Russian–U.S.Arctic Census 2012 Expedition

Meet the Arctic Benthos



Image captions/credits on Page 2.

lesson plan

Focus
Benthic organisms in the Arctic Ocean

Grade Level
7-8 (Life Science)

Focus Question
What kinds of animals are found in benthic communities of the Arctic Ocean?

Learning Objectives
- Students will explain how aspects of structure and function are involved with common feeding strategies used by benthic animals in the Arctic Ocean.
- Students will discuss patterns in interdependent relationships between groups of animals in Arctic benthic communities.
- Students will discuss how changes in the Arctic environment may affect biodiversity in Arctic benthic communities.

Materials
- ❑ *Benthic Habitats* sheet, either redrawn onto a marker board or flip chart, or scanned for display on an interactive whiteboard
- ❑ Library or Internet access for research on Arctic benthos

Audio-Visual Materials
- ❑ Blackboard, marker board, flip chart, or overhead projector and appropriate markers

Teaching Time
One or two 45-minute class periods, depending upon the amount of time spent on introductory material, plus time for students to do library or Internet research

Seating Arrangement
Groups of three or four students

Maximum Number of Students
30

Key Words

Arctic
Bering Strait
Chukchi Sea
RUSALCA
Biodiversity
Benthic

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

The Bering Strait is a narrow body of water that separates the western-most point of Alaska from the eastern-most point of Russia, and provides the only connection between the Pacific and Arctic Oceans. Water flowing through the Strait brings heat, nutrients, and freshwater into the Arctic. Although the Bering Strait is relatively small (about 85 km wide and 50 m deep), this flow has a strong influence on the Arctic Ocean ecosystem, and may also affect the deep ocean thermohaline circulation (the "global conveyor belt" that connects all of Earth's oceans; for additional information, please see *Expedition Education Module for the Russian – U.S. Arctic Census 2012 Expedition*). Despite its importance, relatively little is known about the processes that affect the Bering Strait throughflow, or about how these processes will respond to rapid changes now being observed in the Arctic climate.

To improve our understanding of Arctic ecosystems and the impacts of climate change, the Russian-American Long-term Census of the Arctic (RUSALCA) was established in 2003 as a cooperative project of the National Oceanic and Atmospheric Administration (NOAA) and the Russian Academy of Sciences ("rusalca" means "mermaid" in the Russian language). The overall purpose of this project is to provide ways to detect and measure changes in Arctic Ocean ecosystems. In 2004, the first RUSALCA expedition began investigations of ecosystems in the Bering and Chukchi Seas. A key component of these investigations is the installation of instrument packages attached to moored buoys to measure chemical and physical properties of water flowing through the Bering Strait. In addition, RUSALCA scientists also study Arctic marine life including fishes, plankton, bottom communities, and food webs. Links to reports and photographs from previous RUSALCA expeditions can be found at http://www.arctic.noaa.gov/aro/russian-american/.

These studies have shown that nutrients (needed by marine plants for photosynthesis) are highly concentrated in the western portions of the Bering Sea, with extremely low nutrient concentrations near the coast of Alaska. Rates of photosynthesis were highest just north of the

Images from Page 1 top to bottom:
Launching a CTD.
http://www.arctic.noaa.gov/aro/russian-american/2009/photos/43%20CTD%20launch.jpg

