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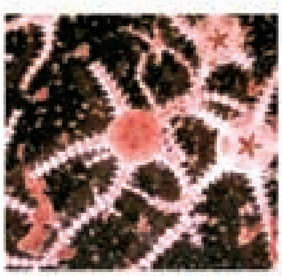
THE JOURNAL OF MARINE EDUCATION

Volume 19 • Number 2 • 2003

ARCTIC






EXPEDITION 2002

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, OFFICE OF OCEAN EXPLORATION

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THE JOURNAL OF MARINE EDUCATION

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CURRENT LOG *Through the Arctic Expedition in the summer 2002, the National Oceanic and Atmospheric Administration (NOAA) had a unique opportunity to reach out in new ways to educators, students, and the general public and share the excitement of daily at-sea discoveries–and the science behind this major ocean exploration initiative with people around the world. Since the Arctic Ocean is the world's least explored ocean, the Arctic Expedition held great potential for generating exciting outreach and educational opportunities, as an international team of 50 scientists from the United States, Canada, China, and Japan explored the frigid depths of the Canada Basin.*

Due to the region's heavy year-round ice cover, this expedition was the first one of its kind. With the aid of a remotely operated vehicle (ROV), specially designed to operate under ice and at great depth, scientists examined the hidden world of life in these extreme conditions. From intricate microscopic organisms found in the brine channels that run through the ice to the creatures that make the sea bottom their home, the science team studied the relationships between pelagic and benthic communities. In this issue of Current, *we present the science and education behind exploring one of Earth's most unknown ocean regions…the frigid, frozen, and very beautiful Arctic Ocean.*

PAULA KEENER-CHAVIS Paula Keener-Chavis is the National Education Coordinator for the National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean Exploration. She has conducted extensive marine fisheries research off the Southeastern coast of the U.S. and research off Belize, Central America, sponsored by the Smithsonian Institution. She has published scientific articles on her research and writes articles for a variety of publications. She is senior author of *Of Sand and Sea...Teachings From the South Carolina Shoreline.*

Keener-Chavis served as a member of The President's Panel on Ocean Exploration. She also served as a member of the Steering Committee for the Center for Ocean Science Education Excellence (COSEE) sponsored by the National Science Foundation. She represents the Office of Ocean Exploration on the NOAA Education Council. She recently served as a member of the National Academies Committee on Exploration of the Seas. She is a Past-President of the NMEA (2000-2001). She works with scientists and educators to produce lesson plans and Professional Development Institutes for NOAA's Ocean Exploration Expeditions and heads up the education initiatives for NOAA's Office of Ocean Exploration.

DR. VALERIE CHASE Dr. Valerie Chase is a consultant for formal and informal marine education. She recently retired as Director of Education at the National Aquarium in Baltimore (NAIB), after almost 23 years in program and curriculum design, teacher education, and exhibits at all levels. Trained as an ecologist, she switched from college professor to informal educator in 1980 and has published both scientific and educational research papers. She is the editor and first author of *Living in Water: An Aquatic Science Curriculum for Grades 5-7.* Her special projects have received funding from the National Science Foundation and the Howard Hughes Medical Institutes while at NAIB.

CONTENTS

2 Foreword
BY VALERIE CHASE

3 Introduction
BY CAPTAIN CRAIG MCLEAN

4 Exploration of the Canada Basin 2002
BY KATHLEEN CRANE, PH.D.

8 Arctic Sea Ice: Channels of Life
BY ROLF GRADINGER, PH.D.

10 Spineless Wonders: The Pelagic Fauna
BY RUSS HOPCROFT, PH.D.

13 Physical Nutrients and Primary Productivity
BY TERRY WHITELEDGE

15 Introduction to the Ocean Exploration Arctic Ocean Curriculum Unit
BY VALERIE CHASE, PH.D. AND MEL GOODWIN, PH.D.

18 Activity: Current Events
BY MEL GOODWIN, PH.D.

21 Activity: Life in the Crystal Palace
BY MEL GOODWIN, PH.D.

23 Activity: Meet the Arctic Benthos
BY MEL GOODWIN, PH.D.

26 Activity: Let's Get to the Bottom of the Arctic!
BY MEL GOODWIN, PH.D.

30 Activity: Would You Like a Sample?
BY MEL GOODWIN, PH.D.

36 Activity: Being Productive in the Arctic Ocean
BY MEL GOODWIN, PH.D.

45 Activity: Polar Bear Panic
BY MEL GOODWIN, PH.D.

48 Message From The BRIDGE: The Tip of the Iceberg
WRITTEN BY LAURA ROSE, ADAPTED FOR THIS PUBLICATION BY SUSANNA MUSICK

This issue of *Current* is sponsored by the National Oceanic and Atmospheric Administration's (NOAA's) Office of Ocean Exploration. The program is within NOAA Research.

Volume 19 • Number 2 • 2003

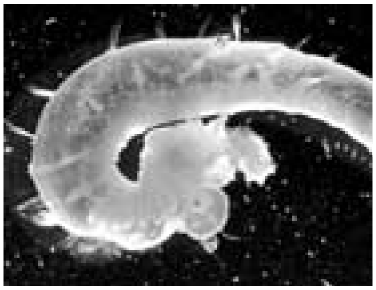
FOREWORD

BY VALERIE CHASE, PH.D.

IN 1977, *I was still a college biology professor, teaching ecology, biology, and botany. And in 1977, I started collecting papers about a topic I never expected to use professionally, just for the sheer excitement of following a stunning new scientific discovery. When my husband, Bill Johnson, and I went to the massive Christmas scientific meetings in Seattle in 1980, I literally ran from sessions in physiology and biochemistry and zoology to papers on oceanography, absorbing the results of research from that 1977 discovery–the exploration of the Galapagos deep-sea hydrothermal vents.*

The NOVA/National Geographic Society film from that expedition, "Dive to the Edge of Creation," remains one of the most effective visual productions ever made–communicating the absolute joy of scientific discovery. For years Bill used it in freshman biology with two messages in mind: 1) doing science can be just plain fun–the scientists on this expedition were clearly having the time of their lives; and 2) there are wonderful, exciting things left to be done–whole worlds to explore.

Why was I so entranced? We tend to think of and to teach science as a "done deal"–a set of facts which may be refined and studied in more detail at the molecular level. Yet here were whole new ecosystems, populated with things never before seen or even imagined, just waiting for us to find them. The years since 1977 have been rich with major new discoveries in ocean science exploration–spurred in part by new technological advances like remotely operated vehicles (ROVs) sustained by the continued modification of vessels like the *Alvin* with its new mother ship.



This polycheate worm was almost seven cm in length. Some of the scientists believe the white spots visible in the body are eggs.

In the intervening years since 1977, the bean counters have gotten the upper hand in funding science–there is more and more emphasis on funding programs and projects that are safe–with predicable outcomes and economic value. Grants are given to projects with neat and tidy research design. Looking for the unknown, just to see what is there, is not that easy to fund. The ocean science community has come together on an international scale to generate support for real ocean exploration–"going where no human has gone before" to quote Star Trek. The National Oceanic and Atmospheric Administration's (NOAA) Ocean Exploration program is a major part of that drive that enables ocean scientists to just go see what is there.

You can follow NOAA's Ocean Exploration efforts, reading about scientific discoveries that range from earth science to biochemistry first hand from scientists and educators using products like the ever expanding Ocean Explorer website http://oceanexplorer.noaa.gov with beautiful color images and graphics, CDs, and print publications. You can bring the process of science used in these discoveries to your classroom with inquiry-based activities, like those found in this issue of *Current*.

Think we know everything now? The content for this issue was totally new to me–finding new ecosystems in the Arctic, including ecosystems in the ice! So read and be amazed, check out the website, get the CD and share the joy of exploration and discovery with your students, your visitors, even your friends and family.

PHOTO CREDITS

Left: Photo courtesy of Casey Debenham
Bottom: Photo courtesy of NOAA

Dave Allen of the University of Washington examines microbiological samples collected during the Arctic expedition.

Volume 19 • Number 2 • 2003

INTRODUCTION

BY CAPTAIN CRAIG MCLEAN

GREAT TALES OF HISTORIC DISCOVERY AND HUMAN TRIUMPH have emerged in the exploration and discovery of the Arctic, from the successful search to occupy the northernmost position on the Earth, the true North Pole, to the courageous ventures of military submarines beneath the polar ice cap during the Cold War. But still, challenges remain. We have yet to submerge aquanauts to the seabed at the North Pole, or to completely map the dynamic ocean areas under the Arctic ice. We are still developing the autonomous devices that will one day replace human explorers and bring back the hidden truths of life under the ice.

The Arctic region holds many secrets awaiting discovery. The polar ice holds clues to our world climate, both in its history and in forecasting its rate of change. Novel organisms inhabit this unique ocean, both beneath and within the ice. And the question of whether the ocean waters of the world mix near the pole and to what extend, perhaps redistributing creatures that evolved in separate seas, is both real and important in our understanding of ocean life. In the Arctic, as in the rest of the world's oceans, many unknowns remain.

We had no trepidation in the National Oceanic and Atmospheric Administration (NOAA) when we decided to sponsor and contribute a U.S. component to an international multidisciplinary mission to the Arctic. In very few places can one look and not discover something new. It is one of the best places to demonstrate how little we know of our oceans, and our world under the sea. The project involved multiple scientific disciplines and countries, and was skillfully guided by the Captain and crew of a Canadian Coast Guard icebreaker. The science practiced on and under the Arctic ice tells some amazing stories about our planet, and the organisms inhabiting that planet, including ourselves. The opportunities were tremendous, and the results fulfilled our expectations.

The Ocean Exploration program in NOAA has set aside 10% of our funding for outreach and education. We provide tailored education and teaching modules developed by professional educators for every major scientific expedition that we conduct. These are posted on our website, www.oceanexplorer.noaa.gov, along with daily logs and images of our activities and discoveries at sea. Please use this resource and take the opportunity to incorporate oceans and ocean science in the teaching of basic science. As we inspire youngsters today to participate in the sciences and technology, we build our next generation of leaders and explorers, and a stronger Nation.

I am pleased that we can share some of the facets of the Arctic experience with you, and hope that the opportunities presented in this issue will provide the material to reach young science minds who themselves may come to dream of making their own trips and discoveries. We are again proud to provide sponsorship to another issue of *Current*, and to join you in conveying the excitement and reward of exploring the world's seas.

Captain Craig McLean is Director of NOAA's Office of Ocean Exploration.

Volume 19 • Number 2 • 2003

EXPLORATION OF THE CANADA BASIN 2002

BY KATHLEEN CRANE, PH.D.

THE ARCTIC OCEAN *and its permanent sea ice cover exert a great influence on our planet's climate. Measurements over the last 30 years indicate that the Arctic sea ice cover has been slowly thinning, perhaps as the result of global warming. However, even though the Arctic plays a pivotal role in the global warming scenario, global climate models, used to predict the impacts of warming, may be poorly constructed due to the lack of concrete oceanographic data from the Arctic region. Very little is actually known about the ecosystems of the ice-covered Arctic, or the physical and chemical oceanography of this remote region.*

Inaccessibility due to severe ice conditions makes the Canada Basin one of the Arctic Ocean's least known areas. Geologically, the Canada Basin is surrounded by the continental margins of Eastern Siberia, Alaska, Canada, and the Alpha-Mendeleev Ridge system. Further to the north lies the Lomonosov Ridge, which due to its shallow depth may inhibit the free flow of deep-water from the Amerasian Basin into the Canada Basin. Some geological reconstructions of the Arctic suggest that the Canada Basin may have been topographically isolated for millions of years from all the other ocean basins of the world. As a result of the physical isolation, migration of deep-sea life in and out of the area may have been greatly limited. Consequently, some scientists believe the basin could harbor an 'Isolated Eden' of undiscovered organisms that may have evolved along unique evolutionary pathways. These unique species may include novel microorganisms–extremophiles specially adapted to survive in the harsh Arctic environment. Studying the deep Arctic basins remained a challenge until recently because of its permanent multi-year ice cover. Drifting ice camps like T3 (Barnard, 1959) or NP22 (Melnikov, 1997) provided the first descriptions of the biota in the deep Arctic basins. The American trans-polar section in 1994 (Wheeler et al., 1996, Gosselin et al., 1997) revealed surprising insights into the biology of these areas, demonstrating large regional differences within the central Arctic, and higher biological activity in the ice and the water column than previously assumed. However, Pomeroy, 1997, refuted the claims of the decadal increase in primary production, based on a reassessment of the 1960s-1970s data from Tom English (English, 1961 and Pomeroy, 1997). Even with these attempts to describe life in the Arctic, until 2002, no scientist had ever mapped the spatial distribution of life in the water column of the Canada Basin in any comprehensive way. This remained a wide-open area for ocean exploration.

From left to right: Ian Macdonald, Russ Hopcroft , Kathy Crane, and Mike Vecchione aboard the ship, *Louis St. Laurent* in August of 2002.

In contrast to deep-water isolation, the intermediate and shallow waters of the Canada Basin are thought to be subjected to a decadal oscillation of the Beaufort High and Gyre, which stimulate change in current flow rates and direction. From 1979 to 1988 there was a remarkable shift in the location of the Beaufort High (over the Canada Basin). In consequence to the change, the direction of the transpolar drift of ice shifted, creating a new pathway of exit from the Arctic to the North Atlantic. During this period, the ice extent decreased 3% per decade, and most dramatically, ice thickness decreased 42% in the last 30 years, according to one study based on data collected by U.S. and Russian submarines in the central Arctic (Rothrock et al., 1999). (However, other information from the coastal regions, especially in the Canadian Archipelage, suggests thicker ice there.) Furthermore, over the last 100 years, the Arctic atmospheric variability oscillated on a quasi-decadal time frame. This phenomenon has become known as the 'Arctic Oscillation'.

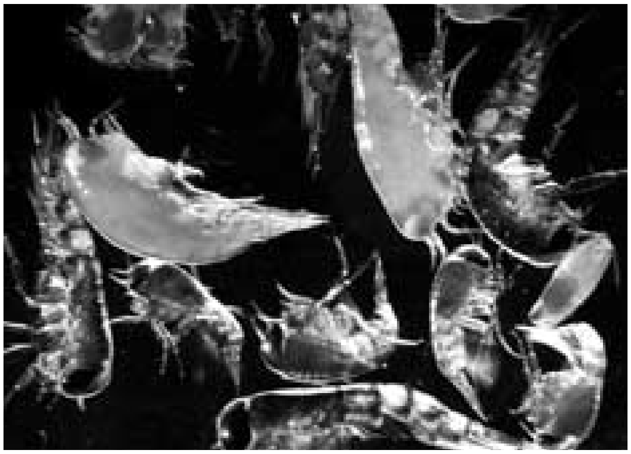
Since the 1970s the amplitude of the oscillations has increased. Perhaps in response to changed atmospheric circulation, Atlantic water has most recently been drawn up into the Arctic, intruding into the much colder Arctic waters. By 1992, the intruding Atlantic warm water core had reached the longitude of mid-Siberia. How fast and by what pathway the Atlantic water core travels remain unanswered questions. The possibility that invasive species could also travel with the core of the Atlantic water across the Arctic and into the Canada Basin is a area of inquiry that necessitates the collaborative efforts of biological, chemical, and physical oceanographers. How the intrusive waters of the Atlantic Ocean play on the instability of the physical and biological oceanography of the region is also unknown to date. In a region so poorly explored, the first order of business was to take the first step at a "census of marine life" in the Canada Basin from the sea surface to the seafloor below. Without a background inventory of life, it is impossible to monitor changes or the response of ecosystems to climate change in the Arctic.

