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## 2006 Tracking Narwhals in Greenland

# Frozen Out

### Focus
Impacts of climate change on Arctic predators

### Grade Level
7-8 (Life Science)

### Focus Question
How does climate change affect top predators in Arctic marine ecosystems?

### Learning Objectives
Students will be able to explain the concepts of indicator species and microhabitats.

Students will able to compare and contrast "average regional conditions" with "site-specific conditions."

Students will able to explain at least three examples of the impacts of climate change on top predators in the Arctic.

### Materials
- ❒ Copies of "Declining Extent of Open-water Refugia for Top Predators in Baffin Bay and Adjacent Waters" (http://faculty.washington.edu/klaidre/docs/HJandLaidre2004.pdf); one copy for each student or student group
- ❒ Copies of "Research Guide for Impacts of Climate Change on Arctic Predators," one copy for each student or student group

### Audio/Visual Materials
- ❒ Map of the Arctic region (http://www.lib.utexas.edu/maps/polar.html#arctic ; click on "Arctic Region" and you will get a pdf entitled "arctic_region_pol02.pdf"

### Teaching Time
One or two 45-minute class periods, plus time for student research

### Seating Arrangement
Classroom style or groups of 3-4 students

### Maximum Number of Students
30

### Key Words
Microhabitat
Indicator species
Arctic Ocean
Predator
Climate change

### Background Information
Global climate is heavily influenced by the Earth's ocean. One of the most significant climatic influences results from the "deep ocean thermohaline circulation" (THC). This circulation is driven by changes in seawater density, and has a major influence on water movements between the Atlantic, Antarctic, Pacific, and Indian Oceans. The causes and effects of the THC are not fully known. But we do know that it affects almost all of the world's ocean and plays an important role in transporting dissolved oxygen and nutrients. For this reason, the deep ocean THC is often called the "global conveyor belt." We also know that the THC is at least partially responsible for

the fact that countries in northwestern Europe (Britain and Scandinavia) are about 9°C warmer than other locations at similar latitudes.
In recent years, changes in the Arctic climate have led to growing concerns about the possible effects of these changes on the deep ocean THC. In the past 30 years, parts of Alaska and Eurasia have warmed by about six degrees Celsius. In the last 20 years, the extent of Arctic sea ice has decreased by at least 5%, and in some areas, sea ice thickness has decreased by 40%. Dense water sinking in the North Atlantic Ocean is one of the principal forces that drives the circulation of the global conveyor belt (see "More About the Deep Ocean Thermohaline Circulation," below). Since an increase in freshwater inflow (such as from melting ice) or warmer temperatures in these areas would weaken the processes that cause seawater density to increase, these changes could also weaken the global conveyor belt.

Changes are being seen in Arctic regions where dense seawater formation occurs, but the significance of these changes is not yet clear. Although the Arctic as a whole is getting warmer, air and sea surface temperatures near western Greenland show a significant cooling trend, and sea ice concentrations in Baffin Bay have increased significantly since 1953. At the same time, deep (400 m and below) water temperatures in Baffin Bay are slowly increasing. Some of this warmer water flows into the Labrador Sea, which is one of the sources for the cold, dense water that drives the deep ocean THC. Because it is a global process, some scientists wonder whether the THC may be related in some way to other changes being seen in Earth's ocean. One such change is an apparent decline in net oceanic primary productivity; more than six percent globally in the last two decades (Gregg, et al., 2003). Nearly 70 percent of the decline occurred in high latitudes (above 30 degrees) in the North Pacific and North Atlantic Basins. These observations, coupled with very limited understanding of how the global ocean influences life on Earth, illustrate why many scientists believe that it is critical to learn more about about the deep ocean THC and how it is being affected by climate change—especially in the Arctic. Profiles of salinity, temperature, and depth are among the most fundamental pieces of information used by biological and physical oceanographers, and are particularly relevant when studying movements of cold, dense water masses. But extreme cold, six-month nights, and ocean areas blocked by sea ice have prevented these kinds of measurements in many parts of the Arctic, particularly during winter. The Tracking Narwhals in Greenland Exploration plans to overcome these difficulties through an unusual partnership between humans and the narwhal whale.