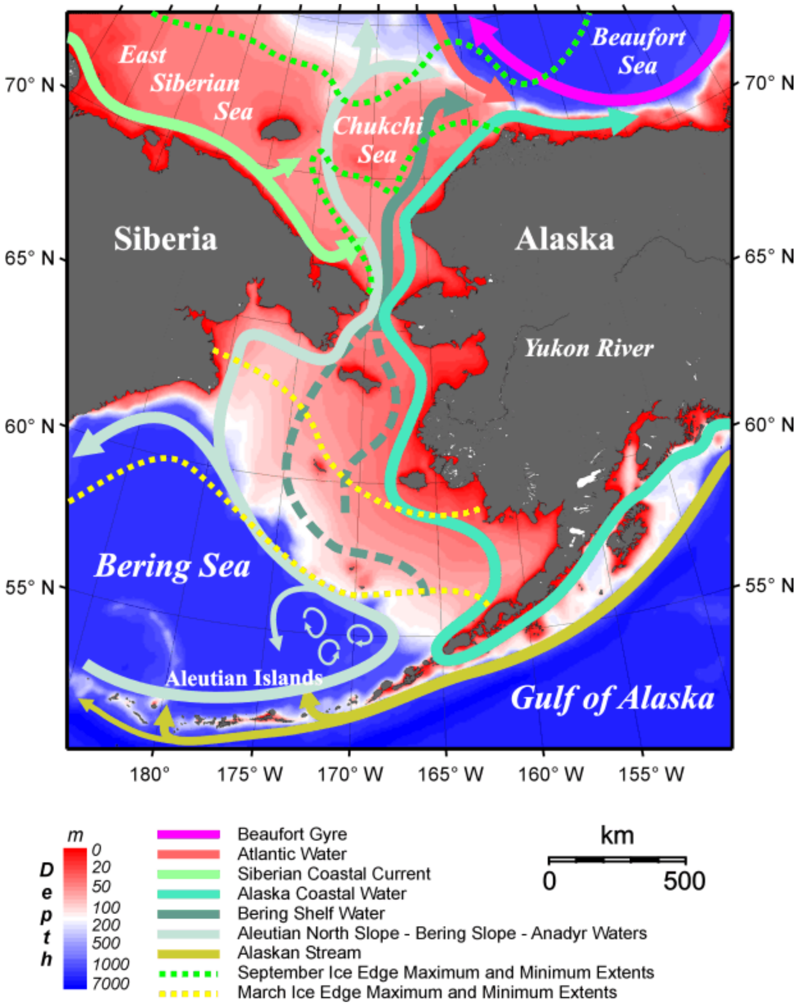
Crossing the sea ice.
http://www.arctic.noaa.gov/aro/russian-american/2009/photos/087%20Crossing%20the%20Arctic%20Ice.jpg

Benthic animals captured in a bottom sampling trawl
http://www.arctic.noaa.gov/aro/russian-american/2009/photos/070%20Benthic%20Samples.jpg

Benthic animal captured in bottom sampling trawl.
http://www.arctic.noaa.gov/aro/russian-american/2009/photos/166%20Sea%20Bottom%20Catch.jpg

All images provided by Kathy Crane, NOAA Arctic Research Office and RUSALCA and were found on http://www.arctic.noaa.gov/aro/russian-american/

NOTE: These links will work if you copy and paste them into your browser.



A schematic of the flows in the region from *Danielson and Weingartner*, from the web page http://psc.apl.washington.edu/HLD/Bstrait/bstrait.html
http://psc.apl.washington.edu/HLD/Bstrait/bering%20chukchi%20map.GIF

NOTE: These links will work if you copy and paste them into your browser.

Bering Strait and in the central Chukchi Sea. Farther north in the Chukchi Sea, photosynthetic rates declined, probably because of lower nutrient concentrations.

High nutrient levels provide a foundation for ecosystems that contain large amounts of living organisms. Such ecosystems are said to have "high biological productivity". In addition to nutrient availability, the productivity of Arctic marine ecosystems is also strongly affected by the presence of sea ice, water temperature, and current patterns. Food chains in these ecosystems tend to be short compared to other marine ecosystems, so that changes near the bottom of the food chain (primary producers and primary consumers) can quickly affect animals near the top of the food chain such as whales, seals, walruses, and sea birds. Benthic (bottom-dwelling) animals include clams, snails, polychaete worms, amphipods, echinoderms, crabs, and fishes. Filter-feeders obtain food from particulate material in the water, while deposit feeders consume organic material from sediments and the remains of other organisms that settle to the bottom. Both groups are important to the recycling of nutrients from degrading organic matter back into the water column, and changes in the distribution of these species may be an indication of changing environmental conditions.

Particulate organic matter (POM) is a major food base for marine ecosystems in the study area. High nutrient concentrations in the western Bering Sea contribute to high levels of primary production, which in turn produces an abundant supply of POM some of which is consumed by benthic organisms. Food webs in this area tend to be relatively simple (primary producer > POM > benthic consumer), because there is an ample supply of food. In the eastern Bering Sea, nutrient concentrations are lower and there is less primary production and less POM. In this area, pelagic organisms have already processed most of the POM by the time it reaches the bottom, so food webs are more complex (primary producer > POM > pelagic consumer > pelagic consumer > benthic consumer). So, changes in food web structure can be used to detect changes in nutrient content and other characteristics of the surrounding water.

