2005 Hidden Ocean Expedition

What's Eating You?

Focus
Trophic relationships in Arctic marine ecosystems

Grade Level
9-12 (Chemistry/Biology)

Focus Question
What are the relationships between sea ice, pelagic, and benthic communities in Arctic marine food webs?

Learning Objectives
Students will be able to describe how ratios of stable nitrogen isotopes can be used to study trophic relationships between marine organisms.

Given data on stable nitrogen isotope ratios, students will be able to make inferences about trophic relationships between organisms and habitats.

Students will be able to compare and contrast organisms in sea ice, pelagic, and benthic communities in terms of feeding strategies and consequent stable nitrogen isotope ratios.

Materials
- ❒ Copies of "Mean $\delta^{15}N$ Ratios of Species in the Canada Basin," one copy for each student

Audio/Visual Materials
- ❒ None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Pelagic realm
Benthic realm
Sea ice realm
Sympagic
Arctic Ocean
Canada Basin
Isotope ratio
Food web
Trophic shift

Background Information
The Arctic Ocean is the most inaccessible and least-studied of all the Earth's major oceans. Although it is the smallest of the world's four ocean basins, the Arctic Ocean has a total area of about 14 million square kilometers (5.4 million square miles); roughly 1.5 times the size of the United States. The deepest parts of the Arctic Ocean (5,441 m; 17,850 ft), known as the Canada Basin, are particularly isolated and unexplored because of year-round ice cover. To a large extent, the Canada Basin is also geographically isolated by the largest continental shelf of any ocean (average depth about 50 meters) bordering Eurasia and North American. The Chukchi Sea provides a connection with the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is

with the Atlantic Ocean via the Greenland Sea. This isolation makes it likely that unique species have evolved in the Canada Basin.

Exploration of the Arctic Ocean, especially the Canada Basin, has become increasingly urgent because the Arctic environment is changing at a dramatic rate. A 2004 report from the Arctic Council states that temperature in the Arctic is increasing at nearly twice the rate of increase as the rest of the world. One visible result is rapid loss of glaciers and sea ice. Less visible are the impacts on living organisms that depend upon glaciers and sea ice for their habitat. Loss of these habitats can also have direct effects on human communities. The Greenland Ice Sheet, for example, holds enough water to raise global sea levels by as much as 7 meters. Sea level increases at this magnitude would be sufficient to flood many coastal cities, including most of the city of London.

The 2002 NOAA Ocean Exploration expedition to the Arctic Ocean focussed specifically on the biology and oceanography of the Canada Basin. These explorations included three distinct biological communities:

- The Sea-Ice Realm includes plants and animals that live on, in, and just under the ice that floats on the ocean's surface;
- The Pelagic Realm includes organisms that live in the water column between the ocean surface and the bottom;
- The Benthic Realm is composed of organisms that live on the bottom, including sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians.

Sea ice provides a complex habitat for many species that are called sympagic, which means "ice-associated." The ice 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 (a process called "primary production"). 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. In the spring, melting ice releases organisms and nutrients that interact with the ocean water below the ice. Large masses of algae form at the ice-seawater interface and may form filaments several meters long. On average, more than 50% of the primary production in the Arctic Ocean comes from single-celled algae that live near the ice-seawater junction. This interface is critical to the polar marine ecosystem, providing an energy source (food) for many organisms, as well as protection from predators. Arctic cod use the interface area as nursery grounds, and in turn provide an important food source for many marine mammals and birds, as well as migration routes for polar bears. In the spring, the solid ice cover breaks into floes of pack ice that can transport organisms, nutrients, and pollutants over thousands of kilometers. Partial melting of sea ice during the summer months produces ponds on the ice surface called polynyas that contain their own communities of organisms. Because only 50% of this ice melts in the summer, ice flows can exist for many years and can reach a thickness of more than 2 m (6 ft).

When sea ice melts, more sunlight enters 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 pelagic organisms, including floating crustaceans and jellyfishes called zooplankton, which are 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. These animals, in turn, provide energy for bottom-feeding fishes, whales, and seals.

A key objective of the 2005 Hidden Ocean expedition is to obtain a better understanding of interactions and coupling between these three biological realms. Because sunlight does not penetrate to the deep benthic realm, bottom-dwelling organisms are totally dependent upon primary production near the ocean surface (an exception is the case of benthic communities whose primary source of nutrition is chemosynthetic production such as is found in the vicinity of hydrothermal vents and methane seeps, but such communities have not been reported in the deep Arctic Ocean; see https://homes.bio.psu.edu/people/faculty/fisher/cold_seeps/ and http://library.thinkquest.org/18828/ for more information on these communities).

To study food webs and coupling between the three biological realms, scientists on the Hidden Ocean expedition analyze naturally occurring stable isotopes of nitrogen, ^{14}N and ^{15}N. Because the ratio of these isotopes shifts by a predictable amount as they are passed up the food chain, the relative concentration of these isotopes can be used to estimate which trophic level an organism feeds upon. Isotope ratios are usually expressed as "δ" values in parts per thousand (‰) according to the equation

$$\delta X = [(R_{sample}/R_{standard}) - 1] \bullet 1{,}000$$

where X is ^{13}C or ^{15}N of the sample and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$.

In this lesson, students will analyze nitrogen isotope data from the 2002 Arctic Exploration expedition to make inferences about nutritional relationships between the three biological realms in the Canada Basin.