One of the species likely to be affected by climate changes in the Arctic is the narwhal, a whale best known for its unicorn-like tusk. Narwhals spend their entire lives in the Arctic, and prefer habitats that are in or near sea ice. But increasing concentrations of sea ice may be "too much of a good thing" for narwhals, since they need some open water to survive. One of the largest populations of narwhals spends most of the winter in Baffin Bay, where they dive repeatedly to depths that exceed 1,500 m in search of food. The Tracking Narwhals in Greenland Exploration plans to enlist the help of narwhals to learn more about climate change in the Arctic and its impact on ocean ecosystems.

Instrument packages called "satellite tags" will be attached to narwhals to record temperature and depth as the whales dive for food. A transmitter in each tag will send the data to a satellite in polar orbit above Earth. Later, the data will be downloaded back to Earth to give scientists the first-ever information on deepwater winter temperatures in Baffin Bay. The purpose of the Tracking Narwhals in Greenland Exploration is to improve our understanding of climatic changes occurring in an offshore ecosystem of Baffin Bay, and how these changes may affect narwhal populations that are part of that ecosystem. Expedition activities are directed toward three objectives:

- To employ narwhals as oceanographic sampling platforms to collect temperature data from deep waters in Baffin Bay;
- To identify narwhals' response to movement of openings in pack ice; and
- To describe relationships between narwhal behavior and properties of the pack ice habitat.

In this lesson, students will investigate some of the ways in which climate change may affect top predators in Arctic marine ecosystems. Because this activity is based on a technical journal article, it also provides an introduction to reading and interpreting scientific writing.

## Learning Procedure

1. To prepare for this lesson, read the introductory essays for the Tracking Narwhals in Greenland Exploration at http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html, and "Declining Extent of Open-water Refugia for Top Predators in Baffin Bay and Adjacent Waters" (from http://faculty.washington.edu/klaidre/docs/HJandLaidre2004.pdf). If students will not have access to the internet for research, make copies of the latter article for each student group to have at least one copy.

2. Briefly review the concept of the deep ocean THC, highlighting the importance of cold, dense water formation in the Arctic. Briefly discuss students' ideas about how global climate change may be affecting the Arctic region. Be sure students realize that an "average temperature increase" does not mean that temperature is increasing everywhere, and that some parts of the Arctic (e.g., western Greenland and Baffin Bay) have been getting colder in recent decades. Introduce the Tracking Narwhals in Greenland Exploration. Have students discuss the difficulties of working in the Arctic region, especially during winter, and "brainstorm" ways in which these difficulties might be overcome. Briefly discuss how scientists plan to use narwhals as "partners" to collect information about winter oceanographic conditions in Baffin Bay.

3. Tell students that their assignment is to write a report based on the scientific paper, "Declining Extent of Open-water Refugia for Top Predators in Baffin Bay and Adjacent Waters." Say that this paper was written for professional scientists and contains a number of technical terms, but that the key points of the paper are not difficult to understand. Distribute copies of the "Research Guide for Impacts of Climate Change on Arctic Predators," and tell students that their reports should include answers to these questions. You may choose to have students prepare their reports individually or in small groups, though the group approach will usually encourage more thought and discussion among students.

   Since the scientific paper contains a number of terms that will probably be unfamiliar, it is important for students to begin by defining the terms in Question 1 using a dictionary, encyclopedia or online resources. Similarly, the paper is easier to understand if one is familiar with the overall geography of the region studied, so Question 2 should also be completed before attempting to answer the remaining questions. Once the first two questions are completed, students should concentrate primarily on the Introduction, Discussion, and Conclusions sections to find answers to the remaining questions.

