Overview:

In this 4-5 day investigation, students examine hypotheses and evidence related to the causes of the sea otter decline. They narrow down the hypotheses to one, then play a food web game to help them better understand relationships in the kelp bed ecosystem, and predict the outcome of an experiment to test the killer whale predation hypothesis. They put together some of the big ideas about interactions in ecosystems to come up with plausible explanations for the sea otter mystery. Finally, they evaluate whether the hypothesis has been proven. They reflect on their learning by diagramming the sea otter's food web and predicting what might happen if parts of the ecosystem changed.

*(**Note:** This is the third investigation from the science unit "The Case of the Missing Sea Otters." Online investigation can be found at http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3.html)*

Essential Question:

In what ways are organisms in aquatic environments connected to each other?

Enduring Understandings:

- Organisms in aquatic habitats interact with and depend on one another in various ways.
- An ecosystem is a community of living things with its physical environment, functioning as a unit.
- Science is a way to help us study the many connections in our world.

Targeted Alaska Content Standards:

Science

[4] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring and communicating. The student will demonstrate an understanding of the attitudes and approaches to scientific inquiry by:

[4] SA2.1 The student develops an understanding of the processes of science by supporting their ideas with observations and peer review. (L)

[4] SA3.1 The student demonstrates an understanding that interactions with the environment provide an opportunity for understanding scientific concepts by identifying the local limiting factors (e.g., weather, human influence, species interactions) that determine which plants and animals survive. (L)

[4] SC3.2 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by identifying a simple food chain and diagramming how energy flows through it and describing the effects of removing one link.

[4] SE2.2 The student demonstrates an understanding that solving problems involves different ways of thinking, perspectives, and curiosity by identifying multiple explanations (e.g., oral traditions, folklore, scientific theory) of everyday events (e.g., weather, seasonal changes). (L)

Materials:

- Student handouts and items for group display
- "Ziploc" plastic bags
- Masking tape
- Red, green, and blue cloth or paper (sashes or signs)
- Popcorn
- LCD or overhead projector
- Sea Otter Story Part 3 (http://aswc.seagrant.uaf.edu/grade-4/investigation-3/sea-otter-story-part-3.html?task=view&id=62)
- Data Sheet (http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/datasheet_foodweb.pdf)
- Pictures of Kelp Forest (photo 1: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/kelp1.jpg), (photo 2: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/kelp2.jpg)

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- Graph of Otter Populations (http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/otter_counts.pdf)
- Pictures of Urchin Barrens (photo 1: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/urchin_barrens1.jpg), (photo 2: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/urchin_barrens2.jpg)
- Food Chain Diagrams (diagram 1: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/foodchain_diagrams_a.pdf), (diagram 2: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/foodchain_diagrams.pdf)
- 1 "Ziploc" bag per student
- Masking tape
- Sashes or signs: green, blue, red (1 per student)
- Popcorn
- Quadrats (large) made from meter sticks, hula hoops, or PVC pipes (optional)
- Facility/Equipment Requirements
- Large indoor or outdoor playing area

Teacher Background Information:

An ecosystem is made up of plants, animals (including humans), microbes, and physical environmental features that interact with one another. Ecosystems are dynamic and interconnected, both by the physical environment (e.g., currents transporting larvae from one part of the ecosystem to another) and by biological interactions (e.g., kelps or creating habitat or predators consuming prey).

Ecosystems come in many sizes, often with small ecosystems nesting inside of larger ones. For example, a kelp forest represents a small habitat ecosystem nested within a large ecosystem connected by the Alaska Coastal Current. Large ecosystems contain multiple habitats such as sandy beaches, rocky beaches, kelp forests, or pelagic habitat.

(The Beaufort Sea, the Eastern Bering Sea, the Chukchi Sea, and the Gulf of Alaska are recognized as Large Marine Ecosystems among 10 within the U.S. Exclusive Economic Zone.)

The story begins with biologist James Estes being surprised by the results of his sea otter survey of an area in the Aleutian Islands that he has been studying for 15 years. The numbers of otters he sees are far less than in previous surveys. What has happened to the missing otters is a mystery.