Benthic scientists hoped that the box core, lowered from the ship's starboard side, would provide the backbone of data collected during the four-week expedition.

Qing Zhang, a member of the Chinese science team, removes a long cylindrical core of ice from the thick Arctic ice pack.

For the reasons mentioned above, we developed the Arctic-JWACS 2002 expedition. The expedition was funded by the NOAA Ocean Exploration and Arctic Research Offices, the Canadian Department of Fisheries and Oceans, the Japan Marine Science & Technology Center (JAMSTEC), and the Chinese Arctic and Antarctic Administration. Canadian Chief Scientist, Dr. Fiona McLaughlin, assisted by me as NOAA's Mission Coordinator, and Dr. Koji Shimada of JAMSTEC led the expedition. NOAA's partners in this expedition included the

Volume 19 • Number 2 • 2003



This amalgam of amphipods hints at the diversity of species scientists can find in the Arctic.

University of Alaska, the University of Washington, the Smithsonian Institution, Harbor Branch Oceanographic Institution, the Monterey Bay Aquarium Research Institute (MBARI), and institutes in China, Canada, and Japan. By using an exploration approach, while monitoring physical and chemical factors that affected communities, we hoped to create a foundation for future exploration and hypothesis-driven projects in this concealed frontier.

Forty-six scientists from the US, Canada, Japan, and China gathered by ship and charter aircraft at the town of Kugluktuk, Canada. The expedition on board the Canadian Coast Guard icebreaker *Louis St. Laurent* lasted 24 days, and covered 2,440 nautical miles, much of the time through ice-covered waters. At the outset we hoped to gather video imagery and take samples using a remotely operated vehicle (ROV) from the ice to the seafloor of the Canada Basin. However, at the initial planning stages, no existing ROV could meet our criteria of portability, low-cost, and ability to operate at depth under ice. With a slim time and funding margin, we hired Deep Sea Systems to build us the Global Explorer, a compact flyaway vehicle system, which could descend to 2,900 m for prolonged operations (Sea Technology, Dec. 2002).

A stern-view of the 392-ft. Canadian Coast Guard Ship, the *Louis St. Laurent*.

During the expedition, we sampled and imaged the biota of the Canada Basin and its peripheral regions by using both the ROV *Deep Explorer*, and under-ice divers, combined with a suite of traditional sampling technologies ranging from ice cores and nets, to pumps and box cores. We gleaned information from the entire water column in four critical areas: the eastern and western sides of the basin, the top of the Northwind Ridge, and the Northwind Basin. We studied life in the ice, under the ice, in the water column, and on the seafloor. Our subjects ranged from macrofauna to microflora.

We conducted an extensive and locally intensive survey of the ice cover and its variation in thickness over space and time, and of the biology and geochemistry of the seabed and near-bottom water column. We characterized the geochemistry of surficial sediments, where possible; measured temperature, salinity, nutrients, and conservative tracers over the full depth of the water column; cataloged macrobiota (larger creatures) living in the ice, in the water column or on or near the seafloor; conducted initial characterizations of benthic (bottom-dwelling) and pelagic (deep-water) species diversity; and correlated the ecological structure of major benthic and pelagic communities with oceanic and geological features. Sediment cores were also collected to help reconstruct climate history and paleo-ecological events in the Arctic Ocean.

Educators, media specialists, and data managers were involved from the beginning in the Arctic Ocean Expedition. Working with divers from the Canadian Department of Oceans and Fisheries, a team of under-ice divers and photographers from the *National Geographic Magazine* photographed, videotaped, and sampled the creatures in this deep-sea ecosystem. Educators and scientists working with NOAA during August 2002 developed a series of lesson plans for students in Grades 5 through 12 that are specifically tied to the Arctic Exploration Expedition. These lesson plans focus on the importance of ocean exploration and the research taking place during the Arctic Ocean, and feature such topics as primary productivity and limiting factors, climate change, benthic communities, and sampling strategies in the Arctic region.

KATHY CRANE is NOAA Mission Coordinator for the Arctic Expedition 2002. In addition to her position as Program Manager in the Arctic Research Group of NOAA, she is also employed as a Professor of Oceanography at Hunter College, the City University of New York, and maintains affiliations with the Lamont-Doherty Earth Observatory. She has been a visiting

scientist at the University of California, Santa Barbara; the University of Hawaii; the University of Oslo, Norway; the University of Paris, France; and at the Environmental Defense Fund, where she developed the Arctic At Risk Program.

REFERENCES

Auel, H. & Hagen, W. 2002. "Mesozooplankton Community Structure, Abundance and Biomass in the Central Arctic Ocean." Mar. Biol., 140, 1013-1021.

Carey, A.G. 1985. "Marine Ice Fauna: Arctic." In: Horner, R. (eds) Sea Ice Biota. CRC Press, Boca Raton, pp. 173-190.

Carey, A. G. Jr., 1992. "The Ice Fauna in the Shallow Southwestern Beaufort Sea, Arctic Ocean." J. Mar. Syst. 3: 225-236.

English, T. S. 1961. "Some Biological Oceanographic Observations in the Central North Polar Sea, Drift Station Alpha, 1957-1958." Arctic Inst. N. Am. Sci. Rep., 15, 79 pp.

Gosselin, M., Levasseur, M., Wheeler, P.A., Horner, R.A., & Booth, B.C. 1997. "New Measurements of Phytoplankton and Ice Algal Production in the Arctic Ocean." Deep-Sea Res. 44: 1623-1644.

Gradinger, R. 1999a. "Integrated Abundances and Biomass of Sympagic Meiofauna from Arctic and Antarctic Pack Ice." Polar Biol. 22: 169-177.

Gradinger, R. 1999b. "Vertical Fine Structure of Algal Biomass and Composition in Arctic pack Ice." Mar. Biol. 133: 745-754.

Gradinger, R., C. Friedrich, & M. Spindler. 1999. "Abundance, Biomass and Composition of the Sea Ice Biota of the Greenland Sea Pack Ice." Deep-Sea Res. 46: 1457-1472.

Gradinger, R., M. Spindler, & D. Henschel. 1991. "Development of Arctic Sea-Ice Organisms Under Graded Snow Cover." Polar Res. 10: 295-307.

Horner, R. 1985. *Sea Ice Biota*, CRC Press, Boca Raton, 215pp.

Ikävalko, J. & Gradinger, R. 1997. "Flagellates and Heliozoans in the Greenland Sea Ice Studied Alive Using Light Microscopy." Polar Biol. 17: 473-481.

Lowry, L. F., Frost, K. J., and Burns, J. J. 1981. "Trophic Relationships among Ice-Inhabiting Phocid Seals and Functionally Related Marine Mammals." NOAA/OMPA Princ. Invest. Rep. Environ. Assess. Alaskan Cont. Shelf., pp. 149-189.

Maranger, R., D.F. Bird, & S.K. Juniper 1994. "Viral and Bacterial Dynamics in Arctic Sea Ice During the Spring Algal Bloom near Resolute, N.W.T., Canada." Mar. Ecol. Prog. Ser. 111: 121-127.

Melnikov, I.A. 1997. The Arctic Sea Ice Ecosystem. Gordon Breach Sci. Publ., Amsterdam.

Melnikov, I., Zhitina, L.S. & Kolosova, H.G. 2001. "The Arctic Sea Ice Biological Communities in Recent Environmental Changes," Mem. Natl. Inst. Polar Res. Spec. Issue 54: 409-416.

Pomeroy, L. R. 1997. "Primary Production in the Arctic Ocean Estimated from Dissolved Oxygen." J. Mar. Systems 10:1-8.

Smith, R.E.H., P. Clement & G.F. Cota. 1989. "Population Dynamics of Bacteria in Arctic Sea Ice." Microb. Ecol. 17: 63-76.

Terazaki, M. & Miller, C.B. 1982. "Reproduction of Meso- and Bathypelagic Chaetognaths in the genus Eukrohnia." Mar. Biol., 71, 193-196.

Thomsen, H. A. & J. Ikävalko, 1997. "Species of Thaumatomastix (Thaumatomastigidae, Protista incertae sedis) from the Arctic Sea Ice Biota (North-east Water Polynya, NE Greenland)." J. Mar. Syst. 10: 263-277.

Weissenberger, J., G. Dieckmann, R. Gradinger & M. Spindler. 1992. "Sea Ice: A Cast Technique to Examine and Analyze Brine Pockets and Channel Structure." Limnol. Oceanogr. 37: 179-183.

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Page 5 (left): Courtesy of Mike Vecchione, NOAA/Smithsonian Institution.

Page 5 (right): Courtesy of Emory Kristof, National Geographic Society

Page 6 (top): Courtesy of Russ Hopcroft, University of Alaska Fairbanks

Page 6 (bottom): Courtesy of David Huntley

Volume 19 • Number 2 • 2003

Arctic Sea Ice: Channels of Life

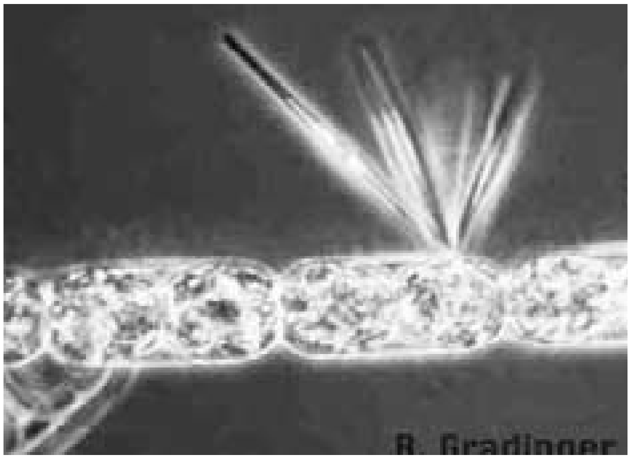
By Rolf Gradinger, Ph.D.

Sea ice is a unique feature of the polar oceans. *Its extent and thickness vary with the seasons. Ice is mainly formed during the winter months and melts in summer. In the Arctic, about 50% (7 million square km) of the winter sea ice melts during the warmer months. Typically, the thickness of "level" sea ice ranges from two to four meters.*

A COMPLEX STRUCTURE

When sea ice forms, small spaces between the ice crystals remain and are filled with a salty solution, called brine. Thus, sea ice consists of a mixture of ice crystals and brine channels, which form a three-dimensional network of tubes with diameters of a few micrometers to several centimeters. A specialized, sympagic (ice-associated) community has adapted to the variable conditions in this matrix. In 1852, Sutherland was the first to describe life in Arctic sea ice as "minute vegetable forms of exquisite beauty." More than 100 years later, in 1985, Rita Horner published the milestone book *Sea Ice Biota*, which is till the standard textbook concerning the history and scientific progress of sea-ice research.

Since then, a wealth of new information has been gathered concerning the structural role of sea ice in both the Arctic and Antarctic. Studying the deep Arctic basins remained a challenge because of its permanent multi-year ice cover and many unsolved scientific questions. American and Russian drifting ice camps, such as T3 and NP22, produced the first descriptions of the biota in these deep basins. In 1994, the American trans-polar section revealed surprising insights into the biology of these areas, demonstrating large regional differences within the central Arctic and much higher biological activity in the ice and the water column than was previously assumed.



Light microscopic image of Arctic ice diatoms: *Melosira arctica* with ephytic diatoms.

A MICROSCOPIC HAVEN

Until recently, diatoms were considered to be the most important microorganisms inside the ice in terms of abundance and productivity, but a greater complexity is now appreciated. Several hundred unicellular species of algae are the main primary producers in this environment. Largely based on studies of sea ice known as "coastal fast" and "first-year level" ice, algal primary production contributes from 4 to 26% of the total primary production in seasonally ice-covered Arctic waters. This fraction can be expected to increase to 50% or more in perennially ice-covered waters due to the reduction in shortwave radiation penetrating the water column.

The production of dissolved organic material within the ice, mainly from the waste of ice algae, supports the growth of ice bacteria. Viruses and fungi also have a surprisingly high biological diversity within this extreme habitat. Small protozoans and metazoans, in particular turbellarians, crustaceans, and rotifers, feed on ice algae and may, in certain periods or locations, restrict the growth of algae.

Ice organisms tolerate a wide range of environmental conditions and experience rapid changes in light intensity, temperature, and salinity. These fluctuations cause an uneven distribution of the ice biota within the floes, with the bulk of the organism biomass concentrated in the lowermost centimeters of ice floes. Strong interactions between the ice biota and plankton exist during periods of complete ice coverage.

A unique, partially endemic fauna, comprising mainly tiny crustaceans (amphipods), thrive permanently at the underside of the ice floes. Moving along the bottom of the ice, they feed

Polar bears use sea ice for migration and hunting.

The ice cover of the Arctic Seas consists of individual ice floes separated by areas of open waters (leads or polynyas).

directly on the bottom community and use brine channels as shelter against possible predators. They serve as mediators for particulate organic matter from the sea ice to the water column and benthos (ocean bottom) through the release of wastes and as food for fish and seals.

Juvenile stages of zooplankton and meroplanktonic larvae of benthic organisms also enter the brine channel network on shallow Arctic shelves to feed on the rich ice bottom community while being relatively well protected from pelagic predators. In early spring, when the water column is still devoid of food, calanoid copepods, such as *Calanus glacialis*, perform diel (daily) vertical migrations from deeper parts of the water column to feed on phytoplankton that accumulate just below the ice. Thus, ice production is linked with the other Arctic marine realms through sedimentation and life cycles.

A LITTLE-KNOWN REALM

The multi-year sea ice cover of the high Arctic, especially within the Canadian Basin, has been poorly studied. It may be that these areas, which form oases for species aggregations and production in the central Arctic, are the most sensitive to global climate change–yet we know very little about them.

The extent of sea ice in the Arctic has decreased by about 2.8% per decade since 1978. Ice-thickness studies by submarines indicate a tremendous decrease in the mean ice thickness and ice volume.