Biodiversity refers to the variety of living organisms in an ecosystem, and can be another important indicator of environmental change. At present, we know that there are at least three distinct biological communities (called "realms") in the Arctic Ocean. The **Sea-Ice Realm** includes plants and animals that live on, in, and just under the ice that floats on the ocean's surface. Sea ice is not usually solid like an ice cube, but is riddled with a network of tunnels called brine channels that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biological material through photosynthesis. Bacteria, viruses, and fungi also inhabit the channels, and together with diatoms and algae provide an energy source (food) for flatworms, crustaceans, and other animals. This community of organisms is called sympagic, which means "ice-associated." Partial melting of sea ice during the summer months produces ponds on the ice surface that contain their own communities of organisms. Melting ice also releases organisms and nutrients that interact with the ocean water below the ice.

The ice in the Chukchi Sea sometimes resembled hills. Image courtesy Catherine Mecklenburg, University of California, Santa Barbara.
http://oceanexplorer.noaa.gov/explorations/09arctic/layerediceimage.html

Until recently, only 50% of sea-ice melted in the summer, so some ice flows existed for many years and were able to reach thicknesses of more than six ft (2 m). Since the first RUSALCA expedition, though, there has been an unexpectedly rapid reduction of Arctic sea ice cover; particularly in the Chukchi Sea located between the Russian Federation (Chukotka) and the United States (Alaska) and northwards into the High Arctic. As a result, in 2009 RUSALCA scientists were able explore about 300 nautical miles farther north than was possible in 2004. Scientists now expect that by the end of the 21st century, all of the Sea-Ice Realm will disappear during summer months.

The **Pelagic Realm** includes organisms that live in the water column between the ocean surface and the bottom. Melting sea ice allows more light to enter the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. These algae provide energy for a variety of floating animals (zooplankton) that include crustaceans and jellyfishes. Zooplankton, in turn, is the energy source for larger pelagic animals including fishes, squids, seals, and whales.

When pelagic organisms die, they settle to the ocean bottom, and become the energy source for inhabitants of the **Benthic Realm**. Sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians are common members of Arctic benthic communities. These animals provide energy for bottom-feeding fishes, whales, and seals.

Small Arctic cod are one of the more abundant fish species caught on the Arctic shelf. Image courtesy of B. Bluhm, UAF.
http://oceanexplorer.noaa.gov/explorations/12arctic/background/biodiversity/media/cod.html

This activity is focused on the Benthic Realm. In most of Earth's ocean, including the Chukchi Sea, benthic species contribute over 90 percent of the species richness (a measure of biodiversity). Benthic and pelagic communities in the Chukchi Sea are mostly of Pacific origin because of the strong exchange processes through the Bering Strait, but Arctic populations are typically highly adapted and fine-tuned to the local conditions. Warming waters in the Arctic could allow other Pacific cold-water benthic species to invade the Chukchi shelf and compete for resources with the highly adapted (and therefore vulnerable) Arctic populations.

Learning Procedure

1. To prepare for this lesson, read the introductory essays for the Russian - U.S. Arctic Census 2012 expedition at http://oceanexplorer.noaa.gov/explorations/12arctic/welcome.html, including the marine biodiversity essay by Bodil Bluhm, Russ Hopcroft, and Katrin Iken. You may also want to review summary reports from previous RUSALCA expeditions linked at http://www.arctic.noaa.gov/aro/russian-american/.

2. Briefly introduce the Russian - U.S. Arctic Census 2012 Expedition, and the three "realms" of biological communities in the Arctic. Highlight the fact that summer reduction of sea ice is happening much more quickly than scientists expected. Assign one or more of the invertebrate groups in Table 1 to each group of students, and say that these are major invertebrate groups that have been reported in previous studies of polar benthic communities. Tell students that their assignment is to prepare a brief report on the assigned group(s) using library and/or Internet resources. Each report should:
   - Describe the animal including size range;
   - Describe the animal's habitat;
   - Identify food source(s) and feeding habits; and
   - If possible, include an illustration of the animal.

Crossota sp., a deep red medusa found just off the bottom of the deep sea. Image courtesy of Kevin Raskoff, California State University, Monterey Bay.
http://oceanexplorer.noaa.gov/explorations/05arctic/logs/hires/01_crossota_sp_hires.jpg

The following websites contain the necessary information:

http://library.thinkquest.org/26153/marine/animalia.htm

http://tolweb.org/tree?group=Animals&contgroup=Eukaryotes

http://virtual.yosemite.cc.ca.us/randerson/Marine%20Invertebrates/index.htm

http://biodidac.bio.uottawa.ca/ – this site has lots of images suitable for downloading

3. Have each student or group present their report to the entire class. Redraw the *Benthic Habitats* sheet, or scan the sheet for display on an interactive whiteboard. Have the students write the name of their invertebrate group(s) in the appropriate habitat area, and indicate whether the animals are sessile (fixed in one place) or mobile.