4. Lead a discussion of students' answers to worksheet questions. The following points should be included:
   - Definitions
     a. *microhabitat* – a small area within a habitat, such as the space beneath a coral in a coral reef habitat
     b. *refugia* – places that provide shelter or protection from danger
     c. *upwelling* – a movement of water from deep areas to shallower areas, often transporting nutrients from deep waters to

shallower zones where they may be used by primary producers

d. *indicator species* – species whose condition or habits provide information about other species that are less easily observed
e. *leads* – narrow channels through ice fields (pronounced "leeds")
f. *polynya* – the Russian word for 'open-water area surrounded by ice'
g. *cetacean* – a member of the order Cetacea, which includes whales, porpoises, and dolphins
h. *pinniped* – a member of the order Pinnipedia, which includes seals and walruses
i. *little auk* – a small diving sea bird having a stout-body and short bill, found in Arctic waters
j. *benthic* – located at the bottom of a sea or lake
k. *eider* – a sea duck belonging to the genus Somateria or related genera
l. *murre* – a sea bird, also known as a guillemot, belonging to the genus *Uria* or related genera
m. *narwhal* – an Arctic whale, *Monodon monoceros*
n. *copepod* – small aquatic crustacean belonging to the subclass Copepoda; often important components of the zooplankton
o. *phenology* – the study of periodic biological phenomena, such as migrations, especially in relation to climate

- Predictability of the year-to-year location of microhabitats allows Arctic seabirds and marine mammals to easily find open-water areas that are critical to survival during winter.
- Predators tend to gather around areas where upwelling events occur because the nutrients associated with upwelling support the growth of phytoplankton (single-celled aquatic algae; primary producers) that provide food for zooplankton and animals that feed on zooplankton (consumers), and thus provide a source of food for predators.
- Concentrations of sea ice have increased in the past two decades in Baffin Bay, Davis Strait, and coastal West Greenland while sea ice has decreased in Hudson Bay, Hudson Strait, and Foxe Basin.
- Seabirds are able to travel relatively long distances in a short period of time to find locations where food is available. Marine mammals have a layer of blubber that provides a food reserve that can sustain the animals during periods in which food availability is limited.
- Of the four marine mammals examined in this study, the walrus is most able to break into thick ice.
- Sea ice may cause immediate mortality in Arctic cetaceans if the ice covers the surface of the ocean so that the animals cannot breathe. The paper states that cetaceans "urgently require oxygen" after deep dives.
- "Cascading effects of changes in marine productivity" refers to the fact that primary producers (phytoplankton) are the base of marine food webs that depend on photosynthesis, and hence affect many other species. Increased sea ice concentrations cause cooler water conditions that may slow or delay phytoplankton production. As a result, less food is available to copepods (a type of zooplankton) that migrate to the surface to feed at certain times of the year. Reduced production of copepods, in turn, would reduce the amount of food available to plankton feeders such as bowhead whales, little auks, and various fishes; and fewer fishes means less food for top predators such as murres, belugas, and narwhals.
- Reduced open water due to increased sea ice limits seabirds' access to food, which can be critical because these birds have a high metabolic rate and must feed frequently to survive. The primary threat to marine mammals from

increased sea ice is that the ice may prevent breathing at the ocean surface. Nutrition may be a problem for the mammals as well, if sea ice reduces the number of suitable feeding sites, so that more animals are concentrated in fewer sites.

## The Bridge Connection

www.vims.edu/bridge/ – Enter "greenhouse" in the "Search" box, then click "Search" to display entries on the Bridge Web site for global climate change and the greenhouse effect.

## The "Me" Connection

Have students which a brief essay describing ways in which changes in Arctic marine ecosystems could be of personal importance.

## Connections to Other Subjects

English/Language Arts, Geography, Physical Science

## Assessment

Students' answers to worksheet questions and participation in class discussions provide opportunities for assessment.

## Extensions

1. Visit http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html for daily logs and updates about discoveries being made by the Tracking Narwhals in Greenland Exploration.

2. Visit http://oceanography.geol.ucsb.edu/Ocean_Materials/Mini_Studies/Greenhouse_gases/Greenhouse_gases.html for more information and activities related to the greenhouse effect.

## Resources

**NOAA Learning Objects**

http://www.learningdemo.com/noaa/ Click on the link to Lesson 8 - Ocean Currents.

