To-do list:

- [x] ~~Select platform to upload CT data and derivatives: MorphoSource~~
- [ ] Check with Jaimi if the megalodon coprolite is uploaded somewhere (MorphoSource); also check what other coprolite CT data she has and what the content looks like (are there at least a few things that are identifiable?)
- [ ] Upload CT data (and derivatives) to publicly accessible platform (1 is already on MorphoSource; 3 more being uploaded)
- [ ] Create separate teacher guide & student worksheet docs
- [ ] List science education standards
- [ ] Dichotomous key for high school only; pictures of pellet contents for middle school students (Jamie's worksheet diagrams)

Lesson Plan: Owl Pellet Dissection (& Fossilized Poop)

The activities related to physical owl pellets are largely taken from California Academy of Sciences: https://www.calacademy.org/educators/lesson-plans/owl-pellet-dissection. Red text or track changes indicate additions and edits by NoCTURN.

Grade Level: Grade 6 – 12

Lesson Plan Length: 50-80 minutes

Science Education Standards: See last section.

Learning Objectives:

After going through these exercises, the students should be able to:

1. analyze and interpret data they have collected from an owl pellet dissection to answer a question.
2. use a dichotomous key to identify bones of prey species found in an owl pellet.
3. use data from modern imaging modality (CT scan) to compare and contrast with what can be observed from the physical specimen

Materials:

- owl pellets (1 per student or per pair)
    - Many pellets that are sold for student use have been heat sterilized to kill bacteria, making them safe to handle with bare hands. Even so, students should wash their hands with soap and clean their work area thoroughly after the dissection and wear gloves. Pellets should not be dissected in areas where food is prepared or consumed.
- tweezers (1 per student)
- hand lens (1 per student)

- napkin or paper towel (1 per student)
- (optional) editable Powerpoint Deck with imagery
- Dichotomous Keys of Barn Owl Prey
    - There are two versions of the key: a visual, branching version and a text version. Use whichever version you feel your students will be more comfortable with.
- What Do Owls Eat? worksheet (1 per student)
- Owl Pellet Dissection Procedure worksheet (1 per student)
- Owl Pellet Lab Notebook

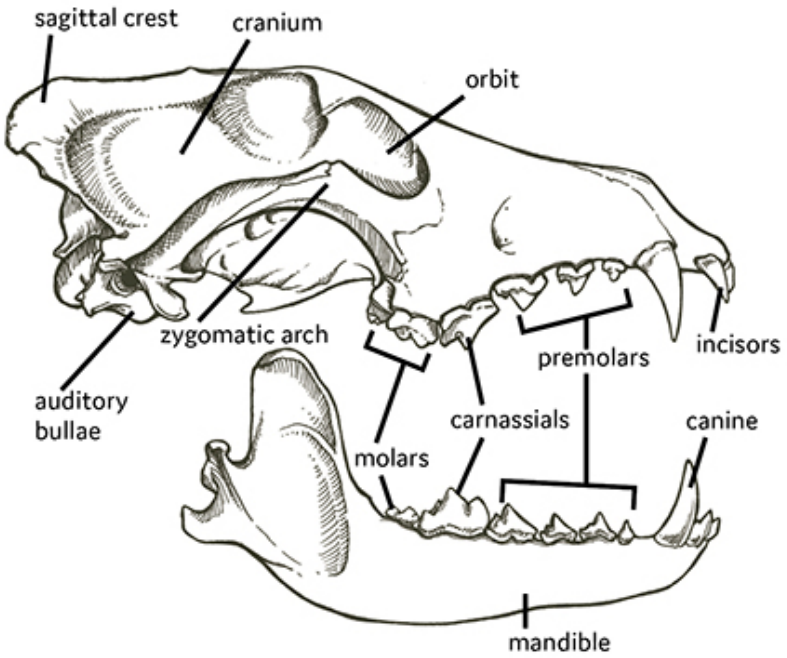
CT Module

- Computer for each or group of students (2–4 students)
- (optional) editable Powerpoint explaining CT imaging
- 3D model of an owl pellet (provided by NoCTURN) [insert link]
- 3D models of coprolites (fossilized droppings) (provided by NoCTURN) [insert link]
- Downloadable scans of owl pellets (optional for later grade levels?)