Arctic exploration tackles questions concerning the existence of life in this unique environment, looking for life on top of the ice, in its interior, and at the ice-ocean boundary layer. These studies will help us to understand the marine biology of the Arctic as a whole and will also support climate predictions in an ever-changing world.

ROLF GRADINGER, PH.D. has been working on the marine biology of ice covered waters since his first ship expedition to the area between Greenland and Spitsbergen in 1984. Since then, he has participated in 14 expeditions to the Arctic and Antarctica, mostly working on the food web dynamics of ice associated communities. Since January 2001, Dr. Gradinger has been an Assistant Professor at the Institute of Marine Science in Fairbanks, studying the sea ice biota in coastal and shelf areas of the Chukchi and Beaufort Seas.

PHOTO CREDITS:

Courtesy of Rolf Gradinger

Volume 19 • Number 2 • 2003

SPINELESS WONDERS: THE PELAGIC FAUNA

BY RUSS HOPCROFT, PH.D.

OVERVIEW

For more than 100 years, we have collected animals that drift in the water column with plankton nets. These nets are pulled blindly through the water, collecting primarily the smaller, slower, more numerous and more robust species. Thus, we have been able to adequately sample only a small fraction of the diversity present in the pelagic realm. As a result, we have a notable gap in our understanding of the linkages between algal production, the production of planktonic herbivores, and in turn the production of their predators in the oceans. We are unable to accurately predict when, where, and how these soft-bodied animals regulate the flow of the materials and energy through oceanic food webs. In contrast, we know a great deal about the more numerous crustacean zooplankton such as the copepods (the sea's insects) and euphausiids (krill) throughout the world's oceans.

Remotely operated vehicles (ROVs) and submersibles offer opportunities for direct observations of the species that are normally missed by plankton nets because they are too rare, too fragile, or too fast for us to catch. Undersea vehicles have substantially expanded our knowledge about behavior, biodiversity, and vertical distribution of pelagic animals. In addition, submersible tools can permit us to capture live, undamaged specimens. ROVs and submersibles also allow us to make observations on finer scales of space and time than is possible by plankton nets.

During the August 2002 Arctic Exploration expedition, we searched the water column under the Arctic ice-sheet for new species of gelatinous zooplankton and cephalopods. We photographed living animals and their behavior, and we

The large copepods, such as *Calanus hyperboreus*, are one of the most dominant players in Arctic and subarctic pelagic ecosystems.

collected specimens for morphological analysis and molecular fingerprinting. We also planned to assess the vertical distribution and abundance of this fauna relative to that of potential prey and the physical structure of the water column.

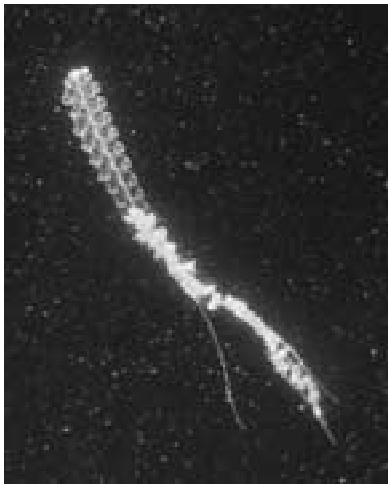
PELAGIC FAUNA IN THE ARCTIC

Gelatinous zooplankton are translucent creatures, often vividly pigmented, as bizarre as they are beautiful. These animals are ubiquitous in the oceans, and many species have persisted for hundred of millions of years. However, we know relatively little about species such as ctenophores, siphonophores, hydromedusae, scyphomedusae, pteropods, heteropods, and pelagic tunicates like salps, doliolids, pyrosomes, and larvaceans. The most obvious explanation for this disparity is their extreme fragility. Collecting these animals with nets usually destroys most soft-bodied species or breaks them into fragments that are usually ignored, discarded, misidentified, or simply recorded as "jelly." Furthermore, conventional preservatives typically dissolve the natural rich iridescent colors of live animals and often liquefy them.

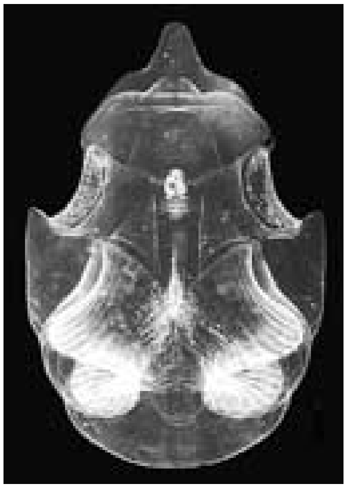
Therefore, it is not surprising that scientists underestimate the basic biodiversity as well as the biomass and abundance of gelatinous animals, especially in Arctic seas. Historically, some scientists assumed that zooplankton are unimportant to ecosystem function. However, recent investigations have demonstrated that these soft-bodied animals are capable of much higher rates of ingestion, growth, and reproduction than crustaceans, which allows them to respond more rapidly to shifts in primary productivity. This fact is especially true in Arctic polynyas, and large populations have been recorded in the Bering Straits.

Until recently, the importance of large populations of carnivorous species has been unappreciated in Arctic surface waters. For example, in the eastern Canadian high Arctic, we have estimated that the ctenophores consume up to 9% of the populations of the larger copepods every day. We expect that other gelatinous predators, when numerous, will have similar ecological impacts, particularly medusae and perhaps siphonophores. Several marine scientists have observed mounds of jellyfishes several feet high, extending for miles along the shoreline near Barrow, Alaska.

During the August 2002 expedition, we expected to find many unidentified species of predators, including ctenophores, siphonophores, hydromedusae, and scyphomedusae. These species feed on copepods, euphausiids, larvaceans, other jellies, and fishes. By learning more about the diversity, occurrence, and density of these groups, we are better able to make predictions about their impact on prey populations in the Arctic.

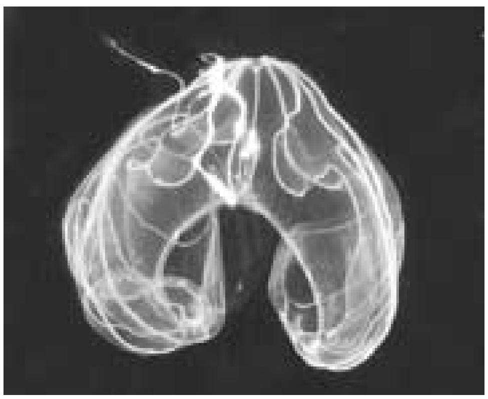


The physonect siphonophores are actually colonies of individuals, each specialized for different functions such as swimming, feeding, and reproduction.

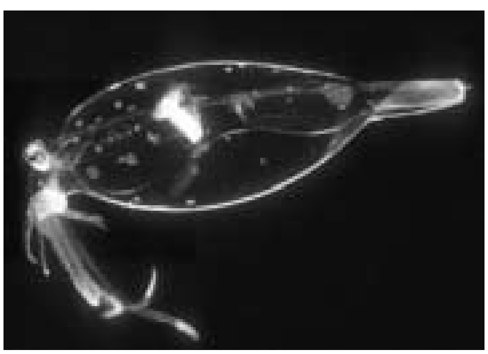


This larvacean called *Oikopleura labradoriensis* produces a fragile mucus 'house' to help it filter small particles from the water.

This small jellyfish has many small golden droplets of oil. The larger white spheres are eggs.



This is an example of a ctenophore, *Bathocyroe fosteri*, which is a mesopelagic species.



Though the squid we eat are muscular, mesopelagic forms such as this cranchiid squid can be relatively gelatinous and transparent.

Presently, the number of species recognized for each group varies depending on the source. A review of the major papers and monographs indicates six species of ctenophores, 45 species of medusae, 12 species of siphonophores, four species of pteropods, and five species of larvaceans. Based on our submersible experience in other oceans, we expected to find at least twice as many species in each group during the 2002 expedition.

In contrast to the fragile gelatinous zooplankton, we know even less about Arctic cephalopods because they are adept at avoiding nets and trawls. We used the ROV as a beacon for pelagic cephalopods that come to feed on fishes and crustaceans which are dazed by the lights of the vehicle. Observations of cephalopods in the water are particularly useful because we can see swimming behaviors and subtle taxonomic characters such as color patterns and skin texture. Gentle collection of specimens with ROV samplers also provided us with accurate records of size and other useful shape measurements.

Although cephalopods play an important role in Arctic food webs as effective predators, we still know little about cephalopod fauna. In fact, we know of only seven cephalopod species that reside in the Arctic, and we know nothing about their ecological roles. Recent research on Antarctic cephalopods has revealed a much higher diversity than we first believed, which is similar to what we expected for the Arctic region.

RUSS HOPCROFT, PH.D. is an Assistant Professor at the University of Alaska's Institute of Marine Science in Fairbanks. Dr. Hopcroft pursues a broad array of research interests, concentrating on the "lower" planktonic trophic levels that ultimately shape the structure of all aquatic communities. His research focuses on the composition, production and energy flow of pelagic ecosystems, and better methods to explore these topics. Although much of his research focuses on copepod and euphausiid crustaceans, he also specializes on the taxonomy, biology, and ecology of the larvacean pelagic tunicates.

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Volume 19 • Number 2 • 2003

PHYSICAL NUTRIENTS AND PRIMARY PRODUCTIVITY

BY TERRY WHITELEDGE, PH.D.

OVERVIEWS

The waters in the Arctic Ocean have not been studied as much as the other oceans because of the difficulty of collecting samples in the cold temperatures and thick ice cover. As a result, we have only recently started to understand how the plant and animal organisms can survive in such a harsh environment. Nearly 40 years ago, water and organisms were sampled from a drifting ice island (known as Fletcher's ice island or T3) as it meandered around the Arctic Basin. The semi-permanent science station was manned for several years and produced most of the early data. However, recent improvements in sampling from icebreakers and nuclear submarines have greatly improved our knowledge of fertility of Arctic Ocean water and the growth of plankton and algae in the water column and ice. However, there is still much that is unknown about the biota of our northern most ocean. The Arctic exploration cruise greatly improved the knowledge of the interactions of water currents, nutrients, and other conditions required for growth of plankton in the water for comparison with sea ice communities. The cruise allowed us to better understand the food that is available to feed all of the animals that live in the Arctic Ocean.

A view from the bow of the *Louis St. Laurent* shows a lead. Ice leads are cracks in the thick ice cover that vessels use because it minimalizes time spent breaking through the ice.

THE PROBLEMS OF COLLECTING SAMPLES

Collecting samples of ice and water in the Arctic is often challenging and dangerous. When large icebreakers are used, many areas of the Arctic Ocean can be sampled, but the ice conditions are often too difficult for them when large ridges of broken ice form. These ridges may be 30-40 feet high and may extend to almost 100 feet below the surface. The ice in the Arctic is very hard, so icebreakers must go very slowly as they travel to the sampling stations. Often, the icebreakers may only travel 1-2 miles per day when thick ice is encountered. Helicopters are normally used to look for cracks in the ice, called leads (pronounced as "leeds"). If a good lead can be found, several additional miles may be covered each day. Once the ship arrives at the sampling station, there still remains the difficulty of obtaining water and ice samples. If the ice is thin, the ship may be able to create a hole through which sampling gear can be lowered. The ship and ice are in constant motion due to the wind and water currents, so the hole in the ice may disappear rather quickly and the sampling gear may be lost. Scientists and equipment may be lowered to the ice to collect samples if conditions are safe. Small holes are drilled into the ice with augers to collect ice samples and may be used to lower water sampling bottles into the water below. Collecting samples on the ice is difficult, but is often the best way to obtain samples that are not affected by the large ship.

DISSOLVED NUTRIENTS-THE FERTILIZER IN SEAWATER

The nutrients dissolved in seawater are similar to the fertilizer used to feed a lawn. The nitrogen, phosphorus, and silicon nutrients are used by the tiny single-celled plants to grow. The amount of nutrients in various parts of the ocean varies, depending on ocean currents and proximity to land. Many of the nutrients are derived from the weathering of rocks on land and carried into the ocean by rivers. As a result, many of the nutrient rich oceanic areas are near river mouths. The nutrients can also be recycled in the ocean with the decay of plant and animal matter by bacterial processes. In general, dissolved nutrients have the highest concentrations close to land or deeper in the ocean. The Arctic Ocean receives nutrients from the currents flowing from both the Atlantic and Pacific oceans and from the various rivers. The nutrient concentrations in the water flowing from the Atlantic Ocean are smaller that those

Volume 19 • Number 2 • 2003

The science team lowers a string of sample bottles through holes drilled in the ice to collect plankton at different water levels. Notice the polar bear observer standing to the left.

from the Pacific Ocean. The nutrient concentrations, therefore, can often be used to identify the origin of the water.

GROWTH OF PLANTS IN ICE-COVERED WATERS

The growth of the single-celled plants in the ocean known as phytoplankton requires nutrient and sunlight to support the process known as photosynthesis. Obtaining enough sunlight to grow is a big problem for phytoplankton in the Arctic Ocean. During several of the winter months, the sun does not rise above the horizon, so very little sunlight is available. In addition, the snow and ice covering the water often absorb or reflect most of the sunlight during the months with sunlight. During the summer months when the snow cover melts, and holes in the ice appear, is the only period when quite a lot of sunlight is available for the phytoplankton to grow. Early estimates of phytoplankton growth rates from the T3 ice island indicated that the Arctic Ocean had the lowest values of all the oceans. More recent measurements have indicated that the early values were underestimated by a factor of 2-10. The Arctic Exploration cruise took special efforts to obtain phytoplankton growth rates under the ice and in open water leads. These measurements will then be compared to plankton growth rates measured inside the ice.

The science team carries their equipment to a sample site away from the *Louis St. Laurent* in an effort to obtain samples that will not be affected by the ship's presence.

TERRY WHITELEDGE, PH.D. is a chemical/biological oceanographer who has been studying the Bering Sea and Arctic Ocean for more than 25 years with respect to nutrient dynamics and responses by the plankton communities. The requirement of light and inorganic nutrients by phytoplankton in order to grow often controls the food available to the higher tropic levels such as zooplankton and fishes. The complex interactions of winds, changing temperatures, ice cover, and freshwater input from the land create a physical environment that is nearly always changing and causes the growth of plankton to respond to a wide range of environmental conditions. The object of the Arctic Exploration studies is to document some of the nutrient and light effects on phytoplankton growth under the ice and in open water where it occurs. Analysis of the salinity and temperature along with nutrient and light conditions will allow for future predictions of the effects of global climate change in the Arctic as temperatures increase and ice cover diminishes.

PHOTO CREDITS:

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Volume 19 • Number 2 • 2003

INTRODUCTION TO THE OCEAN EXPLORATION ARCTIC OCEAN CURRICULUM UNIT

BY VALERIE CHASE, PH.D. AND MEL GOODWIN, PH.D.