Dr. Estes was surprised by the obvious decline in numbers because he had previously studied the sea otters when populations were expanding. Sea otters disappeared from much of their range from the Aleutians to California as a result of the fur trade during the late 18th and the 19th centuries. Several small remnant populations remained, however, in the Aleutians. These populations reproduced rapidly and eventually recolonized all of the available habitat around the islands.

Prior Student Knowledge:

1. Basic understanding of food chains.

Activity Preparation:

1. Read through instructions and background material.
2. Make overhead transparencies or prepare to project digital images.
3. Copy student handouts.
4. Put a piece of masking tape on each "stomach" (plastic bag) so that the bottom edge of the tape is 1½ inches from the bottom of the bag.

5. Teacher's Background (http://seagrant.uaf.edu/marine-ed/curriculum/component/content/53.html?task=view) and Resources (http://seagrant.uaf.edu/marine-ed/curriculum/component/content/54.html?task=view).
6. Teacher Background for Investigation 3 (http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/teacher-background.html?task=view).
7. Some vocabulary words to know: colleagues, evidence,explanation, extinction, food chains, food webs, hypothesis, interconnectedness, kelp forest habitat, keystone species, mystery, photosynthesis, prove.

Tips from Teachers:

No tips are currently available.

Curricular Connections:

1. Literacy connections: what is a mystery? What kinds of prior thinking/questioning do you need to do when you read a mystery? How can you tell when the mystery is solved?
2. Career connections: biologist, wildlife manager.
3. Math connections: graphing, multiplication, division, problem-solving.

Lesson Credit:

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Activity 1 (one 25-minute class period)

Focus Question: How do organisms in an ecosystem depend on each other?
What happened to the sea otters?
How do organisms in an ecosystem interact with each other?

Procedure:

Engagement (1 class period):

1. Review what happened in Part 2 of the story, and take another look at the data table the class created (http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/observations.pdf). What was the hypothesis that we came up with after comparing the otters, kelp, and urchins at the two locations?
2. See Teacher Background for Investigation 3 to share the results and conclusions from the scientists' study with students (see http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/teacher-background.html?task=view).
3. On the board, chart paper, or overhead projector, set up another blank data table (see sample: http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/teacher-background.html?task=view#sample). Remind students that when the scientists returned to the islands in the 1990s they found few otters at either location, and fill in the top row. Ask the students to predict the amounts of kelp and urchins that they would have found at each location.
4. Read the Sea Otter Story Part 3: http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/sea-otter-story-part-3.html?task=view.
5. Brainstorm possible hypotheses about the sea otter disappearance. Lead and prompt students to come up with the 6 possible hypotheses listed (see http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/64.html?task=view), or after they have spent time brainstorming, list the six hypotheses on the board.
6. Discuss what the scientists did to test hypotheses 1-5. Ask students how they might try to prove that killer whales were responsible for the otter decline.

Exploration (2 sessions of 45 minutes each):

Kelp Bed Food Web Game

7. In this game, students will be different animals in marine food webs involving sea otters. They will observe feeding relationships, including predators and prey, and the impacts of overgrazing, not enough resources, too many consumers, etc.
8. This is a very active game where students will be scrambling to gather "food" against a clock. When predators are part of the game, they will be waiting to capture the prey and steal their food, and the prey will be trying to avoid being eaten as they gather food. Students can graph results. Students will also become involved in trying to adjust the number of animals in each group so that enough animals at each level of the food chain are represented and can therefore "survive" and keep the food chain going.
9. Before beginning the game, show students a picture of a kelp forest community from the pictures provided (photo 1: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/kelp1.jpg), (photo 2: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/kelp2.jpg) or the book Sea Otter Inlet. Remind them that the kelp is anchored on the bottom of the ocean and it then grows rapidly up to the surface where the sun is shining to capture sunlight to make food (photosynthesize). Certain areas of the ocean bottom are good places for kelp to grow, so large numbers of kelp plants often grow together, forming a "forest." Ask why animals might like to stay around the kelp forest instead of in the open ocean (currents are slowed down, place to rest).