Optional materials to create a miniature collections tray for one's findings:

- large petri dish (1 per student)
- cotton balls (2-3 per student)
- Sharpie for labeling petri dishes
- scotch tape

Scientific Terms for Students



Picture: Skull of a mammal.

Important Structures for Identification

- **canines:** the long, pointed teeth next to the incisors; general used for piercing and tearing
- **incisors**: the front-most teeth in the jaw; generally used for nibbling
- **molars:** the backmost teeth in the jaw; generally used by humans or rodents for grinding, or for crushing by insectivores.
- **premolars:** the teeth located between the canines and molars
- **root:** the part of the tooth that is anchored in the jaw bone
- **cranium:** the part of the skull that surrounds and protects the brain
- **diastema:** the large space between the incisors and molars; found only in herbivores
- **mandible:** the lower jaw
- **skull:** the structure that includes both the cranium and the mandible together
- **dichotomous key:** a tool to help one identify things in the natural world – such as trees, wildflowers, and mammals – by a series of choices between two items. Pronounced “dye-KAH-tah-mus.”

Educator Prep

1. Make one copy of the What Do Owls Eat? and Owl Dissection Procedure worksheets for each student.
2. Gather materials and set up students’ workstations with materials for the dissection.
3. Decide which dissection procedure you would like students to perform. There are two procedures that can be used to dissect an owl pellet; dry or wet dissection:

Dry dissection

1. Unwrap the foil from the owl pellet.
2. Gently pull the pellet into two halves.
3. Use tweezers to pull apart the soft material surrounding the skull and bones.
4. Place bones into a separate pile.
5. Discard the fur and other soft material.

Wet dissection

1. Unwrap the foil from the owl pellet.
2. Place the owl pellet in a petri dish filled with water. Soak the pellet for 10 minutes.
3. Leave your pellet in the dish and gently pull the pellet into two halves.
4. Use tweezers to pull apart the soft material surrounding the skull and bones. You can soak larger bones in the petri dish to help loosen the material that is packed around the bones.
5. Place bones into a separate pile.
6. Discard the fur and other soft material.
7. Discard water and Petri dish.

Procedure

Part 1: I notice, I wonder…

1. Pass out owl pellets to each student or pair of students.

2. Before starting their dissection, have students spend 2-5 minutes observing their pellet without touching it. During this time, students should use the sentence starters, “I notice, I wonder” on the Owl Pellets Dissection worksheet to help stimulate observations and questions. Wait until students can identify at least one observation they notice or count the total number of items in the pellet.

NGSS Connection: This portion of the lesson connects to the Practice of Asking Questions because students generate their own questions about owl pellets through firsthand observations using the “I notice, I wonder” sentence starters. Questions that are generated from student’s firsthand observations help them to develop their own ideas and explanations for phenomena in the natural world. Students’ questions can be recorded on the Owl Pellets Dissection worksheet. Students can also select one of their questions to try and answer throughout the course of their dissection.

3. Once students have recorded their “I notice, I wonder” observations and questions on the Owl Pellets Dissection worksheet, introduce students to the concept of owl pellets and go over how owl pellets are formed.

Educator Tip: Be sure to address the misconception that owl pellets are poop. Owl pellets are regurgitated material that cannot be digested.

4. Discuss basic information about barn owls. Explain that barn owls hunt in open areas like fields and eat a variety of small animals, depending on what they can catch. You may download and edit this Powerpoint deck, if you'd like.

5. Go over the common prey species of barn owls in the Pacific Northwest and Northern California.

6. Explain that examining the contents of a pellet provides a good record of what the owl has eaten recently. Tell students that they will be collecting data and using a dichotomous key to determine the prey species that are found in the owl pellets.

Part 2: Dissection

1. Inform students that they will first dissect their owl pellets, and then they will use a dichotomous key to identify the bones of the prey species found in the pellet.