4. Lead a discussion of how different benthic groups interact, with particular emphasis on feeding strategies. Students should realize that these groups are adapted to obtain food from the benthic environment in a variety of ways, including filter feeding, deposit feeding, and predation upon other benthic organisms. If necessary, prompt students to describe anatomical structures that are involved with adaptations for specific types of feeding.

   When all student groups have presented their reports, encourage students to infer and discuss how the animals that have been described may be interdependent, including types of food webs that may exist between these animals and organisms in the other two realms. Students should realize that the primary source of food for benthic organisms is primary production that occurs in the sea ice and pelagic realms, and that organic material and nutrients are transported out of these environments when organisms die and settle to the bottom. Feeding activities by benthic organisms are an important process that returns some of these materials to other realms of the polar ocean environment. Ask students why they think there are so many different kinds of animals in these benthic communities, and why this diversity is important.

   Ask students to speculate about how changes in the Arctic environment may affect biodiversity in Arctic benthic communities. Among other possibilities, students should infer that warmer temperatures might make it possible for animals from lower latitudes to enter these communities. Point out that many of the animals students describe in their reports are highly adapted to specific conditions in Arctic marine ecosystems, and may not be able to successfully compete with organisms from other locales if warmer temperatures allow the latter organisms to enter these ecosystems.

The ctenophore, *Beroe cucumis* , is specialized to eat other ctenophores. Image courtesy of Kevin Raskoff, California State University, Monterey Bay
http://oceanexplorer.noaa.gov/explorations/05arctic/logs/july19/media/beroe_cucumis.html

Adaptations to Other Grade Levels

Grades 5-6: Have students complete some or all of the activities described in the *Three Cold Realms* lesson (from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_threecoldrealms.pdf

Grades 9-12: Have students complete some or all of the activities described in the following lessons:

- *Let's Get to the Bottom* (from the 2002 Arctic Exploration Expedition)
  http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_bottom.pdf
- *What's Eating You?* (from the 2005 Hidden Ocean Expedition)
  http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/05arctic_whatseating.pdf
- *Getting to the Bottom* (from the 2005 Hidden Ocean Expedition)
  http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_gettingtothebottom.pdf

The BRIDGE Connection

www.vims.edu/bridge/ – In the menu on the left, scroll over "Ocean Science Topics," then "Habitats," then click "Polar" for links to lessons and activities about polar environments.

The "Me" Connection

Have students write a brief essay on why diverse but relatively unknown groups, like many of those studied in this activity, are important to their own lives.

Connections to Other Subjects

English Language Arts, Social Studies

Assessment

Reports from student groups may be submitted for grading on the basis of thoroughness in addressing the four content areas listed in Step 2. It is also possible to create a matching or fill-in-the-blank identification quiz using images from http://biodidac.bio.uottawa.ca.

Extensions

Visit http://oceanexplorer.noaa.gov/explorations/12arctic/welcome.html for more information and resources related to the Russian - U.S. Arctic Census 2012 Expedition..

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

Grades 5-6

Polar Bear Panic!
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_polarbears.pdf

Focus: Climate change in the Arctic Ocean

Students identify the three realms of the Arctic Ocean, and describe the relationships between these realms; graphically analyze data on sea ice cover in the Arctic Ocean, and recognize a trend in these data; and discuss possible causes for observed trends in Arctic sea ice, and infer the potential impact of these trends on biological communities in the Arctic.

Life in the Crystal Palace
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_crystal.pdf

Focus: Sea-ice communities in the Arctic Ocean

Students identify major groups of organisms found in Arctic sea-ice communities; describe major physical features of sea-ice communities and how these features change during summer and winter; and explain how these changes affect biological activity within these communities. Students will also be able to describe interactions that take place between sea ice communities, and explain the importance of sea-ice communities to Arctic ecosystems.

Jelly Critters
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_jellycritters.pdf

Focus: Gelatinous zooplankton in the Canada Basin

Students compare and contrast at least three different groups of organisms that are included in 'gelatinous zooplankton', describe how gelatinous zooplankton fit into marine food webs, and explain how inadequate information about an organism may lead to that organism being perceived as insignificant.

Three Cold Realms
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_threecoldrealms.pdf

Focus: Pelagic, benthic and sea ice realms

Students compare and contrast the pelagic, benthic and sea ice realms of the Arctic Ocean, name at least three organisms that are typical of each of these three realms, and explain how the pelagic, benthic and sea ice realms interact with each other.