10. Before the game remind students to play in their assigned "role," and go over guidelines for a safe environment. Establish the boundaries of the playing area. Read through the rules and check for understanding. Some students may want to be the information keepers—recording data from the game along the way. Use the data sheet provided (http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/datasheet_foodweb.pdf), with a clipboard, OR help students to set up a recording method for their science notebooks.
11. Explain that students will be playing a game of "tag" where each of the students will represent an animal that is trying to survive in the food chain. The game is divided into rounds. Students will be wearing sashes or signs to show which animal they are. (Green sash/sign = sea urchin; Blue sash/sign = sea otter; red sash/sign = killer whale).
12. Show the group boundaries and scatter popcorn around the playing area. Explain that the popcorn represents the kelp, which make food in their bodies by using the sun's energy plus carbon dioxide and water. Kelp and other algae are the base of the marine food web.

Urchin-kelp rounds:

13. Everyone is a sea urchin and wears a green sash. Set your watch for five minutes. At "go" the urchins begin their feeding frenzy.
14. For urchins to survive they must have popcorn in their stomachs up to the bottom of the tape. Urchins that didn't get enough to eat sit out the next rounds.
15. Continue playing until all of the popcorn is gone. Ask how more kelp could be added to the system (it would have to grow faster than the urchins were able to consume it).
16. Show students what the ocean floor looks like when urchins eat the kelp forest (photo 1 http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/urchin_barrens1.jpg), (photo 2: http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/urchin_barrens2.jpg). (View an alternate photograph at this web site: http://norb.homedns.org/nwp/storycode/cal-web/large-7.html.)

Sea otter-urchin-kelp rounds:

17. Scatter the popcorn again. Select one student to be an otter for every ten urchins. Give the others blue sashes. Play a series of rounds where otters are trying to tag the urchins, while the urchins are trying to collect the popcorn. If an urchin is tagged, the otter gets all the popcorn in his/her bag. The otters must have popcorn in their stomachs up to the top of the bag to survive.
18. Remind students about the killer whale predation theory as the cause of the sea otter decline. Do the next rounds with killer whales added as predators.

Killer whale-urchin-kelp rounds:

19. To begin, let students choose what they want to be (green sash/sign = sea urchin); blue sash/sign = sea otter; red sash/sign = killer whale). You will probably get a lot of killer whales the first round, and that's all right. For the killer whales to survive, they must have the equivalent of two otters or two full bags of popcorn.
20. After the first round with three different kinds of animals, determine if enough species survived to continue the food chain, and play additional rounds until one or more species doesn't get enough food to survive. Then ask the students to adjust the number of predators and prey to keep a food chain going for at least three rounds. They can also suggest one rule change for each round.

Some suggestions might be:

- Change the number of urchins and/or sea otters. Try 50% urchins, 30% sea otters, 20% killer whales.
- Let each urchin come back one more time to feed.

- Provide a safe haven for urchins or sea otters where they cannot be eaten.
- Try timed releases. Let urchins feed first for a certain amount of time (1 minute perhaps), then allow the sea otters to feed (1 minute), then release the killer whales.
- Introduce the problem of the sea otters becoming threatened because population numbers have declined. Change the ratio of players to 70% urchins, 10% sea otters, and 20% killer whales.
- Replenish the kelp after a number of rounds. After each round, record the number of animals from each group that survives and briefly discuss what happened when you made changes. Remind students that there must be kelp left to ensure a food source for the other animals in the ecosystem as well.