2. Go over the steps of the dissection procedure, following the steps outlined in the Owl Pellets Dissection worksheet. Make sure students understand what they will be doing at each point.

3. Inform students that these pellets have been heat-treated to sterilize them. However, to be on the safe side, they will have to wash their hands and clean their work area after the dissection. They should not eat, drink, or put their hands in their mouths during the activity.

4. Give students 30 to 45 minutes to dissect their owl pellets, either in partners or individually. Check the “Bone Sorting Guide” linked above to show what students should be looking for. For now, students should focus on carefully dissecting individual objects in the pellets. If the students are dissecting at a good pace, then you can encourage the students to think about what animal they can identify without relying on a dichotomous key for now.

Educator Tip: Student’s excitement over the first bones that are uncovered can lead to distraction from the dissection. Encourage students to stay organized, follow the procedure, and keep careful track of what they find.

5. Circulate throughout the classroom to answer questions and help with the dissection.

Educator Tip: During the time that students are dissecting their owl pellets, you can draw the class data table and “Percentage of Prey Species Found in Owl Pellets” graph from the What do owls eat? worksheet on the board.

Part 3: Dichotomous key

1. Tell students that they have collected the data of what owls eat by dissecting their owl pellets; now they need to analyze their data. To do this, students will need to identify the skulls of the prey species in their owl pellets using a dichotomous key.

2. Go over what a dichotomous key is (a tool to help one identify things in the natural world – such as trees, wildflowers, and mammals – by a series of choices between two items). The key works through a series of questions, each with two possible answers. Each answer leads to a new question until the identification is reached.

3. Before handing out the dichotomous key, go over the vocabulary that students will encounter in the key related to identifying the skulls (e.g.; skull, cranium, mandible, diastema, molar, incisor, canine, and root).

4. For each skull that the students find, have them use the dichotomous key to identify it. Explain that each student should record the total number of skulls of each prey species they find on their What do owls eat? worksheet.

5. Tell students to start at STEP 1 on the key.

6. Once each student has identified and counted the total number of each prey species found in their pellet, compile a class data set. Have students come up to the board and put tally marks in the box next to the prey specie(s) that they found inside their pellet.

7. Calculate the fraction and percentage of barn owl diet for each prey species. A bar graph displaying these percentages can be filled in on the What do owls eat? worksheet.

8. Based on the class data, have students answer the question, “Which prey species was eaten the most by the owls?”

NGSS Connection: This portion of the lesson connects to the Practice of Analyzing and Interpreting Data because students must draw conclusions from their analysis of the data table and bar graph to determine which of the prey species was eaten the most by the owls. Based on their calculations of fractions and percentages, students should be able to determine the answer to the scientific question, “Which prey species was eaten the most by the owls?”

9. Engage students in a class discussion about the data table and bar graph. Ask students if they notice any patterns in the data. Ask students to make a prediction, based on the pattern that they see in the data, which prey species might be the most common in the owl’s environment.

   Additional Activity: Looking at the Bone-Sorting Guide, have students record the bone types included in their pellet: skull, mandible, sternum, humerus, scapula, pelvis, femur, fibula/tibia, radius/ulna. Use a similar worksheet as “What Do Owls Eat” exercise, but with bone types.

NGSS Connection: This portion of the lesson connects to the Crosscutting Concept of Patterns because students are asked to identify patterns in the data to make a prediction about the owl’s environment. For example, if your class data shows that 90% of the prey species found in the owl pellets were voles, then you can predict that voles were the most abundant prey species in the environment.

Part 4: Display owl pellet bones in a petri dish (optional)

1. Instruct students to write their names on the lid of the Petri dish with a Sharpie. This container will store the skulls and bones from their owl pellet.

2. Have students spread out a layer of cotton ball padding on the bottom of the petri dish and place the clean skulls and bones from their pellet onto this soft layer.