Grades 7-8

Would You Like a Sample?
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_sample.pdf

Focus: Sampling strategies for biological communities

Students identify the three realms of the Arctic Ocean, describe the relationships between these realms and discuss the advantages and limitations of sampling techniques to study biological communities.

Where Have All the Glaciers Gone?
(from the *Okeanos Explorer Educational Materials Collection - Volume 1: Why Do We Explore?*)
http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_glaciers.pdf

Focus: Arctic climate change

Students describe how climate change is affecting sea ice, vegetation, and glaciers in the Arctic region; explain how changes in the Arctic climate can produce global impacts; and provide three examples of such impacts. Students will explain how a given impact resulting from climate change may be considered 'positive' as well as 'negative', and will be able to provide at least one example of each.

Grades 9-12

Being Productive
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_productive.pdf

Focus: Primary productivity and limiting factors in the Arctic Ocean

Students identify the three realms of the Arctic Ocean, and describe the relationships between these realms; and identify major factors that limit primary productivity in the Arctic Ocean, and describe how these factors exert limiting effects. Given data on potentially limiting factors and primary productivity, students infer which factors are actually having a limiting effect.

Let's Get to the Bottom
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_bottom.pdf

Focus: Factors that influence the composition of benthic communities in the deep Arctic Ocean

Students identify the three realms of the Arctic Ocean, and describe the relationships between these realms; describe different species associations in a benthic community; and infer probable feeding strategies used by benthic organisms and relate these strategies to sediment characteristics.

Message in the Bottles
(from the 2002 Arctic Exploration Expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_message.pdf

Focus: Estimating primary productivity

Students identify the three realms of the Arctic Ocean, and describe the relationships between these realms; explain the relationships between gross primary productivity, net primary productivity, and respiration; and understand how oxygen production and consumption can be measured and used to estimate primary productivity in water bodies.

Current Events
(from the 2002 Arctic Exploration expedition)
http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_c_events.pdf

Focus: Currents and water circulation in the Arctic Ocean

Students identify the primary driving forces for ocean currents and will be able to infer the type of water circulation to be expected in the Arctic Ocean, given information on temperature, salinity, and bathymetry.

What's Eating You?
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/05arctic_whatseating.pdf

Focus: Trophic relationships in Arctic marine ecosystems

Students describe how ratios of stable nitrogen isotopes can be used to study trophic relationships between marine organisms; make inferences about trophic relationships between organisms and habitats; and compare and contrast organisms in sea ice, pelagic, and benthic communities in terms of feeding strategies and consequent stable nitrogen isotope ratios.

Getting to the Bottom
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_gettingtothebottom.pdf

Focus: Benthic communities in the Canada Basin

Students identify major taxa that are dominant in deep benthic communities of the Arctic Ocean. Given distribution data for major taxa in different Arctic benthic communities, students identify patterns in the distribution of these taxa and infer plausible reasons for these patterns.

Burp Under the Ice
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/05arctic_burp.pdf

Focus: Potential role of Arctic methane deposits in climate change

Students identify the natural processes that produce methane, describe where methane deposits are located in the Arctic region, explain how warmer climates may affect Arctic methane deposits, explain how the release of large volumes of methane might affect Earth's climate, and describe how methane releases may have contributed to mass extinction events in Earth's geologic history.

The Good the Bad and the Arctic
(from the 2005 Hidden Ocean expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_goodandbad.pdf

Focus: Social, economic and environmental consequences of Arctic climate change

Students identify and explain at least three lines of evidence that suggest the Arctic climate is changing, identify and discuss at least three social, three economic and three environmental consequences expected as a result of Arctic climate change, identify at least three climate-related issues of concern to Arctic indigenous peoples, and identify at least three ways in which Arctic climate change is likely to affect the rest of the Earth's ecosystems.

Just Jelly
(from the 2005 Hidden Ocean Expedition)
http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_justjelly.pdf

Focus: Water masses and gelatinous zooplankton in the Canada Basin

Students compare and contrast the feeding strategies of at least three different types of gelatinous zooplankton, and explain why gelatinous zooplankton may function at several trophic levels within a marine food web. Given information on the vertical distribution of temperature in a water column, students make inferences about potential influences on the distribution of planktonic species in the water column.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/explorations/12arctic/welcome.html – Web page for the Russian - U.S. Arctic Census 2012 Expedition

http://psc.apl.washington.edu/HLD/Bstrait/bstrait.html – Bering Strait: Pacific Gateway to the Arctic; Web page about current research on Arctic marine ecosystems; includes sections on Bering Strait Basic Facts, why the Bering Strait throughflow is important, what research is being done, and what is being learned

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Web site for Ocean Explorer 2002 Arctic Exploration Expedition

http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html – Web site for the Hidden Ocean Arctic 2005 Expedition

Relationship to A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas

The objectives of this lesson integrate the following Practices, Crosscutting Concepts, and Core Ideas:

Objective: Students will explain how aspects of structure and function are involved with common feeding strategies used by benthic animals in the Arctic Ocean.