Explanation (1 class period):

21. Back in the classroom, post the data that you recorded showing the number of animals remaining after each round. Discuss ways that the various parts of the ecosystem were interconnected, and how a change in one element of the ecosystem affected other things.
22. Review the three different "states" of the ecosystem:
    a. No otters—urchins can reduce kelp to very low levels.
    b. With otters—otters keep urchins from reducing the kelp to very low levels.
    c. With otters and killer whales—killer whales can reduce otters to low levels, then urchins will reduce the kelp to low levels.
23. Show the food chain diagram of the system with and without the otters (see http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/foodchain_diagrams_a.pdf).
24. Ask why otters might be considered "extra-important" in a marine habitat or ecosystem because they eat so many urchins. Tell them that the term for species like the otters that play this important or key role is "keystone species." Removing the keystone has effects on the entire food web, and in the case of the kelp forest, the structure of the kelp forest habitat is lost.
25. Show the food chain diagram that compares the systems with and without killer whales (see http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/foodchain_diagrams.pdf). Bring students' attention back to the killer whale predation hypothesis represented by this diagram.
26. Explain that some scientists, working with Jim Estes, wanted to determine if the killer whale predation hypothesis was the right one to explain the decline. They used mathematics to calculate how many killer whales it would take to have eaten the missing otters. (See Killer Whale Math Problem and involve your students in the math as appropriate: http://seagrant.uaf.edu/marine-ed/curriculum/grade-4/investigation-3/65.html?task=view.) They determined that the killer whales present in the area could easily have eaten the 40,000 sea otters that were missing. Play the Arctic Science Journeys radio interview with Terrie Williams (http://seagrant.uaf.edu/news/05ASJ/02.18.05killer-appetites.html).
27. The scientists also carried out an experiment. They put radio collars on sea otters that lived in two different areas of Adak Island. One group lived in Clam Lagoon, which had a narrow entrance that killer whales didn't enter. The second group lived in Kuluk Bay, which was open to the ocean and to killer whales. They relocated the groups and counted the number in each group during a five-year period from 1993 to 1998. Ask the students to describe what would happen to the two populations if the killer whale predation hypothesis was correct.
28. Share the graph with students to see what actually happened and discuss its meaning (http://seagrant.uaf.edu/marine-ed/curriculum/images/stories/grade4/otter_counts.pdf).
29. Ask the students if the mystery has been solved. Has the killer whale predation hypothesis been proven? What data or evidence proved it?

30. Share the following:
    The Story as of March 2007:

    Jim Estes is convinced by the evidence but not all scientists agree with him. The Southwest Alaska stock of sea otters were listed as threatened under the Endangered Species Act in 2005. The Recovery Team for the sea otter (which includes Jim Estes) views the killer whale predation hypothesis as unproven and requiring additional study, but it is the only hypothesis with the "weight of evidence" supporting it.

Extension (Application): (20 minutes)

Science journals:

31. Ask students to draw a diagram showing how otters, kelp, urchins, and killer whales interact with each other in the Aleutian marine ecosystem.
32. Ask them to write about:

    If killer whales stopped eating the sea otters around Amchitka, what might happen to the kelp beds and the urchins in that area?

    Or:

    What might happen if people decided to harvest all the kelp around Amchitka?

Further Exploration: (Optional)

35. Play the NPR radio story Killer Whales Thinning Otter Populations, an interview with Terrie Williams talking about her observations of killer whales attacking sea otters and her calculations about how many killer whales could have eaten the missing otters, followed by a rebuttal of the killer whale predation hypothesis by Doug DeMaster, who says it can't be proven (http://www.npr.org/templates/story/story.php?storyId=4665067).
36. Brainstorm with the students about what could have caused the killer whales to begin eating sea otters in the Aleutian Islands in the late 1980s.
37. Play the Arctic Science Journeys story Sea Otter Crash, about the prey-switching hypothesis (http://seagrant.uaf.edu/news/02ASJ/02.15.02sea-otter-crash.html). Jim Estes, Terrie Williams, and other scientists have hypothesized that industrial whaling removed thousands of large whales from the ecosystem in the late 1800s and early 1900s. The killer whales switched to eating sea lions and harbor seals, which have undergone a precipitous crash in western Alaska. As these prey items became scarcer, some killer whales switched to sea otters. Can you explain why it would be very difficult to collect data and other forms of evidence to prove this hypothesis?

Evaluation:

38. Formal Evaluation will be done at the end of the unit.