ARCTIC OCEAN GEOGRAPHY

The Arctic Ocean is the world's least explored ocean. NOAA's Ocean Exploration to the Arctic, as well as other scientific expeditions, is currently providing expanded knowledge of this polar frontier. The Arctic Ocean is the smallest of the world's four ocean basins–a total area of about 5.4 million square miles or 14 million square kilometers. That is roughly 1.5 times the size of the United States. Greenland, Canada, Alaska, Norway, and Russia are its borders. Since it has the widest continental shelf of any ocean, extending as much as 750 mi (1,210 km) from the coast, much of the Arctic Ocean is shallow. There are, however, areas that are quite deep. The average depth is 12,000 ft (3,658 m), and the maximum depth is 17,850 ft (5,441 m). The Arctic Ocean exchanges water with both the Atlantic and the Pacific Oceans. The Chukchi Sea connects the Arctic Ocean to the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow. Most water exchange is with the Atlantic Ocean via the Greenland Sea.

The 24-day Arctic Expedition in the summer of 2002 focused on the deep and poorly understood Canada Basin.

Scientists were surprised to find evidence of reproduction late in the Arctic summer. This copepod (Family Aetideidae), laden with eggs, was captured in a net tow by the Pelagic Ecological Group.

The Arctic Ocean is not easily explored. It is covered almost entirely by ice for eight months of the year. A drifting polar ice pack covers the central and western portions year-round, and the sea temperature seldom rises above 0˚C. Three submarine ridges divide the floor of the Arctic Ocean: the Alpha, Lomonosov, and the Arctic Mid-Oceanic Ridges. The Lomonosov Ridge creates a relatively isolated area known as the Canadian Basin. The Canadian Basin is of particular scientific interest because its isolation could have resulted in the evolution of unique lifeforms.

ARCTIC OCEAN COMMUNITIES

Three distinct biological communities are currently recognized in the Arctic Ocean:

The Sea-Ice Realm includes organisms that live on, in, or just under the drifting surface ice. Because only 50% of the ice melts in the summer, ice flows may persist for many years and reach a thickness of more than six ft (two m). Sea ice is not usually solid like an ice cube, but rather is riddled with a network of tunnels called brine channels because they are saltier than sea water. These channels range in size from

This mother polar bear and two cubs were spotted leaping between ice floes early in the cruise.

microscopic–a few thousandths of a millimeter–to more than an inch in diameter.

Diatoms and other algae live in these channels. They use energy from sunlight to produce biological material through photosynthesis. Bacteria and fungi also live in the channels. Together with diatoms and other algae, they provide food for flatworms, crustaceans, and other invertebrates. This community of organisms is called sympagic, which means ice-associated.

In autumn, temperatures at the upper surface of the ice decrease with the approach of winter, causing more ice to build up. As the ice solidifies, brine channels become smaller. The brine between the ice crystals becomes saltier still. Brine salinities may reach 250 parts per thousand near the ice surface, whereas normal sea water has a salinity of about 35 parts per thousand. At such high salinities, the salts begin to precipitate as

This *Chrysaora* jelly was spotted on the ROV's return to the surface. Unfortunately, it was too large to capture with the suction sampler.

opaque minerals. This extreme salinity creates osmotic challenges for the organisms living in the brine.

In winter, an ice-dwelling organism's survival depends on its ability to prevent the formation of ice crystals in its body during the extreme cold. Many organisms accumulate large deposits of organic molecules and fat-like materials which act as antifreeze. The ice itself has insulating properties, so while temperatures at the surface of the ice may be as cold as -35°C, the temperature at the bottom of the ice is the same as the adjacent sea water–about -2°C.

Partial sea ice melting during the spring and summer produces ponds on the ice surface that develop their own assemblage of organisms. Melting ice also releases organisms and nutrients to the ocean water and its inhabitants below the ice.

Masses of algae form at the ice-sea water interface in spring and summer. They may form filaments several meters long. On average, more than 50% of the primary productivity in the Arctic Ocean comes from algae that live near the ice-sea water junction. Consequently, this interface is critical to the polar marine ecosystem. In addition to providing food for many organisms, the sea-ice interface also provides 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. Additionally, polar bears use the ice surface for migration.

The Pelagic Realm includes organisms that live in the open water between the ocean surface and the bottom–in the water column or pelagic zone. As sea ice melts in the summer, the reduced ice surface and thinner ice allows more light to enter the water below. Algae in the water column grow rapidly in summer, also aided by almost constant daylight. These algae provide food for a variety of drifting (planktonic) animals or zooplankton, including crustaceans and jellyfish. These zooplankton, in turn, are food for larger pelagic animals including fish, squid, seals, and whales.

The Benthic Realm includes organisms that are on or attach to the ocean floor. When pelagic organisms die, they settle to the ocean bottom where they become food for bottom-dwelling, or benthic, organisms. Sponges, bivalves, crustaceans, polychaete worms, sea anemones, bryozoans, tunicates, and ascidians are common members of Arctic benthic communities. These animals, in turn, are food for bottom-feeding fish as well as whales and seals.

Most of our knowledge about Arctic Ocean communities comes from studies on portions of the ocean near the continental shelves. Very little research has been done on the Sea Ice, Pelagic, and Benthic Realms in the deeper parts of the Arctic Ocean. These areas were the focus of NOAA's 2002 Arctic Ocean Expedition.

ROPOS being deployed for deep water operations inside its steel cage.

Because the deep Arctic Ocean is virtually unexplored, the first questions researchers want to investigate are fairly basic: what are the physical conditions of the Benthic Realm; what organisms make up the realm's biological communities; and how do these organisms obtain energy? Traditionally, investigations of benthic communities have used various mechanical devices such as grabs, dredges, or cores, to obtain samples of sediments and living organisms. These devices often damage living specimens and may miss some species entirely. Only a small fraction of the total habitat can actually be sampled, and some species are able to avoid the sampling device. To reduce these problems, researchers on the Arctic Ocean Expedition used a deep-diving remotely operated vehicle (ROV) known as *ROPOS*, short for *Remotely Operated Platform for Ocean Science*, to obtain photographs and video recordings of the study area. This ROV also has a variety of manipulator arms and sampling devices, so researchers were able to obtain specimens of organisms they see on video for further examination and identification.

ARCTIC OCEAN CURRICULUM UNIT

The Arctic Ocean Expedition activities on pages 18-47 are presented in an order that leads students to an ever deeper understanding about the Arctic Ocean, its unique communities of organisms, and their adaptations for survival under challenging conditions. Along the way, you and your students will encounter organisms unlike anything you have ever seen. The activities are most appropriate for secondary students. You may elect to use only a few or follow the entire sequence. A description of each activity follows:

• *Current Events*: A hands-on examination of the role of salinity and temperature in ocean circulation patterns

• *Life in the Crystal Palace*: Students use library and Internet research to study the common groups of invertebrates living in the Sea-Ice Realm and then make models to demonstrate their understanding of adaptations to sympagic lifestyles.

• *Meet the Arctic Benthos*: Students use library and Internet research to study the diverse groups of benthic invertebrates found in the Arctic Ocean, write and/or give reports, and place examples of their organisms on a benthic habitats, cross section.

• *Let's Get to the Bottom of the Arctic*: Students use data from the Arctic Ocean to infer the connections between bottom sediment texture and community species composition.

• *Would You Like a Sample?*: Complicated to set up the first time, this exercise enables your students to model the behavior of ocean scientists, trying to learn as much about benthic communities as possible during the short Arctic summer; uses mathematics and produces realistic data; must have an Internet connection to download the cards.

• *Being Productive in the Arctic Ocean*: Students use real research data to study the limits to primary production in the Arctic Pelagic Realm.

• *Polar Bear Panic*: Students explore whether or not the thickness and extent of Arctic Ocean sea ice changes with time.

VALERIE CHASE, PH.D. started out on a path to be a research biologist, but got waylaid by a love of teaching. After seven years as a college professor, she resigned to move to Maryland so she could live under the same roof as her marine ecologist husband. She stumbled onto a job at the then unbuilt National Aquarium in Baltimore, where she worked in education and exhibits for almost 23 years before retiring in the fall of 2002.

MEL GOODWIN, PH.D. works in the office of The Harmony Project in Charleston, South Carolina for the National Oceanic and Atmospheric Administration—and wrote all the activities for the "Ocean Exploration Arctic Ocean Curriculum Unit" on pages 18-47."

PHOTO CREDITS

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Volume 19 • Number 2 • 2003

ACTIVITY: CURRENT EVENTS

BY MEL GOODWIN, PH.D.

FOCUS

Currents and water circulation in the Arctic Ocean

GRADE LEVEL

Secondary Earth Science

FOCUS QUESTION

What factors drive water circulation in the Arctic Ocean?

LEARNING OBJECTIVES

Students will identify several of the primary driving forces for ocean currents.

Students will infer the type of water circulation to be expected in the Arctic Ocean, given information on temperature, salinity, and bathymetry.

MATERIALS

- ❏ *Influence of Salinity on Density and Influence of Temperature on Density* activity sheets, one for each student group
- ❏ Maps of: Arctic Region printed on overhead sheets from http://www.lib.utexas.edu/maps/islands_oceans_poles/arctic_ ref802647_1999.jpg
  Arctic Ocean Bathymetry from http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/current map.html
- ❏ *Diagram of Arctic Ocean Water Structure* from http://www.grida.no/db/maps/arctic/pages/arcticwater-structure.htm
- ❏ Data sheet sets of *Arctic Ocean Salinity and Arctic Ocean Temperature*, one set for each student group; six maps total–three for salinity at 0 m, 100 m, and 2,000 m, and three for temperature at the same depths. Download these sheets as follows:
  a. Point your web browser to http://www.nnic.noaa.gov/atlas/html/clim/clim_tsd.htm #d0
  b. In the table labeled Depth 0 m, click on the cell in the Means row of the Temperature column.
  c. Save the image.
  d. Repeat steps b and c for the cell in the Means row of the Salinity column.
  e. Repeat Steps b through d for the tables labeled Depth 100 m and Depth 2000 m.
- ❏ Table salt, about 4 tablespoons per student group
- ❏ Plastic squeeze bottles, two per student group
- ❏ Red and blue food coloring
- ❏ 100 ml graduated cylinder, one per student group
- ❏ Glass or clear plastic pan, about 9″ x 13″ x 3″, one per student group
- ❏ Plastic zip-lock bags, 1-quart size, two per group
- ❏ Binder clips, medium size, two per student group
- ❏ Ice cubes, about 500 ml per student group
- ❏ Hot tap water, about 800 ml per student group

AUDIO/VISUAL MATERIALS

- ❏ Overhead transparencies of maps and diagrams for group discussions

TEACHING TIME

Two 45-minute periods

SEATING ARRANGEMENT

Groups of four students

KEY WORDS

Pelagic	Salinity
Benthic	Density
Sympagic	Canadian Basin

BACKGROUND INFORMATION

This activity focuses on water circulation in the Arctic Ocean and on some of the processes that drive ocean circulation. Ocean currents are caused by winds and changes in seawater density. Density can be changed by evaporation or freshwater input which raises or lowers the salinity, as well as by temperature changes. Near the equator, evaporation causes seawater salinity and temperature to increase. The density of seawater increases as salinity rises and decreases as temperature rises. So even though the water is saltier, the higher temperature keeps the surface water from sinking. As surface water flows toward the poles it's driven by wind, and becomes cooler and sinks due to its increased density.

In this activity, students make observations about the relationships between temperature, salinity, and density. These observations provide the basis for drawing inferences about circulation in the Arctic Ocean when the students are given information about temperature, salinity, and topography of the Arctic Ocean basin.

LEARNING PROCEDURE

1. Give each group materials and worksheets and challenge them to follow instructions for the *Influence of Salinity on Density* and the *Influence of Temperature on Density* activities. You may wish to have each group do both activities or divide the activities among the groups to save time.
2. Have each group present its results. Students should also draw inferences about the effects of salinity and temperature on water density. Students should have observed that water with added salt (higher salinity) tends to settle beneath water without salt (lower salinity) and infer that increasing salinity increases the density of water. They should also have observed that when water is cooled, it tends to sink, while increasing temperature causes water to rise, and infer that increasing temperature reduces the density of water. (Note: this is not strictly true when water is near freezing.) Pure water reaches its maximum density at a temperature of 4°C, while the maximum density of seawater is below 0°C.
3. Show the class the *Arctic Region* and *Arctic Ocean Bathymetry* maps. Have students identify countries that border the Arctic Ocean and places where circulation might be possible with other oceans. Students should observe that there are relatively few places where such circulation can occur and that the largest of these is off the eastern coast of Greenland.
4. Distribute copies of *Arctic Ocean Salinity* and *Arctic Ocean Temperature* data sheets. Be sure students realize that each set of data sheets contains information about temperature or salinity at the ocean surface and at depths of 100 m and 2000 m.
5. Have each group examine and discuss both sets of data sheets and prepare a brief written statement about water circulation in the Arctic Ocean.
6. Lead a discussion based on students' inferences about circulation in the Arctic Ocean. Students should identify areas of low salinity along the coast of Russia and attribute these to large rivers—the Lena, Yenisei, and Ob—that flow into the Arctic. The Mackenzie River has a similar effect on the Canadian coast. Students should infer that these areas of low salinity will also have a lower density than other portions of the ocean and this would contribute to stratification of the ocean by reducing vertical circulation and mixing. In deeper waters, salinity is much more uniform, so there would be little circulation caused by density differences.

   At first glance, temperature data might seem to suggest that there could be some vertical mixing due to temperature effects on density, since temperatures of surface waters are colder than deeper water. These differences are relatively small, however, and are offset by the effect of salinity on density. Moreover, density of deeper waters is increased by a third factor: water pressure, which causes an increase in density with increasing pressure. Students should recognize that very deep (2000 m) portions of the Arctic Ocean are almost entirely isolated by topography. Only a very small area near the east coast of Greenland has a connection to the North Atlantic Ocean. Ocean ridges further divide and isolate the deeper portions of the Arctic Ocean basin.

   Ask the students to speculate on the effect of this isolation on biological communities.

   When students have completed their inferences, show the *Arctic Water Structure* diagram, which shows the general patterns of surface circulation and confirms the relative isolation of deeper waters by topography and density conditions.

THE BRIDGE CONNECTION

www.vims.edu/BRIDGE/polar.html

THE "ME" CONNECTION

Have students describe how ocean currents affect their own lives. They should recognize the influence that oceanic heat transfer has on global and regional weather, and may also mention other interactions such as fisheries or ocean pollution.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Geography, Biology, Chemistry, Physics

EVALUATION

Written statements prepared in Step 5 provide a means for evaluating the performance of each student group. Oral participation in discussions provides a supplemental means of evaluating individual student performance.