Practices:
6. Constructing explanations

Crosscutting Concepts:
6. Structure and function

Core Ideas:
LS1.A: Structure and Function
LS1.C: Organization for Matter and Energy Flow in Organisms

Objective: Students will discuss patterns in interdependent relationships between groups of animals in Arctic benthic communities.

Practices:
2. Developing and using models
7. Engaging in argument from evidence

Crosscutting Concepts
1. Patterns

Core Ideas:
LS2.A Interdependent Relationships in Ecosystems

Objective: Students will discuss how changes in the Arctic environment may affect biodiversity in Arctic benthic communities.

Practices:
7. Engaging in argument from evidence

Crosscutting Concepts:
2. Cause and effect

Core Ideas:
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Correlations to Common Core State Standards for English Language Arts

RI.4 – 4. Determine the meaning of words and phrases as they are used in a text, including figurative, connotative, and technical meanings; analyze the impact of a specific word choice on meaning and tone.

W.1 – Write arguments to support claims with clear reasons and relevant evidence.

SL.1 – Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 2.
The ocean and life in the ocean shape the features of the Earth.

Fundamental Concept a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

Fundamental Concept b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

Fundamental Concept c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.

Essential Principle 3.
The ocean is a major influence on weather and climate.

Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Fundamental Concept f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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

Fundamental Concept e. 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.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Credit

Table 1
Common Invertebrate Groups Reported from Arctic Benthic Communities

Phylum Cnidaria – Jellyfish, corals, sea anemones, and similar animals that have stinging cells called nematocysts. The Class Anthozoa, particularly sea anemones, is often abundant in polar benthic communities.

Phylum Nemertea (also known as Rhyncocoela and Nemertinea) – Their long flat shape gives these animals the common name "ribbon worms." These worms have no segments and are often predators.

Phylum Annelida (segmented worms) – The Class Polychaeta (worms with many appendages) has many representatives in polar benthic communities and is highly diverse in physical form as well as feeding strategy.

Phylum Echiurida (or Phylum Annelida, Class Echiura) – "spoon worms," that also live in burrows and are primarily deposit feeders

Phylum Ectoprocta (or Phylum Bryozoa, Subphylum Ectoprocta) – small, tube-dwelling animals that feed by means of a crown of tentacles called a lophophore

Phylum Priapulida – mud-dwellers that resemble a little cucumber with teeth

Phylum Sipunculida – "peanut worms," which live in burrows or crevices; most eat sand or mud and use whatever food material they may contain, but one species is carnivorous

Phylum Arthropoda (animals with a hard external skeleton and jointed appendages) – Four groups are common among the polar benthos; all belong to the class Crustacea:

- Subclass Cirripedia – barnacles
  - Order Amphipoda – These laterally flattened arthropods employ a variety of feeding strategies and are the dominant group in many benthic communities.
  - Order Cumacea – These animals are usually quite small (1-4 mm long), but deep sea and Arctic species may be ten times as large, and live in burrows or mucous tubes in bottom mud.
  - Order Isopoda – Dorso-ventrally flattened arthropods resembling bugs; may be free-living or parasitic, but are never filter feeders.

Phylum Mollusca (invertebrates usually having a muscular foot and an external shell)

- Class Pelecypoda – clams, which are all filter feeders
- Class Gastropoda – snails, which have a variety of feeding strategies
- Class Amphineura – chitons, which feed by scraping algae and other materials from hard surfaces

Phylum Echinodermata (invertebrates with a spiny skin)

- Class Echinoidea – Sea urchins and sand dollars; sand dollars are often found in areas where strong currents make it difficult for other animals to live
- Class Holothuroidea – Sea cucumbers
- Class Ophiuroidea – Brittle stars

Phylum Chordata

- Class Ascidiacea – tunicates or "sea squirts," leathery-skinned bottom dwellers that grow singly or in colonies attached to stable surfaces

Benthic Habitats