**Other Relevant Lesson Plans from the Ocean Exploration Program**

### Getting to the Bottom

http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_gettingtothebottom.pdf
(7 pages, 295k) (from the Hidden Ocean, Arctic 2005 Expedition)

Focus – (Biology) Benthic communities in the Canada Basin

In this activity, students will be able to identify major taxa that are dominant in deep benthic communities of the Arctic Ocean. Given distribution data for major taxa in different Arctic benthic communities, students will be able to identify patterns in the distribution of these taxa and infer plausible reasons for these patterns.

### Burp Under the Ice

http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/05arctic_burp.pdf
(5 pages, 269k) (from the Hidden Ocean, Arctic 2005 Expedition)

Focus - (Earth Science) Potential role of Arctic methane deposits in climate change

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

### The Good the Bad and the Arctic

http://oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/arctic05_goodandbad.pdf
(13 pages, 368k) (from the Hidden Ocean, Arctic 2005 Expedition)

Focus – (Biology/Earth Science) Social, economic and environmental consequences of Arctic climate change

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

### Top to Bottom

http://oceanexplorer.noaa.gov/explorations/05stepstones/background/education/ss_2005_topbottom.pdf
(7 pages, 348k) (from the North Atlantic Stepping Stones 2005 Expedition)

Focus (Earth Science/Life Science) - Impacts of climate change on biological communities of the deep ocean

In this activity, students will be able to describe thermohaline circulation, explain how climate change might affect thermohaline circulation, and identify the time scale over which such effects might take place. Students will also be able to explain how warmer temperatures might affect wind-driven surface currents and how these effects might impact biological communities of the deep ocean, and discuss at least three potential impacts on biological communities that might result from carbon dioxide sequestration in the deep ocean.

### The Big Burp: Where's the Proof?

http://oceanexplorer.noaa.gov/explorations/03windows/background/education/media/03win_proof.pdf
(5 pages, 364k) (from the 2003 Windows to the Deep Expedition)

Focus: Potential role of methane hydrates in global climate change (Earth Science)

In this activity, students will be able to describe the overall events that occurred during the Cambrian explosion and Paleocene extinction events and will be able to define methane hydrates and hypothesize how these substances could contribute to global climate change. Students will also be able to describe and explain evidence to support the hypothesis that methane hydrates contributed to the Cambrian explosion and Paleocene extinction events.

### Being Productive

http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_productive.pdf
(14 pages, 512k) (from the 2002 Arctic Exploration Expedition)

Focus: Primary productivity and limiting factors in the Arctic Ocean (Chemistry/Biology)

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

### Current Events

http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_c_events.pdf
(8 pages, 472k) (from the 2002 Arctic Exploration Expedition)

Focus: Currents and water circulation in the Arctic Ocean (Earth Science)

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

### Other Links and Resources

*The web links below are verified at the time of publication, but over time, some links may change or become obsolete. Searching with key words may help to locate an updated site.*

http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html – Follow the Tracking Narwhals in Greenland Exploration daily as documentaries and discoveries are posted each day for your classroom use.

http://www.narwhal.info/ – Web site dedicated to the gathering and sharing of information about narwhals

http://www.nasa.gov/centers/goddard/news/topstory/2003/0815oceancarbon.html – "Ocean Plant Life Slows Down and Absorbs Less Carbon;" article about decreasing ocean primary productivity

http://www.nasa.gov/home/hqnews/2003/jun/HQ_03182_green_garden.html – "Global Garden Grows Greener;" article about increases in terrestrial primary productivity

Laidre, K. L. and M. P. Heide-Jørgensen. 2005. Winter feeding intensity of narwhals. Marine Mammal Science 21(1):45-57. http://faculty.washington.edu/klaidre/docs/LaidreandHJ_2005b.pdf

Laidre, K. L. and M. P. Heide-Jørgensen. 2005. Arctic sea ice trends and narwhal vulnerability. Biological Conservation 121:509-517. http://faculty.washington.edu/klaidre/docs/LaidreandHJ_2005a.pdf

Laidre, K. L., M. P. Heide-Jørgensen, M. L. Logsdon, R. C. Hobbs, P. Heagerty, R. Dietz, O. A. Jørgensen, and M. A. Treble. 2004. Seasonal habitat associations of narwhals in the high Arctic. Marine Biology 145:821-831. http://faculty.washington.edu/klaidre/docs/Laidreetal_2004c.pdf