Learning Procedure

1. To become more familiar with the Hidden Ocean expedition, you may want to visit the expedition's Web page (http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html) for an overview of the expedition and background essays. You may also want to review essays and reports from the 2002 Arctic Exploration expedition (http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html).

2. Briefly review the geography of the Arctic Ocean, highlighting the location of the Canada Basin and the activities of the Hidden Ocean expedition. Introduce the "three realms" of marine life in the Canada Basin. You may also want to briefly discuss Arctic climate change and why it is so important to gather information on species that presently inhabit the three realms as soon as possible.

   Briefly review the concept of using stable isotope ratios to study food web relationships. Be sure students understand that $\delta^{15}N$ increases by about 3.3 – 3.8‰ between trophic levels. For purposes of this lesson, tell students to use an enrichment factor of 3.8‰. So, dividing the $\delta^{15}N$ composition of different organisms by 3.8 will give an indication of the relative trophic position of each organism in a food web.

3. Provide each student with a copy of "Mean $\delta^{15}N$ Ratios of Species in the Canada Basin". Tell students that their assignment is to analyze these data and use their analyses to make inferences about the trophic position of sympagic, pelagic, and benthic organisms in the Canada Basin marine food web.

4. Lead a group discussion to review students' results. Students' calculations of mean $\delta^{15}N$ ratios of sympagic, pelagic, and benthic organisms should resemble the following:

pelagic organisms	12.44‰
benthic organisms	13.70‰
sympagic organisms	6.46‰

   Dividing these values by an enrichment factor of 3.8‰ per trophic level suggests that there are four trophic levels in the overall food web. Organisms in the pelagic habitat cover a wide range of $\delta^{15}N$ values (e.g. Gastropoda and Decapoda) suggesting that several trophic levels are represented. In general, benthic organisms show the greatest enrichment. Ask student to speculate on the feeding strategies that produce the observed values. Students should realize that pelagic and sympagic species are predominantly herbivorous and predatory, and constitute a relatively short food chain based on primary production in sea ice and the upper water column. Benthic species, on the other hand, are more apt to be deposit feeders, relying on organic material and the remains of other animals produced in shallower depths. Ask students how they would interpret a benthic species with a $\delta^{15}N$ value of around 6. They should infer that such a species would represent a relatively lower trophic level, and was receiving its nutrition directly from a source of primary production. In the study upon which this lesson is based, a few benthic species with low $\delta^{15}N$ values were found, indicating that at least some material produced by photosynthetic organisms finds its way directly into the benthic realm. Be sure students understand that high $\delta^{15}N$ values do not necessarily signify "top predators." In this case, they are the result of consuming organic material that has been highly "reworked"; in other words, consuming materials that have been previously consumed by a number of other organisms.

The BRIDGE Connection

www.vims.edu/bridge/polar.html

The "Me" Connection

Have students write a brief essay describing one way in which improved understanding of Arctic food webs might be of personal benefit.

Connections to Other Subjects

English/Language Arts, Geography

Evaluation

Student analyses prepared in Learning Procedure Step 3 and group discussion in Step 4 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html to keep up to date with the latest 2005 Hidden Ocean Expedition discoveries.
2. Visit http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_lessonplans.html for more lesson plans and activities related to the 2002 Hidden Ocean expedition.

Resources

Iken, K., B. A. Bluhm, and R. Gradinger. Polar Biology 28:238-249 – The technical journal article on which this lesson is based.

Grebmeier, J. M., H. M. Feder, and C. P. McRoy, 1989. Pelagic-benthic coupling on the shelf of the northern Bering and Chukchi Seas. II. Benthic community structure. Marine Ecology Progress Series 51:253-268.

http://www.arctic.noaa.gov/ – NOAA's Arctic theme page with numerous links to other relevant sites.

http://maps.grida.no/arctic/ – Thematic maps of the Arctic region showing populations, ecoregions, etc.

http://www.thearctic.is/ – A Web resource on human-environment relationships in the Arctic.

http://www.dfo-mpo.gc.ca/regions/central/index-eng.htm — Web site produced by Fisheries and Oceans Canada on the Arctic.

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Structure of atoms

Content Standard C: Life Science

- Interdependence of organisms
- Matter, energy, and organization in living systems

Content Standard F: Science in Personal and Social Perspectives

- Natural resources

For More Information

Paula Keener, Director, Education Programs
NOAA Office of Ocean Exploration
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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http://oceanexplorer.noaa.gov

Student Handout

Mean $\delta^{15}N$ Ratios of Species in the Canada Basin

Taxon	Habitat	$\delta^{15}N$
Cnidaria		
Nausithoe	benthic	13.34
Sminthea arctica	pelagic	15.79
Mollusca		
Bivalvia	benthic	12.37
Gastropoda	pelagic	5.91
Scaphopoda	benthic	10.74
Polychaeta	benthic	15.33
Echiura	benthic	16.57
Crustacea		
Copepoda		
Paraeuchaeta	pelagic	12.57
Pseudocalanus	sympagic	5.49
Amphipoda		
Gammarus	sympagic	7.10
Apherusa	sympagic	6.78
Parathemisto	pelagic	10.47
Ostracoda	pelagic	12.27
Isopoda	benthic	15.57
Decapoda	pelagic	16.38
Echinodermata	benthic	11.99
Chaetognatha	pelagic	13.67