Pollution video: http://www.montereyinstitute.org/noaa/lesson13.html
- Plastic Pollution: https://www.montereybayaquarium.org/conservation-and-science/our-priorities/ocean-plastic-pollution

Credits and More Information

These lessons were developed for NOAA's Cordell Bank National Marine Sanctuary and Papahānaumokuākea Marine National Monument, by Meghan Marrero of Mercy College and Oikonos - Ecosystem Knowledge. This lesson cannot be used for commercial purposes. Permission is hereby granted for the reproduction, without alteration, of this lesson for educational use only on the condition its source is acknowledged. When reproducing this lesson, please cite NOAA's Office of National Marine Sanctuaries and Oikonos - Ecosystem Knowledge as the source, and provide the websites below.

Data integrated into these lessons were provided courtesy of Michelle Hester (Oikonos), David Hyrenbach (Hawai'i Pacific University), Josh Adams (USGS), and David Anderson (Wake Forest University). Data from Tern Island, Kure Atoll and Cordell Bank were obtained in partnership with USFWS, State of Hawaii, and Cordell Bank NMS.

Special contributions of paintings and photography donated by Sophie Webb and high resolution images of albatross bolus contents donated by David Liittschwager.

Content created and reviewed by Meghan Marrero, David Hyrenbach, Michelle Hester, Carol Keiper, Jennifer Stock, and Andy Collins. Tracking and bathymetry maps were created by Pam Michael (Oikonos).

Graphics and design by NOAA, Tara Alvarez, and Greg Hester. We thank the many people who donated photographs, illustrations and video.

Some content was adapted from Oikonos' Albatross and Plastic Pollution Activities for the California Coastal Commission Science Activity Guide: Waves, Wetlands, and Watersheds.

We appreciate feedback, corrections and questions. Please email WingedAmbassadors@oikonos.org

Free lessons and resources available at:

http://cordellbank.noaa/gov/education/teachers.html

http://oikonos.org/education

http://papahanaumokuakea.gov/education/wa.html

Education Standards

National Education Standards	NSES Grades 6-8: • Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models. • Mathematics is important in all aspects of scientific inquiry. • Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances. • Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identifying faulty reasoning, pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. • Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations. • Living systems at all levels of organization demonstrate the complementary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems. • Behavior is one kind of response an organism can make to an internal or environmental stimulus. A behavioral response requires coordination and communication at many levels, including cells, organ systems, and whole organisms. Behavioral response is a set of actions determined in part by heredity and in part from experience. • An organism's behavior evolves through adaptation to its environment. How a species moves, obtains food, reproduces, and responds to danger are based in the species' evolutionary history. • Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water, and air. • Causes of environmental degradation and resource depletion vary from region to region and from country to country. • Human activities also can induce hazards through resource acquisition, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
Ocean Literacy Principles	• 1g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean. • 1h. Although the ocean is large, it is finite and resources are limited. • 6b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security. • 6c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures. • 6d. Much of the world's population lives in coastal areas. • 6e. 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 • (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean. • 7f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.
California	Grade 5: • Life Science 2c: Students know the sequential steps of digestion and the roles of teeth and the mouth, esophagus, stomach, small intestine, large intestine, and colon in the function of the digestive system. • Earth Science3a: Students know most of Earth's water is present as salt water in the oceans, which cover most of Earth's surface. • Investigation and Experimentation 6b: Develop a testable question. Investigation and Experimentation 6g: Record data by using appropriate graphic representations (including charts, graphs, and labeled diagrams) and make inferences based on those data. • Investigation and Experimentation 6h: Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion.

Education Standards (continued)

California (continued)	Grade 6: • Investigation and Experimentation 7b: Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data. Investigation and Experimentation 7d: Communicate the steps and results from an investigation in written reports and oral presentations. • Investigation and Experimentation 7e: Recognize whether evidence is consistent with a proposed explanation. Grade 7: • Life Science 2b: Students know the differences between the life cycles and reproduction methods of sexual and asexual organisms. • Life Science 5b: Students know organ systems function because of the contributions of individual organs, tissues, and cells. The failure of any part can affect the entire s • Investigation and Experimentation 7 a: Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data. • Investigation and Experimentation 7b: Use a variety of print and electronic resources (including the World Wide Web) to collect information and evidence as part of a research project. Grade 8: • Investigation and Experimentation 9c: Evaluate the accuracy and reproducibility of data.
Hawai‘i	Grades 6-8: Inquiry: • Develop questions and hypotheses that can be answered through scientific investigations. • Design and conduct scientific investigations to answer questions or to test hypotheses. • Collect, organize, analyze and display data/information, using tools, equipment, and techniques that will help in data collection, analysis, and interpretation. • Develop conclusions and explanations showing the relationship between evidence and results drawn. • Communicate and defend scientific procedure used and conclusion and explanation drawn from evidence. • Reflect and revise conclusion and explanation based on new evidence given from other valid points of view. Values: • Distinguish between facts and speculations/inferences. • Evaluate all evidence that support or contradict the hypothesis. • Ask questions to understand the multiple perspectives and interpretations of a problem, situation, or solution. • Ask questions and explain findings and answers scientifically. Safety: • Apply school, classroom, laboratory, and field trip rules, as appropriate, to maintain a safe learning environment. • Identify potentially unsafe conditions prior to the activity and explain how accidents can be prevented. Nature of Inquiry: • Identify good scientific explanations and justify their soundness based on evidence, logical and consistent arguments, and use of scientific principles, models, or theories. • Give examples where scientists used mathematics and technology to gather, quantify, and analyze results of an investigation. • Give examples of how science advances through legitimate questioning. • Describe and exemplify the nature of scientific explanations. Unity and Diversity: • Compare and contrast the body structures of organisms that contribute to their ability to survive and reproduce.