Laidre, K. L., M. P. Heide-Jørgensen, O. A. Jørgensen, and M. A. Treble. 2004. Deep ocean predation by a high Arctic cetacean. ICES Journal of Marine Science 61(3):430-440. http://faculty.washington.edu/klaidre/docs/Laidreetal_2004b.pdf

Heide-Jørgensen, M. P. and K. L. Laidre. 2004. Declining Extent of Open-water Refugia for Top Predators in Baffin Bay and Adjacent Waters. Ambio 33(8):488-495. http://faculty.washington.edu/klaidre/docs/HJandLaidre2004.pdf

Heide-Jørgensen, M. P., R. Dietz, K. L. Laidre, P. Richard, J. Orr, and H. C. Schmidt. 2003. The migratory habits of narwhals. Canadian Journal of Zoology 81:1298-1305. http://faculty.washington.edu/klaidre/docs/HJetal_2003b.pdf

http://www.tyndall.ac.uk/publications/tyn_symp/arctic.pdf – Synopsis of a conference on "Climate Change, the Arctic and the United Kingdom: directions for future research;" 8 May 2002, University of East Anglia

http://www.arctic-council.org – Web site for the Arctic Council

http://www.acia.uaf.edu – Web page for the Arctic Climate Impact Assessment secretariat

http://www.ngdc.noaa.gov/paleo/ctl/about4.html – "Overview of Climate Processes" from NOAA's Paleoclimatology Web site

http://www.uky.edu/KGS/education/geologictimescale.pdf and http://www.uky.edu/KGS/education/activities.html#time – Great resources on geological time and major events in Earth's history

## National Science Education Standards

**Content Standard A: Science As Inquiry**

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

**Content Standard C: Life Science**

- Populations and ecosystems
- Diversity and adaptations of organisms

**Content Standard E: Science and Technology**

- Understandings about science and technology

**Content Standard F: Science in Personal and Social Perspectives**

- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

## Ocean Literacy Essential Principles and Fundamental Concepts

**Essential Principle 1.**
**The Earth has one big ocean with many features.**

- *Fundamental Concept c.* Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.
- *Fundamental Concept h.* Although the ocean is large, it is finite and resources are limited.

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

- *Fundamental Concept b.* The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
- *Fundamental Concept f.* The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.
- *Fundamental Concept g.* Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.

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

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

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

- *Fundamental Concept c.* The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
- *Fundamental Concept e.* Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
- *Fundamental Concept g.* Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

**Essential Principle 7.**
**The ocean is largely unexplored.**

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

- *Fundamental Concept b.* Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
- *Fundamental Concept d.* New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
- *Fundamental Concept f.* Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

## Send Us Your Feedback

We value your feedback on this lesson.
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## For More Information

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

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## Student Handout
## Research Guide for Impacts of Climate Change on Arctic Predators

1. Define the following terms:
   a. microhabitat
   b. refugia
   c. upwelling
   d. indicator species
   e. leads
   f. polynya
   g. cetacean
   h. pinniped
   i. little auk
   j. benthic
   k. eider
   l. murre
   m. narwhal
   n. copepod
   o. phenology

2. Locate on a map
   Baffin Bay
   Davis Strait
   Hudson Strait
   Northern Hudson Bay
   Foxe Basin
   Lancaster Sound
   Robeson Channel

3. Why is it important that microhabitats occur predictably in the same locations year after year?

4. Why do predators tend to gather around areas where upwelling events occur?

5. Compare changes in the amount of sea ice in Baffin Bay, Davis Strait, and coastal West Greenland with changes in the amount of sea ice in Hudson Bay, Hudson Strait, and Foxe Basin.

6. Compare the strategies used by marine mammals and seabirds to deal with periods of time in which food availability is limited.

7. Of the four marine mammals examined in this study, which is most able to break into thick ice?

8. How can sea ice cause immediate mortality in Arctic cetaceans?

9. In the conclusion of the paper, the authors refer to "cascading effects of changes in marine productivity." What does this mean?

10. How are the effects of increased sea ice on Arctic seabirds different from the effects of increased sea ice on Arctic marine mammals?