3. Close the lid of the Petri dish and tape it closed with Scotch tape.

Part 5. Using CT scans to digitally dissect an owl pellet

NOCTURN
Non-Clinical Tomography Users Research Network

1. Go to the website where the owl pellet model and CT image stack could be visualized and manipulated (insert URL)

2. Familiarize yourself with the tools to remove materials at certain density thresholds .
    a. Rotate the object [include directions: which button to press on a mouse vs. just trackpad/keyboard]
    b. Zoom in and out [include directions: which button to press]
    c. Pan, center [include directions: which button to press]

3. Ask the students: what does altering the threshold do? What are the materials that show up and disappear first and last?

4. Go over basics of CT scanner (density based imaging)

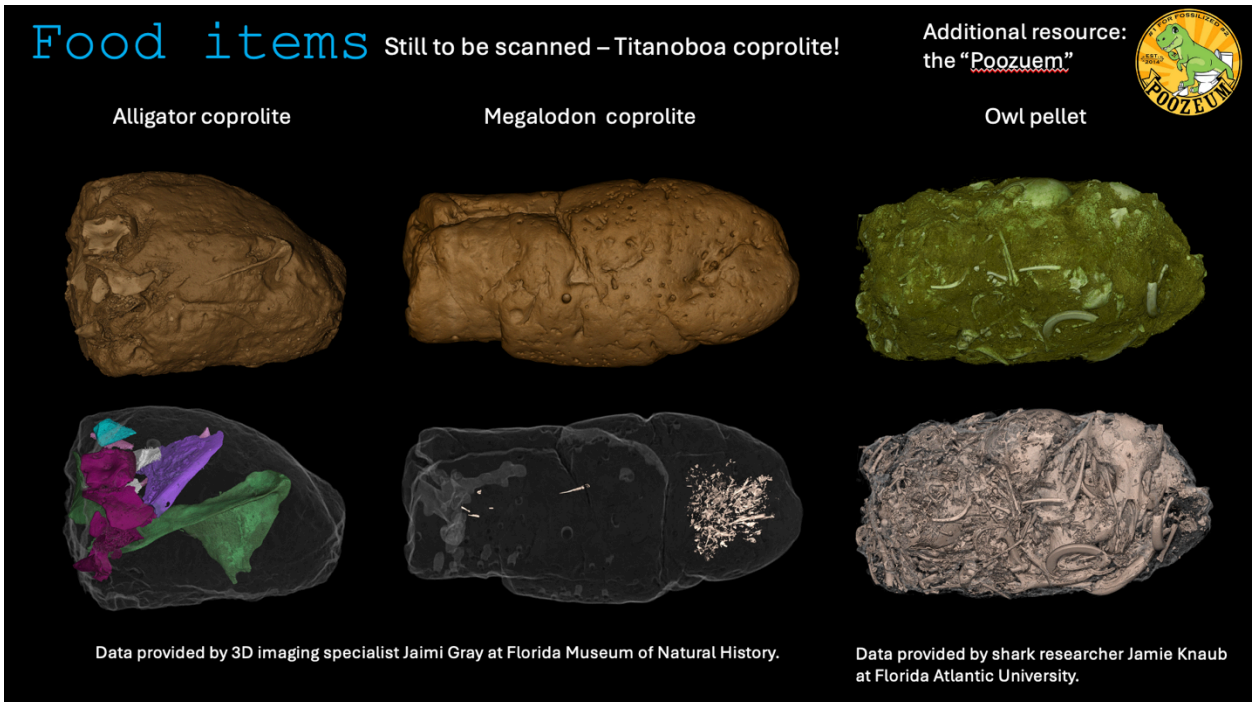
    [Include YouTube video or other existing resources here]

5. Use the same dichotomous key on the CT data of the owl pellet.

6. Compare and contrast what objects you found in the owl pellet

    [create a 2-column checklist for physical vs. CT owl pellets]