EXTENSIONS

Visit http://topex-www.jpl.nasa.gov/education/activities.html for numerous lesson plans and ideas on ocean-related activities, particularly on aspects related to physical oceanography.

Have students investigate water circulation systems in other oceans and determine which forces are the primary drivers of these systems.

RESOURCES

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Find out more about the Arctic Ocean Expedition and read daily documentaries and reports of discoveries posted for your classroom use.

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.cru.uea.ac.uk/cru/info/thc/ – Explanation of thermohaline ocean circulation and discussion of the potential effects of climate change.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry

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

Content Standard D: Earth and Space Science

- Energy in the Earth system
- Geochemical cycles

FOR MORE INFORMATION

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CREDIT

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STUDENT HANDOUT

INFLUENCE OF SALINITY ON DENSITY ACTIVITY GUIDE

1. Prepare a concentrated salt solution by dissolving 4 tablespoons of table salt in approximately 250 ml tap water. Color the solution with red food coloring (about 4 drops). Pour the solution into a plastic squeeze bottle.
2. Prepare a second squeeze bottle with tapwater only.
3. Squeeze about 50 ml of the tapwater into a 100 ml graduated cylinder.
4. Holding the tip of the squeeze bottle against the inside of the graduated cylinder near the top, slowly squeeze about 25 ml of the concentrated salt solution into the cylinder. Record your observations. Empty and rinse the graduated cylinder.
5. Squeeze about 50 ml of the concentrated salt solution into the 100 ml graduated cylinder.
6. Holding the tip of the squeeze bottle against the inside of the graduated cylinder near the top, slowly squeeze about 25 ml of the tapwater into the cylinder. Record your observations.
7. What do you infer about the effect of dissolved salt on the density of water?

INFLUENCE OF TEMPERATURE ON DENSITY ACTIVITY GUIDE

1. Fill a glass pan with tapwater.
2. Put ice cubes into a 1-quart size plastic zip-lock bag so that the bag is half full. Attach the bag to one end of the glass pan with a medium binder clip.
3. Half-fill another 1-quart size plastic zip-lock bag with hot tapwater. Attach this bag to the opposite end of the glass pan with another medium binder clip.
4. Add four drops of red food coloring to the water next to the plastic bag containing the hot water. Add four drops of blue food coloring to the water next to the plastic bag containing the ice cubes. Observe the motion of the food coloring for several minutes and record your observations.

Volume 19 • Number 2 • 2003

ACTIVITY: LIFE IN THE CRYSTAL PALACE

BY MEL GOODWIN, PH.D.

FOCUS

Sea ice communities in the Arctic Ocean

GRADE LEVEL

Secondary Life Science

FOCUS QUESTION

What organisms live in the Arctic Ocean sea ice?

LEARNING OBJECTIVES

Students will construct models showing a sea ice community during summer and winter.

Students will identify major groups of organisms found in Arctic sea ice communities.

Students will describe major physical features of sea ice communities and how these features change during summer and winter.

Students will explain how seasonal changes affect biological activity within sea ice communities.

Students will describe interactions that take place between sea ice communities and will be able to explain the importance of sea ice communities to Arctic ecosystems.

MATERIALS

- ❑ Variety of art materials such as pipe cleaners, clay, aluminum foil, wires, etc.
- ❑ Internet access or copies of web pages from http://www.arctic.noaa.gov/essay_krembsdeming.html and http://www.unikiel.de/ipoe/Websitealt/resgroup/seaice.html

AUDIO/VISUAL MATERIALS

None

TEACHING TIME

Two 45-minute class periods

SEATING ARRANGEMENT

Classroom style for discussion portions of the activity; tables for model construction

KEY WORDS

Pelagic	Algae	Turbellaria
Benthic	Protozoa	Amphipod
Sympagic	Nematode	Copepod
Brine channel	Ciliate	

LEARNING PROCEDURE

1. Have students visit http://www.arctic.noaa.gov/essay_krembsdeming.html and http://www.unikiel.de/ipoe/Websitealt/resgroup/seaice.html to obtain background information on sea ice communities, or provide copies of pages from these sites. Assign half the groups of students to a sea ice community during winter and the other half to a sea ice community during summer. Each student should construct a model of at least one organism.

2. Have each group of students prepare a plan for their models, including the size, key features, and biological organisms to be included. You may approve these plans before students begin constructing their models.

3. Students complete their models using art materials provided by you or from home. Students may also provide a backdrop drawing upon which their models are displayed.

4. Have each group of students describe conditions in the sea ice community as illustrated by their models.

5. Lead a discussion about relationships among the organisms, and how these organisms use the physical features of the sea ice community to survive. Key points to include are:
   - the changes in the brine channels between summer and winter;
   - increased salinity of the brine liquid in the winter months;
   - the insulating effect of the sea ice layer;
   - use of brine channels as habitats by algae and animals; and
   - the ways in which the sea ice community affects animals in adjacent communities, such as polar bears, fishes, and seals.

Volume 19 • Number 2 • 2003

THE BRIDGE CONNECTION

www.vims.edu/BRIDGE/polar.html

THE "ME" CONNECTION

Have students write excerpts from an imaginary diary kept by an explorer on a year-long assignment to a research camp based on a large Arctic Ice floe. The explorer's mission is to study biological activity within the ice and at the ice-seawater interface. Excerpts should cover all four seasons and describe some of the things they might have observed at various times of the year.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Geography, Environmental Science, Earth Science

EVALUATION

Following presentations in Step 4, you may have each student write a short (1-2 page) description of the relationships between organisms in sea ice communities, and how the relationship of physical conditions in the communities to biological activity changes with the seasons. Overall quality of the models may also be used to evaluate performance of group members.

EXTENSIONS

Have students visit http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html to find out what happened during the 2002 Arctic Ocean Expedition.

Visit www.nsf-gov/of/ipa/nstw1996/ice/start.htm for an activity to design a research community for polar conditions.

RESOURCES

http://oceanexplorer.noaa.gov – Find out more about the Arctic Ocean Expedition and others

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/regionhs/CENTRAL/arcexplor – Website 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
- Understanding about scientific inquiry

Content Standard C: Life Science

- Populations and ecosystems
- Diversity and adaptations of organisms

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This activity was produced by Mel Goodwin, Ph.D., The Harmony Project, Charleston, South Carolina for the National Oceanic and Atmospheric Administration (NOAA).

CREDIT

If reproducing this lesson, please cite NOAA as the source, and provide the following URL for further information: http://www.oceanexplorer.noaa.gov.

ACTIVITY: MEET THE ARCTIC BENTHOS

BY MEL GOODWIN, PH.D.

FOCUS

The Benthic Realm: Studying Benthic Invertebrates in the Arctic Ocean

GRADE LEVEL

Secondary Life Science

FOCUS QUESTION

What kinds of invertebrates live on the bottom of the Arctic Ocean?

LEARNING OBJECTIVES

Students will use the Internet to research benthic Arctic invertebrate groups.

Students will compare and critique websites with regard to quality of information.

Students will learn to appreciate diversity, feeding relationships and strategies, and community structure of Arctic benthic invertebrates.

MATERIALS

- ❏ *Benthic Habitats Sheet* enlarged for class discussion (drawn onto a blackboard or copied onto an overhead transparency)
- ❏ Internet access for research on Arctic invertebrates

AUDIO/VISUAL MATERIALS

- ❏ Blackboard or overhead projector and markers

TEACHING TIME

Three 45-minute class periods with time for students to do Internet research

SEATING ARRANGEMENT

Classroom style

MAXIMUM NUMBER OF STUDENTS

There are 18 groups to be studied. Students may work individually or in groups to complete the research activity.

KEY WORDS

Community	Echiurida	Isopoda
Planktonic	Ectoprocta	Pelecypoda
Pelagic	Bryozoa	Gastropoda
Benthic	Lophophore	Amphineura
Sympagic	Priapulida	Echinoidea
Sessile	Sipunculida	Holothuroidea
Anthozoa	Cirripedia	Ophiuroidea
Nemertea	Amphipoda	Ascidiacea
Polychaeta	Cumacea	

BACKGROUND INFORMATION

This activity focuses on the Benthic Realm. Because the deep Arctic Ocean is virtually unexplored, the first questions researchers want to investigate are pretty basic:

- What are the physical conditions of the Benthic Realm?
- What organisms make up the Benthic Realm's biological communities?
- How do these organisms obtain food?

Research in shallower polar waters suggested that many different types of organisms are likely to be found and that the majority of these will probably be invertebrates. These organisms are an essential part of Arctic Ocean food webs and play a major role in recycling mineral nutrients.

This activity introduces students to the major invertebrate groups found on polar ocean expeditions and acquaints them with the feeding habits of these animals. It will serve as basis for making inferences about benthic communities and their connection to other components of the larger Arctic Ocean ecosystem.

A brief description of major invertebrate groups that have been reported in previous studies of polar benthic communities follows. It is almost certain that other groups will also be found by expeditions to the deep Arctic Ocean, and it is quite possible that some organisms will be found that are new to science. Warning: the classification of invertebrate groups is subject to debate and varies from one author to another.

Phylum Cnidaria – jellyfish, corals, sea anemones, and similar animals that have stinging cells called nematocysts.

Class Anthozoa – particularly sea anemones; often abundant in polar benthic communities.

Phylum Nemertea (also known as Rhyncocoela and

Nemertinea) – long flat shape gives these animals the common name ribbon worms; these worms have no segments and are often predators.

Phylum Annelida – segmented worms

Class Polychaeta – worms with many paddle-like appendages; many representatives in polar benthic communities and highly diverse in physical form as well as feeding strategy.

Phylum Echiurida (or Phylum Annelida, Class Echiura) – spoon worms 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 – also called penis worms; mud-dwellers that resemble a little cucumber with teeth.

Phylum Sipunculida – peanut worms, live in burrows or crevices; most eat sand or mud and digest whatever food (organic material) is in the sediment; one species is carnivorous.

Phylum Arthropoda – animals with a hard external skeleton and jointed appendages; four groups are common among the polar benthic invertebrates.

Class Crustacea

Subclass Cirripedia – barnacles; attached to surfaces; sweep food into their mouths with appendages.

Class Malacostraca

Order Decapoda

Superorder Peracarida

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 pillbugs; 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 are all filter feeders.

Class Gastropoda – snails and nudibranchs have a variety of feeding strategies.

Class Amphineura – chitons feed by scraping algae and other materials from hard surfaces.

Phylum Echinodermata – invertebrates with a spiny skin; largely radially symmetric.

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; radially symmetrical with spines articulated with hard test (shell).

Class Holothuroidea – sea cucumbers; secondarily bilateral, generally with soft body.

Class Ophiuroidea – brittle stars; central radial disc with thin arms.

Phylum Chordata

Class Ascidiacea – sea squirts, leathery-skinned bottom dwellers that grow alone or in colonies attached to stable surfaces; filter feed.

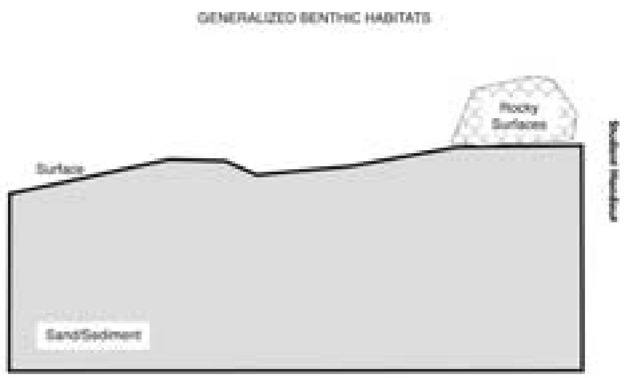
LEARNING PROCEDURE

1. Discuss briefly the concepts of invertebrate diversity, benthic existence, and the Arctic in particular. Have the students then use the NOAA Ocean Explorer website to review the general focus of the Arctic Ocean Exploration if they have not already used the site. Go to http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html to find out what organisms researchers actually found in the Benthic Realm. Use this list to refine each group's search for organisms it is studying. Groups may also use http://maps.grida.no/arctic/ for maps that show ecoregions, populations, and geology.

2. Write the names of each group of organisms from the Key Words list on pieces of paper. Have students or groups of students draw one or more of the groups to research online. Ask them to try to focus only Arctic members of the group. Have each group prepare a brief report on the assigned group(s) using Internet resources – see *References*. Each report should include (a) description(s) of the animal(s), including size range; (b) habitat; (c) food source(s) and feeding habits; and (d) illustrations, if possible.

   The following websites contain the necessary information:
   - http://library.thinkquest.org/26153/marine/animalia.htm
   - http://www.teachinhgbiomed.man.ac.uk/bs1999/bs146/biodiversity/metadiv.htm
   - http://tolweb.org/tree?group=Animals&contgroup=Eukaryotes
   - http://virtual.yosemite.cc.ca.us/randerson.Marine%20Invertebrates /index.htm
   - http://biodicac.bio.uottawa.ca – this site has lots of images suitable for downloading

3. Each student or group will present its report to the entire class in a 5 minute report, including an evaluation of the



quality and value of the different websites it used. Which seemed most trustworthy/reliable/scientifically accurate? With 18 groups, this will take two 45-minute periods. Reproduce the Benthic Habitat cross section on the board or copy the sheet onto an overhead. Have the students write the name of their group(s) in the appropriate habitat area and indicate whether the animals are sessile (fixed in one place) or mobile.

EXTENSION

Lead a discussion of how different benthic groups might interact, with particular emphasis on feeding strategies. These groups have a variety of feeding strategies, including filter feeding, deposit feeding, and predation upon other benthic organisms. The main source of food for benthic organisms is primary production that occurs above in the sea ice and pelagic realms. Organic material is transported out of these environments when organisms die and settle to the bottom. Feeding by benthic organisms is an important process that returns some of these materials to other realms of the polar ocean environment—either by releasing mineral nutrients or when pelagic species feed on the bottom dwellers.

THE BRIDGE CONNECTION

www.vims.edu/BRIDGE/polar.html

THE "ME" CONNECTION

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

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts

EVALUATION

In addition to evaluation of student presentations, written reports may be graded on the basis of thoroughness in addressing the four content areas. It is also possible to create a matching or fill-in-the-blank identification quiz using images from http://biodicac.bio.uottawa.ca.

LITERATURE

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. – Scientific journal article on which this activity is based.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Populations and ecosystems
- Diversity and adaptations of organisms

FOR MORE INFORMATION

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Volume 19 • Number 2 • 2003

ACTIVITY: LET'S GO TO THE BOTTOM OF THE ARCTIC!

BY MEL GOODWIN, PH.D.

FOCUS

Sampling benthic communities in the deep Arctic Ocean

GRADE LEVEL

Secondary Life Science

FOCUS QUESTION

What factors influence community composition in the Benthic Realm of the deep Arctic Ocean?

LEARNING OBJECTIVES

Students will describe different species associations in a benthic community.

Students will infer probable feeding strategies used by benthic organisms and relate these strategies to sediment characteristics.

MATERIALS

- ❏ *Benthic Sampling Data Sheets* copy, one for each student.
- ❏ Samples of sand and silt (beach sand and fine dirt with organic material)

PREPARATION

Completion of *Meet the Arctic Benthos Activity*

AUDIO/VISUAL MATERIALS

Chalkboard, marker board, flip chart, or overhead projector to facilitate presentations of data summaries

TEACHING TIME

Two or three 45-minute class periods, depending upon length of time devoted to discussions, evaluations, and extensions

SEATING ARRANGEMENT

Four groups of 4-6

KEY WORDS

Benthic	Amphipod	Echinoid
Biomass	Bivalve	Ophiuroid
Total organic carbon	Polychaete	Zoanthid
Diversity	Bryozoan	
	Ascidian	

BACKGROUND INFORMATION

This activity focuses on the Benthic Realm.
Because the deep Arctic Ocean is virtually unexplored, the first questions ocean scientists investigate are basic:

- What are the physical conditions of the Benthic Realm?
- What organisms make up the Benthic Realm's biological communities?
- How do these organisms obtain energy?

Traditionally, investigations of benthic communities have used mechanical devices such as grabs, dredges, or core samplers to collect bottom samples of sediments and living organisms. These tools may damage living specimens and often miss some species entirely, since only a small fraction of the total habitat can actually be sampled. Some species are able to avoid capture altogether. On the Ocean Explorer Arctic Exploration these problems were reduced by using a deep-diving remotely operated vehicle (ROV), known as *Remotely Operated Platform for Ocean Science (ROPOS)* which makes photographs and video recordings of the study area. *ROPOS* also has a variety of manipulator arms and sampling devices so researchers can collect organisms they see on video for further examination and identification.

When ecologists describe biological communities, they often refer to community diversity. This concept includes two components: variety—the total number of species, and relative abundance—the number of individuals in each species. Using these two components, one might compare two communities that each have 10 species and one hundred individuals. By the measures biologists use, if 90 individuals in one community belonged to a single species, that community is considered less diverse than if there were 10 individuals of each species.

Sediments provide the primary source of energy (food) for the benthic communities, though carnivorous species are also present. The sediment's physical structure has a major influence on the types of organisms present. Filter feeders, such as bivalves, are better suited to sites with fine silt, while animals such as amphipods that are adapted to grazing the surface of small particles are better suited to sites with sandy sediments. In addition, the total organic content of the sediments determines how many organisms can be supported. Sites with higher organic content can support more animals.

LEARNING PROCEDURE

In this activity, students will analyze real benthic sample data to draw inferences about community structure and strategies used by individual species to obtain energy.

1. Complete *Meet the Arctic Benthos Activity* which provides the content foundation for this exercise.
2. Copy the two pages of *Benthic Sampling Data*, cut each in half and distribute one half-page to each student group. Explain that these are real data from four different areas in the Arctic Ocean, with three samples taken from each area. Each group will analyze one area and then data will be pooled in class discussion.
3. Discuss the concept of biomass–the total standing crop of organisms by weight. Have the class as a group discuss the data sheet that they will use to report total biomass and percent by species of the biomass.
4. Provide samples of silt and sand if possible. Particle size is a major difference. Silt also tends to have more fine organic material.
5. Challenge the students to calculate the total average biomass for their three samples (by adding all of the biomass figures and dividing by three). Then calculate the percent of that total represented by each type of organism. Refer to *Meet the Arctic Benthos Activity* for the feeding habits of the organisms found in their samples.
6. Have each group summarize its data for the entire class. Each group should state what organisms were present, the feeding habits of each type of organism, the relative abundance of each type of organism, the average total biomass for its site, the type of sediment found at the site, and the total organic carbon found in the sediment. Be sure students understand that total organic carbon is a measure of the food value or energy available to organisms that consume the sediment.
7. Lead a discussion to interpret the pooled results. Begin by asking what the relationship is between sediments and the types of organisms present at the sites.

   Ask the students to comment on the diversity of organisms at their sites. They should consider both the total quantity of organisms present (average total biomass) as well as the relative quantities of each type of organism present ("evenness"). They should realize that sites with higher potential food value (measured by total organic carbon) are likely to have more organisms (higher total biomass; Sites I and II). In addition, sites with a greater variety of sediment types (Sites I and III) provide feeding opportunities for a greater variety of organisms, so sites dominated by one type of sediment are more likely to be dominated by a few species particularly adapted to feeding on that type of sediment.

THE BRIDGE CONNECTION

www.vims.edu/bridge/polar.html
www.vims.edu/bridge/benthos.html

THE "ME" CONNECTION

Have students write a short essay or prepare a brief oral presentation on how knowledge of unexplored biological communities might benefit them personally, and/or why they think this knowledge is (or is not) important. Ask students to share their thoughts with the rest of the class.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Mathematics

EVALUATION

Individual data summaries prepared by each student group may be collected to assess the thoroughness of their work. Additionally, students may be asked to prepare individual written interpretations of the pooled results before participating in a group discussion.

EXTENSIONS

Visit http://www.ropos.com to find out about the ROV that was used to explore biological communities during the Arctic Ocean Expedition.

Investigate other Arctic Ocean exploration programs. Search for keywords *Shelf Basin Interactions* and *Canadian Arctic Shelf Exchange Study*.

RESOURCES

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Read about the 2002 Arctic Ocean Expedition

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything, including sources for information on invertebrate feeding habits.

DATA SOURCE

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. – Scientific journal on which this activity is based.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Interdependence of organisms
- Matter, energy, and organization in living systems

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STUDENT HANDOUT

BENTHIC SAMPLING DATA SHEET

SITE I

Species Group	Biomass (g/m^2) Sample 1	Sample 2	Sample 3
Ascidians	151	465	166
Bivalves	58	179	64
Polychaetes	55	170	61
Others	26	80	29

Sediment Analysis:

Silt & Clay	16%
Fine Sand	36%
Medium Sand	31%
Coarse Sand	17%
Total Organic Carbon	4.9 (mg carbon per g sediment)

BENTHIC SAMPLING DATA SHEET
SITE II

Species Group	Biomass (g/m^2) Sample 1	Sample 2	Sample 3
Amphipods	261	182	123
Bivalves	275	192	130
Others	189	132	89

Sediment Analysis:

Silt & Clay	47%
Fine Sand	45%
Medium Sand	6%
Coarse Sand	2%
Total Organic Carbon	7.2 (mg carbon per g sediment)

BENTHIC SAMPLING DATA SHEET
SITE III

Species Group	Biomass (g/m2) Sample 1	Sample 2	Sample 3
Tunicates	94	198	17
Bivalves	23	49	4
Polychaetes	23	49	4
Others	55	115	10

Sediment Analysis:

Silt & Clay	42%
Fine San	35%
Medium Sand	13%
Coarse Sand	10%
Total Organic Carbon	2.1 (mg carbon per g sediment)

BENTHIC SAMPLING DATA SHEET
SITE IV

Species Group	Biomass (g/m2) Sample 1	Sample 2	Sample 3
Amphipods	63	23	10
Bivalves	23	8	4
Polychaetes	22	8	4

Sediment Analysis:

Silt & Clay	11%
Fine Sand	10%
Medium Sand	67%
Coarse Sand	12%
Total Organic Carbon	1.2 (mg carbon per g sediment)

Volume 19 • Number 2 • 2003

ACTIVITY: WOULD YOU LIKE A SAMPLE?

BY MEL GOODWIN, PH.D.

FOCUS

Sampling strategies for benthic biological communities

GRADE LEVEL

Secondary Life Science

FOCUS QUESTION

How well do biological samples represent the actual biological communities from which they are taken?

LEARNING OBJECTIVES

Students will experiment with and discuss the advantages and limitations of various sampling techniques for the description of benthic biological communities.

MATERIALS

- ❏ Sampling grids - one complete set for each student group; must print from the CD or Ocean Explorer website http:oceanexplorer.noaa.gov/explorations/02arctic/welcome.html and cut into pieces, then attach to poster board; done once, they are ready for reuse.
- ❏ *Sampling Plan Sheets*, one for each student
- ❏ *Data Sheets*, one for each student
- ❏ *Complete List of All Organisms* in the Model Community copied onto an overhead transparency for use during discussion
- ❏ Table of random numbers or telephone directory

AUDIO/VISUAL MATERIALS

None, unless desired for discussions

TEACHING TIME

Two 45-minute class periods

SEATING ARRANGEMENT

Groups of four or five students

KEY WORDS

Pelagic	Transect	Benthic
Quadrat	Sympagic	Grid

BACKGROUND INFORMATION

One of the classic problems faced by researchers working on biological communities is how best to sample the living organisms that make up these communities. Even if all of the organisms are large enough to see and are out in the open on a flat surface, it is usually impractical to count every single organism present. Researchers have developed various systems for collecting samples from a community. They then use these samples to draw conclusions about the community as a whole.

There is always a question, though, of how well the samples represent the community. The situation becomes even more complicated when organisms are hidden under rocks or in sediment, are very small or very large, or are very fast. New technologies, including remotely operated vehicles (ROVs), underwater video recorders, high resolution digital cameras, and side scan sonar were used by researchers on the Arctic Ocean Expedition to overcome some of the difficulties of sampling biological communities. Still, the explorers know that some organisms will go undetected.

When ecologists describe biological communities, they often refer to the idea of "diversity." This concept includes two components: variety (the total number of species) and relative abundance (the number of individuals in each species). Considering these two components, two communities could have 10 species and one hundred individuals, but if 90 individuals in one community belonged to a single species, that community would be less diverse than if there were 10 individuals in each species.

LEARNING PROCEDURE

In this activity, students will use several common sampling techniques to investigate an "unknown" biological community. They will compare the strengths and weaknesses of these techniques in giving an accurate impression of the community.

1. Print and cut up sets of the grid cells. Arrange one row at a time, face down on large foam core or cardboard sheets, starting at the bottom, so that when a grid cell is flipped up, it will be right side up. Tape each entire row across its top. When the bottom row has been placed and taped, then do the next row above the bottom row. Continue untill all rows have been taped in place. See the Complete List of all Organisms for the order to be used. Be sure that cells are arranged in grid order, so that the cell labeled "1,**1**" is in the lower left corner, and the cell labeled "20,20" is in the upper right corner. Preparation takes a while, but once completed, the boards may be reused. Write the numbers as they appear on the list so that rows and columns allow the students to locate the quadrats.

2. The Arctic Ocean Expedition investigated areas that have never been explored before. Scientists had only a general idea of what they might find. The 20 x 20 grid of sampling sites represents a piece of the ocean floor that they sampled. Ocean work is expensive and the Arctic summer is short.

   Challenge the students to develop a sampling plan for this model of a benthic community 10,000 feet deep the Arctic Ocean. Side scan sonar indicates that the area is almost completely flat, with no large rocks or other distinct features. Using precision mapping and global positioning equipment, the site has been divided into a grid of 400 squares.

   The plan is to send an ROV to the site to collect samples. There are many other areas to investigate, sampling time is limited, and only 25 grid squares can be visited at this site. The good news is that the ROV is equipped with photographic and video equipment, as well as a variety of manipulator arms and sampling devices, so we have a good chance of detecting the most of the non-microscopic organisms present in the community.

3. Introduce some of the most common sampling strategies: a.) transects are lines made across an area; samples are collected at fixed intervals along the transect line. For visual surveys, these samples are often taken within a square area of fixed size called a quadrat. In the case of our model community, individual quadrats are represented by the individual grid squares. b.) As an alternative to transects, students should consider the possibility of collecting samples randomly throughout the community. To apply a random sampling system to the model community, each grid square should be assigned a pair of coordinates beginning with 1,1 (for the square in the lower left corner) and ending with 20,20 (for the square in the upper right corner), just as one would describe coordinates on a map. The grid squares to be sampled are selected by using a table of random numbers taken four at a time. If the first four numbers in the table were 1, 3, 0, and 7, then the first square to be sampled would be 13 squares across and seven squares up. Coordinate pairs greater than 20,20 are skipped, and the process continues until 25 usable coordinate pairs have been selected. If a table of random numbers is not available, use a telephone directory, selecting the last digit of each number from a randomly selected page.

4. Have students plan their sampling techniques for 25 quadrats and mark them on the Sampling Plan Sheet. Then conduct the survey each group has planned. Score the results on the Data Sheet.

5. Discuss which groups most accurately described the community with their sampling plan. (a) what species groups are present in the model community; (b) what is the relative abundance of these groups; (c) which species groups tend to occur together—these associations give clues as to how different species groups may be interacting in the community.

6. Each group should make a list of all the species groups found; this answers question (a). Next, tally the number of quadrats in which each group occurred. Classify each group as "Abundant" if it occurred in more than 50% of the samples, "Common" if it occurred in 20% but less than 50% of the samples, and "Rare" if it occurred in less than 20% of the samples. This answers question (b). Finally, identify species groups that are commonly found together.

7. Have each group present a summary of its data that includes:
   - the total number of species found;
   - the relative abundance of each species; and
   - which species appear together in more than three samples. Record these summaries on the board or overhead.

8. Lead a discussion that includes a.) comparing the results of the different techniques; b.) speculation about what features of the model community might lead to the results they obtained; c.) how organisms are actually distributed in nature (more often clumped than randomly distributed); d.) how the students' results could be used to design a follow-up sampling program.

9. Compare the students' results with the Complete List of All Organisms in the Model Community. This type of list is almost never available in actual research situations, but shows how difficult it is for a single sampling program to detect all of the species in a community. Be sure the students understand that they were able to sample 1/16th of the entire model community and that the coverage possible with most real sampling programs is much less.

THE BRIDGE CONNECTION

www.vims.edu/bridge/polar.html
www.vims.edu/bridge/benthos.html

THE "ME" CONNECTION

Have students write a short essay or give a brief oral presentation on how knowledge of unexplored biological communities might benefit them, and/or why this knowledge is or isn't important. Have students share with the class.

CONNECTIONS TO OTHER SUBJECTS

Mathematics, Earth Science, Physical Science

EVALUATION

Individual sampling plans and data summaries prepared by student groups may be collected to assess the thoroughness of work. Additionally, students may be asked to define key words and/or address discussion points 8 a, b, c, and d in writing before participating in a group discussion.

EXTENSIONS

Visit http://oceanexplorer.noaa.gov to find out what organisms were found.

Visit http://www.ropos.com to find out about the ROV.