7. Go over what is the advantage of using the CT data over the physical pellet? Any disadvantages?

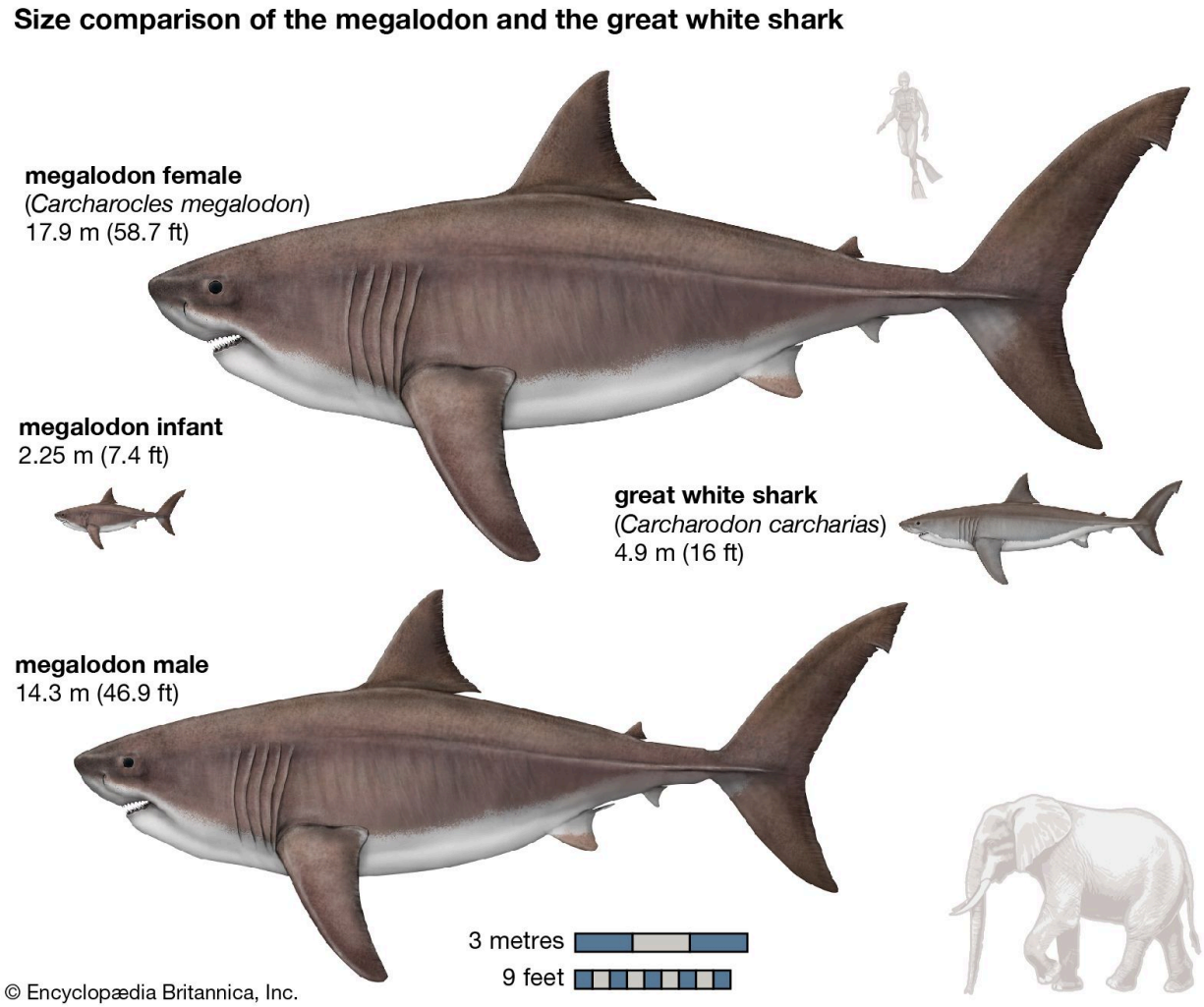


Slide by Jaimi Gray

Part 6. Identifying prey species in fossilized feces [UNDER CONSTRUCTION]

1. Explain that coprolites are fossilized poop. Like owl pellets, you can use what's in coprolites to discover what that animal ate. With coprolites, you can reveal what animals from millions of years ago ate.

2. We will be going over a CT scan of a coprolite thought to be from *Megalodon*, a giant shark that lived in the oceans 3–23 million years ago.



3. Open the CT scan data of Megalodon coprolite [insert link to the model]

4. List of everything you can find in the CT pellet data for students to match with what they're seeing in the 3D model, maybe also pictures.

Wrap-Up

Discuss with the students:

1. Did each student find the same prey species in their pellet? Why or why not?

   Owls eat a mixed diet depending on what is available, so different owls will probably have eaten different things.

2. What is a dichotomous key? How does it help you learn more about organisms?

   A dichotomous key is a tool that helps you identify things in the natural world – such as trees, wildflowers, and mammals – by a series of choices between two items.

CT-related questions:

3. Why are we able to see bones really well in the CT data of the pellet? Why wouldn't you be able to see hair very well?

   What you can see with CT scans depend on the density of objects, where denser objects appear brighter and more clearly. Bones and teeth are the densest tissues in an animal's body, so these structures show up really well in CT scans. You don't see hair well because they are made from keratin, which is less dense than bone so they tend to blend in with the density of the pellet themselves. Also, hairs are thin, which make them tricky to see too.

> What are the advantages of using CT data over physical specimens? And vice versa?

   The advantage of using CT data is to be able to see structures in greater detail, by being able to zoom in very close to structures. Also, it allows you to see the inside of the pellet and coprolites without dissecting and damaging them apart. Physical specimens are important because they allow you to start discovering their contents rather than having to wait to schedule and work on the scan.

Extensions

1. Ask students to select one of their favorite questions from their "I wonder…" list on the Owl Pellets Dissection worksheet to investigate.

2. Instruct students to spend a couple minutes looking closely at the shape and size of the prey species' teeth in their petri dishes. Ask students to compare the teeth of the different species (e.g.; a vole's teeth compared to a shrew's). Ask if their teeth look the same or different. Ask students to predict what each animal eats, based on what their teeth look like.

NGSS Connection: This portion of the lesson connects to the Crosscutting Concept of Structure and Function because students are asked to observe the shape and size of the prey species' teeth and think about how that is related to their function. For instance, the skulls of rodents, such as mice and voles, have front teeth that grow continuously. These front teeth help them to nibble the leafy vegetation that they eat. Moles and shrews will have differently shaped teeth because they have a different diet.

3. Challenge students to design their own dichotomous key to classify everyday items. Items that could be classified include student's shoes or different types of candy. The beginning of a candy dichotomous key for classifying types of candy might look like this:

START

1. Candy is chocolate. Go to 2.
   Candy is not chocolate. Go to 3.
2. Candy is rectangle-shaped. Hershey's bar.
   Candy is circular-shaped Go to 4.

Background for Educators

Owl Pellets

- Owls swallow their prey whole, therefore in addition to the meat that they digest for food, they swallow other material such as bones, fur, or feathers. Owls are unable to digest these materials, so they are regurgitated in a compacted mass. This compacted mass of fur, bones, and any other indigestible material is called an owl pellet. Despite what it looks like, pellets are not owl poop (which is what many students assume). Owl pellets are more like owl puke.
- Most owls produce about two pellets each day. A pile of pellets can often be found below an owl's roosting site. The bones of prey that are found within an owl pellet can be identified with the help of dichotomous keys or bone-sorting charts. Studies with captive owls have shown that pellets give an almost perfect record of what the bird has actually eaten. The contents of owl pellets provide a fascinating window into the life of a barn owl. In fact, fossilized pellets have been used to study the diet of ancient owls.

Barn Owls

- The pellets provided with this kit are collected from common barn owls (Tyto alba). Barn owls are the most widespread species of owl and one of the most widely distributed vertebrate species on the planet. They are found on every continent except for Antarctica.
- Barn owls hunt in open areas, such as fields, marshes, and grasslands. They are mainly nocturnal and depend on their remarkable sense of hearing to hunt. Their hearing is so accurate that they are able to capture prey in complete darkness. Barn owls nest in enclosed spaces, such as small caves or holes in trees. Human-built structures, including barns, also provide comfortable nesting spaces. Human activities, such as clearing forests for farmland, have extended the open areas in which barn owls can hunt.