RESOURCES

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Read about the 2002 Arctic Ocean Expedition

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything, including sources for information on invertebrate feeding habits.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Populations and ecosystems

FOR MORE INFORMATION

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ACKNOWLEDGEMENTS

This activity was produced by Mel Goodwin, Ph.D., The Harmony Project, Charleston, South Carolina for the National Oceanic and Atmospheric Administration (NOAA).

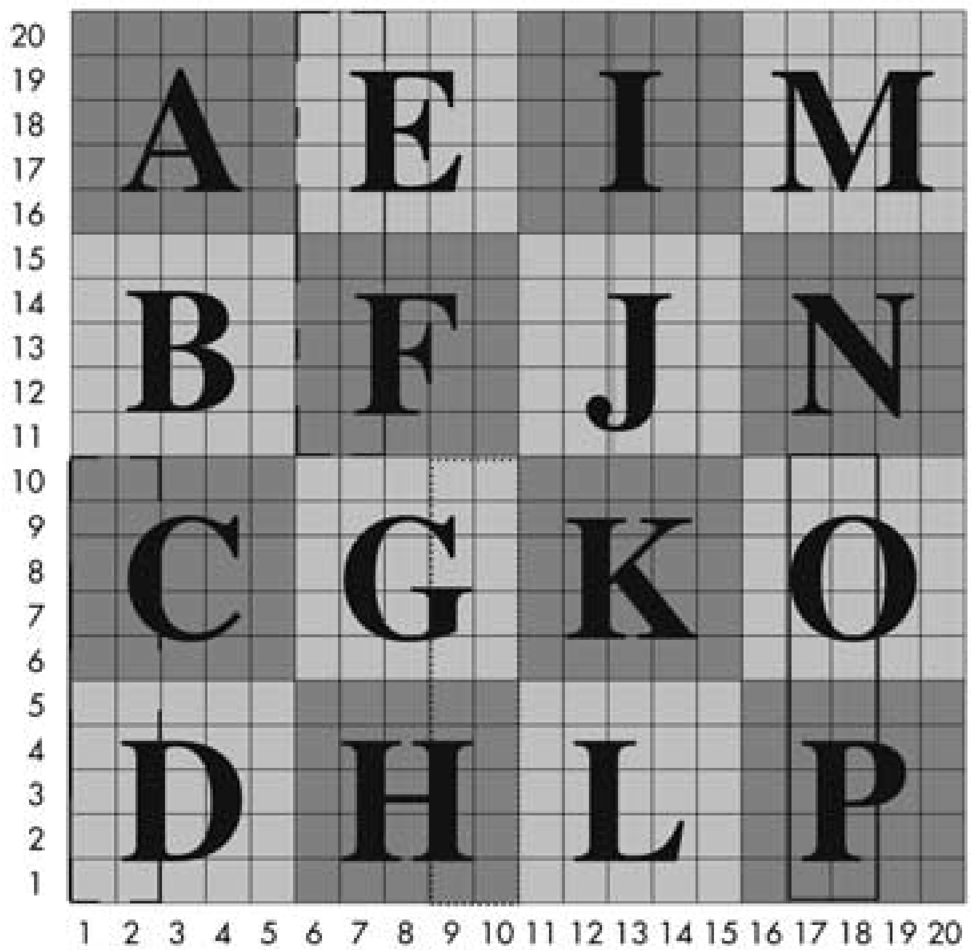
CREDIT

If reproducing this lesson, please cite NOAA as the source, and provide the following URL for further information: http://www.oceanexplorer.noaa.gov.

Student Handout

Complete List of All Organisms in the Model Community

All Quadrats in Columns 1 - 5 Contain:	All Quadrats in Columns 6 - 10 Contain:	All Quadrats in Columns 11 - 15 Contain:	All Quadrats in Columns 16 - 20 Contain:
Sand Dollars **Sipunculids**	**Sea Urchins** **Ascidians**	**Sand Dollars** **Sipunculids**	**Sea Urchins** **Ascidians**



All Quadrats in Rows 16 - 20 Contain: **Bivalves**

All Quadrats in Rows 11 - 15 Contain: **Bivalves**

All Quadrats in Rows 6 - 10 Contain: **Tunicates**

All Quadrats in Rows 1 - 5 Contain: **Tunicates**

The 25 quadrats labelled C, D, G, H, and L also contain **Brittle Stars** and **Sea Anemones.**
The 25 quadrats labelled D, H, L and P also contain **Snails.**
The 25 quadrats labelled C, G, K, and O also contain **Isopods.**
The 25 quadrats labelled A, B, E, F, and J also contain **Polyplacophora.**

These contain **Polychaetes** and **Amphipods.**

These contain **Bryozoans** and **Sea Cucumbers.**

These quadrats also contain **Cumaceans.**

These quadrats also contain **Priapulida.**

These quadrats also contain **Ectoprocta.**

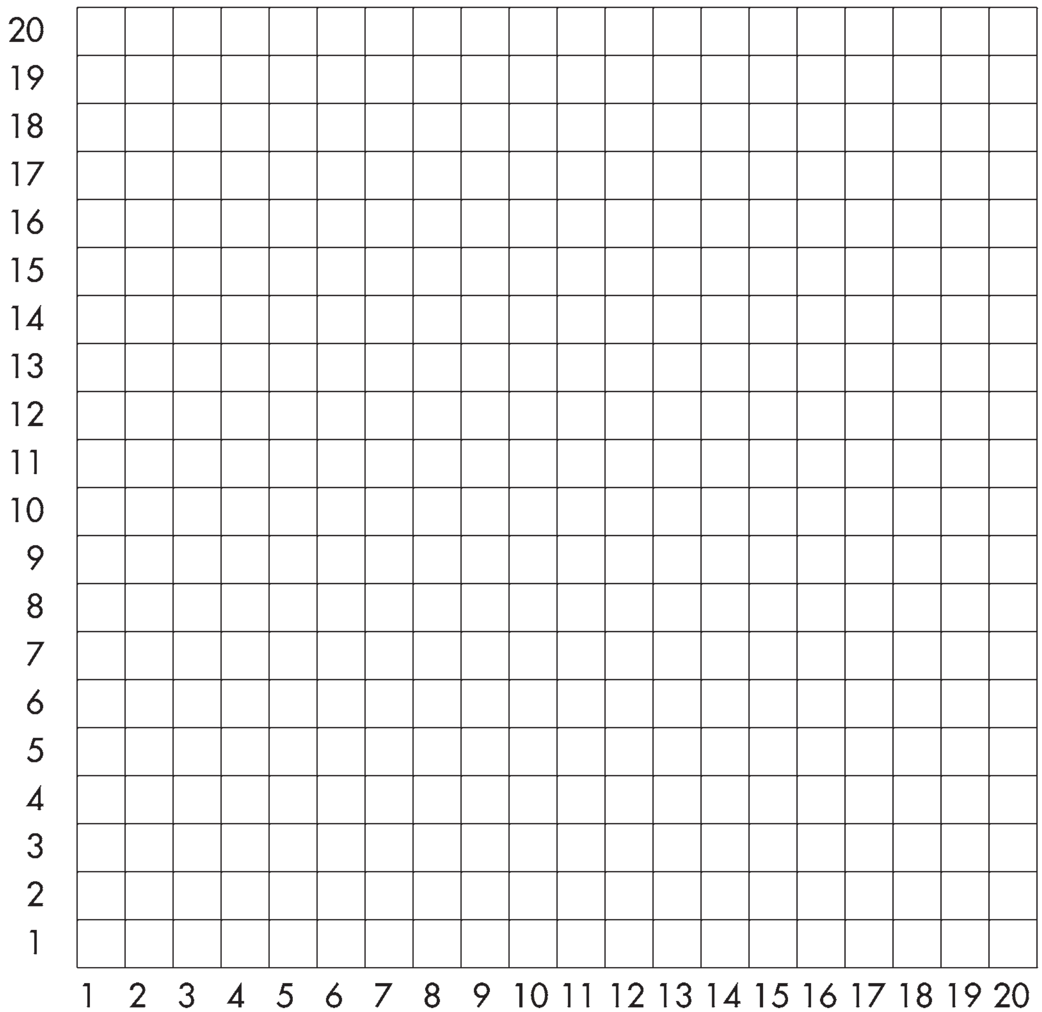
These quadrats also contain **Nemertine Worms.**

Volume 19 • Number 2 • 2003

Student Handout

Sampling Plan Sheet

Mark 25 quadrats to be sampled.



Sampling Plan Data Sheet

The columns below are labeled with the first letter of each word; if there is one word, the first three letters are used except for POL (polychaetes) and PLP (polyplacophorans). Check presence in each quadrat.

Quadrat	SD	SIP	SU	ASC	BIV	TUN	BS	SA	SNA	ISO	PLP	PLC	AMP	CUM	ECT	NEM	BRY	SC	PRI
Total Present																			

Volume 19 • Number 2 • 2003

ACTIVITY: BEING PRODUCTIVE IN THE ARCTIC OCEAN

BY MEL GOODWIN, PH.D.

FOCUS

Factors limiting primary productivity

GRADE LEVEL

Secondary Life Science and Chemistry

FOCUS QUESTION

What factors limit primary productivity in the Arctic Ocean?

LEARNING OBJECTIVES

Students will identify major factors that limit primary productivity in the Arctic Ocean.

Students will describe how these factors might limit primary production.

Students will infer which factors are limiting in a data set of potentially limiting factors and primary productivity.

MATERIALS

- ❑ Sets of *Sample Data Cards*, one set of 10 cards for each student group
- ❑ Blank *Data Summary Sheet* for each group

AUDIO/VISUAL MATERIALS

None

TEACHING TIME

One or two 45-minute class periods

SEATING ARRANGEMENT

Groups of 4 - 6 students

KEY WORDS

Pelagic	Primary Productivity
Benthic	Phytoplankton
Sympagic	PAR
Zooplankton	Chlorophyll a

BACKGROUND INFORMATION

This activity focuses on primary productivity in the pelagic realm. Primary productivity refers to the amount of organic matter (usually expressed as grams of carbon per square meter per day) produced by organisms that are able to manufacture food from simple inorganic substances using energy from sunlight (in the case of photosynthesis) or chemical reactions (in the case of chemosynthesis). As far as we know, primary productivity in the Arctic Ocean occurs only through photosynthesis, and much of that photosynthesis is carried out by microscopic drifting algae (phytoplankton) in the water column. Photosynthesis requires organisms with photosynthetic pigments that use light, carbon dioxide, water, and mineral nutrients. The availability of photosynthetic organisms, light, temperature, and mineral nutrients collectively determine the amount of photosynthesis possible. We do not know which of these factors limits primary production in the Arctic Ocean, or how much primary production actually occurs there.

LEARNING PROCEDURE

1. Review the Background Information on the Arctic Ocean and its three known biological realms with your students. Emphasize that the three realms are connected by the exchange of organic matter and mineral nutrients among them (they are said to be coupled) and that photosynthesis by microscopic algae (phytoplankton) provides the energy for other organisms in these realms. The algae are the base of the food chain. You may want to mention that a few marine systems, such as those at hydrothermal vents, are not dependent on photosynthesis for energy, but rely on chemosynthesis instead.

   If necessary, review the basic concepts of photosynthesis. Be sure students understand that photosynthesis can be limited if one or more of the necessary components is in limited supply.

2. Challenge students to sample real data on primary productivity and factors that may limit this production in the Arctic Ocean. Each group should examine 10 data sets which represent samples taken at 10 different times of the year. As each sample is studied, students should be looking for connections between photosynthesis and limiting factors.

3. Distribute the five sets of *Sample Data Cards* to the student groups. Groups may pass the cards from one to the next as they record the data from the cards on the *Data Summary Sheet* as if they were recording data in the lab. You may briefly discuss the meaning of each set of cards: *Ice Cover* refers to the percent of the sea surface that is covered with ice, *PAR* cards describe the amount of photosynthetically-active radiation—the light that is useable for photosynthesis—as a percentage of the maximum radiation that occurs during the year, *Chlorophyll a* cards show the amount of chlorophyll a—a measure of the amount of photosynthetically-capable organisms in the surface seawater, *Nitrate* cards show the nitrogen-containing mineral nutrients in the water, *Primary Productivity* cards describe the amount of organic matter that has been produced through photosynthesis at the sea surface.

4. Have each group record its data, filling out the *Data Summary Sheet*. Then ask the students to look for correlations between different data sets for each sample day.

5. For the discussion, refer to the *Teacher's Master Data Summary* and use the following guide as needed to aid these discussions.

   Sample Day #1: This is a fairly high rate of Primary Productivity. Students should note that there is no ice to block sunlight, and PAR is fairly high. The significance of Chlorophyll a and Nitrate concentrations will become apparent as other days are examined.

   Sample Day #2: 50% of the sea surface is covered with ice. This limits Primary Productivity to less than half the value on Sample Day #1, even though the PAR and Nitrate levels are actually higher, and there are only slightly fewer algae (as indicated by Chlorophyll a) than on Sample Day #1. Reduction of sunlight by sea ice can be a major limiting factor for primary productivity in the Arctic Ocean.

   Sample Day #3: Primary Productivity again is much lower than on Sample Day #1. A combination of ice cover and reduced PAR (perhaps it was a cloudy day!) are probably responsible, since Nitrate and Chlorophyll a levels are similar to previous days.

   Sample Day #4: Primary Productivity is lowest yet. The obvious cause is the greatly-reduced level of Nitrate.

   Sample Day #5: Everything seems favorable here, but Primary Productivity is low. Let the students speculate on the cause. They should notice that PAR is nearly 100% (i.e., close to maximum) and may wonder whether there is such a thing as too much light. In the Arctic Ocean, photosynthetic algae may be adapted to low light conditions. It is possible for photosynthesis to be inhibited if they are exposed to too much light.

   Sample Day #6: Low Primary Productivity again; students should have no problem figuring out that extensive ice cover is the likely cause.

   Sample Day #7: Time for inferences! When would you expect ice to cover 100% of the sea surface? Winter, of course! So, PAR would be zero because night lasts 24 hours at the peak of polar winter. We would expect Chlorophyll a and Primary Productivity to be pretty close to zero as well.

   Sample Day #8: Reviewing the preceding data sets, students should notice that Nitrate does not appear to limit Primary Productivity except when it is in very low supply. Since Primary Productivity is relatively high, and there is 30% ice cover, students could reasonably infer that Nitrate is not limiting in this case, so it could be any of the previous levels except 0.2.

   Sample Day #9: Low PAR is the key here. It is probably early winter, so students could conclude that ice cover is probably fairly high (above 70%) and Primary Productivity is probably quite low.

   Sample Day #10: Since all other factors seem pretty favorable, yet Primary Productivity is low, students should suspect that Nitrate levels are low enough to be limiting.