Barn Owl prey species

- While some predators prefer to eat a specific type of prey, others are less picky and will eat whatever is readily available. Barn owls eat a mixed diet of whatever small critters they can catch in their fields. They feed mainly on the small land mammals that live in the fields where they hunt. They will also eat small birds, bats, and occasionally small reptiles. As a result, the barn owl diet varies regionally depending on what prey animals are common in the area. For example, owl pellets from Northwestern United States most frequently contain the remains of voles, which are abundant in the area. On the other hand, voles are absent from parts of the Southeast; in those areas, rats are more commonly found in owl pellets.

The pellets provided with this kit are collected in the Pacific Northwest and Northern California. Common prey of barn owls in this region include the following:

RODENTS

- Rodents are mammals that have front teeth that grow continuously. 40% of all mammal species are rodents.
- Deer mice: Deer mice feed on seeds, nuts, fruit, and leafy vegetation. They have large round ears, long furless tails, and brown fur with lighter fur on their undersides.
- Voles: At first glance, voles can be easily confused with mice. They are similar in size and color, but voles have a stouter body than mice, smaller eyes and ears, and short furry tails. Voles eat stems, leaves, seeds, fruit, roots, and flowers.
- Pocket gophers: These are burrowing rodents that eat roots and tubers. Pocket gophers use their fur-lined cheek pouches to carry food into their tunnels for storage.

OTHER MAMMALS

- These animals are not rodents because they lack the characteristic of continuously growing incisors. Moles and shrews belong to a group of mammals called insectivores. Bats belong to their own group and are the only mammals capable of true flight. Other mammals commonly eaten by barn owls include:
- Moles: Moles have strong front feet and large claws that they use to burrow in search of earthworms, insects, and other small invertebrates. Moles have very poor vision, but have excellent hearing and use small hairs on their feet and tails to help sense their surroundings.
- Shrews: Shrews are some of the smallest living mammals. They have small eyes, hidden ears, and pointy snouts. Shrews eat insects, worms, snails, and spiders, and dig narrow burrows. Although they look similar to mice, shrews are more closely related to moles and hedgehogs.
- Bats: Smaller bats are sometimes eaten by barn owls. These nocturnal flying mammals are not surprising prey choices since they tend to be out hunting at the same time as owls are.

BIRDS

- While mammals are the consistent staple of a barn owl's diet, small birds are an important alternative during the winter, when mammals tend to be less active and more difficult to find. Bird bones are thin and delicate; as a result they may be partially digested by barn owls, making them more difficult to find in the pellets.

Next Generation Science Standards

Science and Engineering Practices

Asking questions

- K-2: Ask questions based on observations to find more information about the natural and/or designed world(s). Ask and/or identify questions that can be answered by an investigation.
- 3-5: Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.
- Analyzing and interpreting data

- K-2: Use observations (firsthand or from media) to describe patterns and/or relationships in the natural and designed world(s) in order to answer scientific questions and solve problems.
- 3-5: Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation. Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- 6-8: Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. Analyze and interpret data to provide evidence for phenomena.
    - Grade 6–8: MS-LS2-3 (Next Generation Standards): https://www.nextgenscience.org/pe/ms-ls2-3-ecosystems-interactions-energy-and-dynamics): Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

Disciplinary Core Ideas

K-LS1-C: Organization for Matter and Energy Flow in Organisms

- All animals need food in order to live and grow. They obtain their food from plants or from other animals.

4-LS1-A: Structure and function

- Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

Crosscutting Concepts

Patterns

- K-2: Children recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.
- 3-5: Students use patterns to make predictions.
- 6-8: Students use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.

Structure and function

- K-2: Students observe the shape and stability of structures of natural and designed objects are related to their function(s).
- 3-5: Students learn that different materials have different substructures, which can sometimes be observed; and substructures have shapes and parts that serve functions.

Related Performance Expectations

- Remember, performance expectations are not a set of instructional or assessment tasks. They are statements of what students should be able to do after instruction. This activity or unit is just one of many that could help prepare your students to perform the following hypothetical tasks that demonstrate their understanding:
- MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

References

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