6. Have students write individual summaries of factors that limit Primary Productivity in the Arctic Ocean.

THE BRIDGE CONNECTION

www.vims.edu/bridge/polar.html
www.vims.edu/bridge/plankton.html

THE "ME" CONNECTION

Have students write a short essay or prepare a brief oral presentation on how knowledge of Primary Productivity in the Arctic Ocean might benefit them personally, and/or why they think this knowledge is (or is not) important. Ask students to share their thoughts with the class.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Mathematics

EVALUATION

Have students write their own interpretations of Sample Days #6 – 10 before these are discussed as a group.

EXTENSIONS

Have students visit http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html to find out what organisms researchers actually find in the three realms.

Have students research primary productivity in temperate and/or tropical ocean waters, and compare these data with primary productivity in the Arctic Ocean.

RESOURCES

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Find out what explorers discovered during the Arctic Ocean Expedition by reviewing their daily postings.

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

http://photoscience.la.asu.edu/photosyn/education/learn.html – Links to many sites and activities about photosynthesis

Smith, Jr., W. O. 1995. "Primary productivity and new production in the Northeast Water (Greenland) Polynya during summer." 1992. *Journal of Geophysical Research* 100:4357-4370. – The scientific journal article upon which this activity is based.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Chemical reactions

Content Standard C: Life Science
- Interdependence of organisms

Content Standard D: Earth and Space Science
- Energy in the Earth system

FOR MORE INFORMATION

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Teacher's Master Data Summary

Sample Day	Ice Cover (% of surface)	PAR* (% of maximum)	Chlorophyll a (µg/l)	Nitrate (µmol/l)	Primary Productivity (mg C/m²/day)
1	0	75	87	6.2	9.3
2	50	78	76	8.4	4.3
3	20	45	73	11.3	5.1
4	10	76	82	0.2	3.4
5	0	98	85	7.1	4.3
6	70	79	71	6.7	3.4
7	100	GUESS	GUESS	5.2	GUESS
8	30	82	76	GUESS	6.5
9	GUESS	10	5	7.6	GUESS
10	15	79	73	GUESS	2.6

*photosynthetically active radiation

Student Handout

ICE COVER DATA **Sample Day #1** Ice Cover = 0%	**ICE COVER DATA** **Sample Day #2** Ice Cover = 50%
ICE COVER DATA **Sample Day #3** Ice Cover = 50%	**ICE COVER DATA** **Sample Day #4** Ice Cover = 10%
ICE COVER DATA **Sample Day #5** Ice Cover = 0%	**ICE COVER DATA** **Sample Day #6** Ice Cover = 70%
ICE COVER DATA **Sample Day #7** Ice Cover = 100%	**ICE COVER DATA** **Sample Day #8** Ice Cover = 30%
ICE COVER DATA **Sample Day #9** Ice Cover = GUESS!	**ICE COVER DATA** **Sample Day #10** Ice Cover = 15%

Student Handout

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #1

PAR = 75% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #2

PAR = 78% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #3

PAR = 45% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #4

PAR = 76% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #5

PAR = 98% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #6

PAR = 79% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #7

PAR = GUESS!

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #8

PAR = 82% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #9

PAR = 10% of maximum

PHOTOSYNTHETICALLY ACTIVE RADIATION DATA

Sample Day #10

PAR = 79% of maximum

Volume 19 • Number 2 • 2003

Student Handout

CHLOROPHYLL a DATA **Sample Day #1** Chlorophyll a = 87 µg/l	**CHLOROPHYLL a DATA** **Sample Day #2** Chlorophyll a = 76 µg/l
CHLOROPHYLL a DATA **Sample Day #3** Chlorophyll a = 73 µg/l	**CHLOROPHYLL a DATA** **Sample Day #4** Chlorophyll a = 82 µg/l
CHLOROPHYLL a DATA **Sample Day #5** Chlorophyll a = 85 µg/l	**CHLOROPHYLL a DATA** **Sample Day #6** Chlorophyll a = 71 µg/l
CHLOROPHYLL a DATA **Sample Day #7** Chlorophyll a = GUESS!	**CHLOROPHYLL a DATA** **Sample Day #8** Chlorophyll a = 76 µg/l
CHLOROPHYLL a DATA **Sample Day #9** Chlorophyll a = 5 µg/l	**CHLOROPHYLL a DATA** **Sample Day #10** Chlorophyll a = 73 µg/l

Student Handout

NITRATE DATA **Sample Day #1** Nitrate = 6.2 μmol/l	**NITRATE DATA** **Sample Day #2** Nitrate = 8.4 μmol/l
NITRATE DATA **Sample Day #3** Nitrate = 11.3 μmol/l	**NITRATE DATA** **Sample Day #4** Nitrate = 0.2 μmol/l
NITRATE DATA **Sample Day #5** Nitrate = 7.1 μmol/l	**NITRATE DATA** **Sample Day #6** Nitrate = 6.7 μmol/l
NITRATE DATA **Sample Day #7** Nitrate = 5.2 μmol/l	**NITRATE DATA** **Sample Day #8** Nitrate = GUESS!
NITRATE DATA **Sample Day #9** Nitrate = 7.6 μmol/l	**NITRATE DATA** **Sample Day #10** Nitrate = GUESS!

Student Handout

PRIMARY PRODUCTIVITY DATA

Sample Day #1

Surface Primary Productivity =
9.3 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #2

Surface Primary Productivity =
4.3 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #3

Surface Primary Productivity =
5.1 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #4

Surface Primary Productivity =
3.4 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #5

Surface Primary Productivity =
4.3 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #6

Surface Primary Productivity =
3.4 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #7

Surface Primary Productivity =
GUESS!

PRIMARY PRODUCTIVITY DATA

Sample Day #8

Surface Primary Productivity =
6.5 mg $C/m^2/day$

PRIMARY PRODUCTIVITY DATA

Sample Day #9

Surface Primary Productivity =
GUESS!

PRIMARY PRODUCTIVITY DATA

Sample Day #10

Surface Primary Productivity =
2.6 mg $C/m^2/day$

Volume 19 • Number 2 • 2003

ACTIVITY: POLAR BEAR PANIC

BY MEL GOODWIN, PH.D.

FOCUS

Climate change in the Arctic Ocean

GRADE LEVEL

Secondary Earth Science

FOCUS QUESTION

What has been observed with regard to a reduction in Arctic sea ice, and what are the potential consequences?

LEARNING OBJECTIVES

Students will graphically analyze data on sea ice cover in the Arctic Ocean and recognize trends in these data.

Students will discuss possible causes for observed trends in Arctic sea ice and infer the potential impact of these trends on biological communities in the Arctic Ocean.

MATERIALS

- ❏ *Polar Ice Data Sheets*: one sheet for each student group
- ❏ Graph paper

AUDIO/VISUAL MATERIALS

None

TEACHING TIME

Two 45-minute class periods

SEATING ARRANGEMENT

Groups of 4-6

KEY WORDS

Pelagic
Benthic
Sympagic

BACKGROUND INFORMATION

Some scientists believe there is a particular urgency to the Arctic Ocean Expedition: the polar ice is shrinking, and no one is sure why. One explanation is that this is part of long-term climate cycles (like El Niño) that bring warm air and Atlantic Ocean water into the region. But other scientists think increased greenhouse gases in the atmosphere may have caused unusually severe changes to the Arctic climate that are affecting many species.

LEARNING PROCEDURE

In this activity, students analyze data from several sources to look for trends in the extent and thickness of Arctic Ocean sea ice. They then infer what these trends might mean for the Arctic Ocean's biological communities.

1. Review the Background Information on the Arctic Ocean and its three known biological realms with your students. Emphasize that the three realms are coupled and that photosynthesis by microscopic algae (phytoplankton) provides the energy for other organisms in these realms–the algae are the base of the food chain. Have students make a diagram showing the feeding relationships among the three realms.

2. Distribute the *Polar Ice Data Sheets* to each student group and have each group prepare a graph of one of these three data sets. To do so, first average each data set, then graph the numbers on an expanded scale around the average with numbers above and below the average. The x axis will be in the middle with the y-axis extending above and below the left hand side of the x-axis. The average might be 4.5 and the scale above will go up to 5 and the scale below will go down to 4.

3. Have each group describe its graph. Lead a discussion of the significance of these data. Students should recognize that data from three different sources show a similar trend of declining extent of Arctic sea ice. A fourth source shows that the ice is getting thinner as well. Students should refer to their diagrams of interactions between species and infer what would happen if the Arctic sea ice

were to continue to shrink. While it is likely that some species (particularly those that live on the surface of the ice) would be adversely affected and might even disappear, other species might become more abundant. Be sure students realize that the cause of these trends could be natural climate cycles or greenhouse warming caused by human actions or a combination of both.

4. Ask the students what they think should be done; is this a situation that requires urgent action, or should we wait for scientists to do more research into the cause? Are there things that could or should be done regardless of the cause? Is this really a problem, and whose problem is it, anyway?

   You may wish to have students read "Arctic Life, On Thin Ice" (*Science* 291:424-425, January 19, 2001) as the basis for a more in-depth discussion.

THE BRIDGE CONNECTION

www.vims.edu/bridge/polar.html
www.vims.edu/bridge/endangered.html

THE "ME" CONNECTION

Have students write an essay on why polar bears are important (or are not important) to them as individuals.

CONNECTIONS TO OTHER SUBJECTS

English/Language Arts, Mathematics, Earth Science

EVALUATION

Individual graphs prepared by each student group may be collected to assess the thoroughness of their work. Additionally, students may be asked to prepare individual written interpretations of the pooled results before participating in a group discussion.

EXTENSIONS

Have students visit http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html to find out what organisms researchers actually found in the three realms.

Have students research the greenhouse effect and global climate change and prepare written or oral reports on the causes, potential impacts, and possible solutions.

RESOURCES

http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html – Find out what explorers discovered during the 2002 Arctic Ocean Expedition by reading their daily postings.

http://www.sciencegems.com/earth2.html – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything, including sources for information on invertebrate feeding habits

Vinnikov, K. Y., A. Robock, R. J. Stouffer, J. E. Walsh, C. L. Parkinson, D. J. Cavalieri, J. F. B. Mitchell, D. Garrett and V. F. Zakharov. 1999. "Global warming and northern hemisphere sea ice extent." *Science* 286:1934-1937 – Scientific journal article on which this activity is based.

Johannessen, L. M., E. V. Shalina, and M. W. Miles. 1999. "Satellite evidence for an Arctic sea ice cover in transformation." *Science* 286:1937-1939 – Scientific journal article on which this activity is based

Krajick, K. 2001. "Arctic life, on thin ice." *Science* 291:424-425. News magazine-style report on the effects of warming in the Arctic.

NATIONAL SCIENCE EDUCATION STANDARDS

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard C: Life Science
- Population and ecosystems

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments

FOR MORE INFORMATION

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Volume 19 • Number 2 • 2003

MESSAGE FROM THE BRIDGE:

THE TIP OF THE ICEBERG

By Laura Rose and adapted for this publication by Susanna Musick

THEY COULD BE CALLED MOTHER NATURE'S ICE CUBES. *Of course, none are molded from the same tray, and the tip of the iceberg is just the beginning. Approximately seven-eighths of an iceberg lies under the surface of the ocean. With an iceberg the size of Rhode Island, can you imagine what's underwater? Mother Nature doesn't think small.*

Glaciers are the ice machines producing icebergs, churning away primarily in Greenland and Antarctica. A very small number of icebergs originate in Alaska and in Siberia or south of Franz Joseph Land in the Barents Sea. Since icebergs come from glaciers, they are composed of freshwater. Glaciers are formed by thousands of years of snowfall accumulation that is eventually compressed into ice. Winds, tides, and warming temperatures of spring weaken glacial masses, and great chunks of ice break off in a process known as "calving." The bergs are then at the mercy of the currents.

Icebergs are serious hazards in shipping lanes. At the time of the Titanic disaster, there were no systems in place to track icebergs and forewarn ship captains. Shortly afterwards, however, the International Ice Patrol was formed and assigned this important task. Another agency that tracks icebergs and provides sea ice data is the National Ice Center (NIC). In order for an iceberg to be worthy of tracking by the NIC, it has to meet two criteria: (1) it has to measure at least 10 nautical miles (nm) on its longest side; and, (2) the iceberg sighting must have occurred within the last 30 calendar days. Bring some coolness to your classroom by using data from the NIC to track icebergs in the BRIDGE's "Tip of the Iceberg" Data Tip <http://www.vims.edu/bridge/index_archive1299.html>.

FOR INFORMATION AND ACTIVITIES THE BRIDGE RECOMMENDS:

BRIDGE Data Tip: Tip of the Iceberg:
http://www.vims.edu/bridge/index_archive1299.html

BRIDGE Data Tip: Winter Wonderland:
http://www.vims.edu/bridge/index_archive0102.html

TEA (Teachers Experiencing Antarctica and the Arctic):
http://tea.rice.edu/index.html

Antarctica:
http://octopus.gma.org/surfing/antarctica/index.html

Huge tabular icebergs, calved from the ice shelf in the southern ocean's Weddell Sea.

Volume 19 • Number 2 • 2003

Newton's Apple Antarctica I:
http://www.tpt.org/newtons/10/antarctic1.html

Newton's Apple Antarctica II:
http://www.tpt.org/newtons/10/antarctic2.html

Live from Antarctica 2:
http://quest.arc.nasa.gov/antarctica2/index.html

United States Antarctic Research Center:
http://usarc.usgs.gov/

Antarctic Connection: Marine Life:
http://www.antarcticconnection.com/antarctic/science/marinelife.shtml

Glacier:
http://www.glacier.rice.edu/invitation/1_introduction.html

Arctic Circle:
http://arcticcircle.uconn.edu/

Arctic Studies Center:
http://www.mnh.si.edu/arctic/

Northern Alaska Environmental Center:
http://northern.org/artman/publish/

The BRIDGE website, www.marine-ed.org/bridge, is a unique clearinghouse of the best K-12 ocean sciences education websites available online. Educators can find information on almost any ocean science topic. The BRIDGE is supported by the National Sea Grant Office, the National Oceanographic Partnership Program (NOPP), and the National Marine Educators Association (NMEA). For more information, contact Lisa Ayers Lawrence at ayers@vims.edu or Susanna Musick at sxmusi@vims.edu.

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Volume 19 • Number 2 • 2003

Introduction

Exploration of the Canada Basin 2002

Arctic Sea Ice: Channels of Life

Spineless Wonders: The Pelagic Fauna

Physical Nutrients and Primary Productivity

Introduction to the Ocean Exploration Arctic Ocean Curriculum Unit

Activity: Current Events

Activity: Life in the Crystal Palace

Activity: Meet the Arctic Benthos

Activity: Let's Get to the Bottom of the Arctic!

Activity: Would You Like a Sample?

Activity: Being Productive in the Arctic Ocean

Activity: Polar Bear Panic

Message from the BRIDGE: The Tip of the Ice Berg

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