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2006 Tracking Narwhals in Greenland

The Good, the Bad and The Arctic

(adapted from the Hidden Ocean, 2005 Arctic Expedition)

Focus
Social, economic and environmental consequences of Arctic climate change

Grade Level
9-12 (Biology/Earth Science)

Focus Question
What social, economic and environmental consequences are expected to result from Arctic climate change?

Learning Objectives
Students will be able to identify and explain at least three lines of evidence that suggest the Arctic climate is changing.

Students will be able to identify and discuss at least three social, three economic and three environmental consequences expected as a result of Arctic climate change.

Students will be able to identify at least three climate-related issues of concern to Arctic indigenous peoples.

Students will be able to identify at least three ways in which Arctic climate change is likely to affect the rest of the Earth's ecosystems.

Materials
- ❒ Copies of "Impacts of Arctic Climate Change Worksheet," one copy for each student or student group
- ❒ (Optional) Copies of resource materials needed for student research; see "Learning Procedure"

Audio/Visual Materials
None

Teaching Time
One 45-minute class period for introduction and two or more periods for student reports, plus time for student research; see Note in "Learning Procedure" Step 1

Seating Arrangement
Groups of 2-6 students

Maximum Number of Students
30

Key Words
Arctic Ocean
Baffin Bay
Narwhal
Climate change
Indigenous peoples
Traditional knowledge
Marine pollution
Biodiversity
Integrated management

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.

Ocean Exploration expeditions in 2002 and 2005 focussed on the Canada Basin, which includes the deepest parts of the Arctic Ocean which is particularly isolated and unexplored because of year-round ice cover. A key objective of these expeditions was to obtain detailed information about the living and physical components of Canada Basin ecosystems, including a wide range of organisms from microbes to vertebrates. A strong element of urgency accompanied these expeditions, because the Arctic environment is changing at a dramatic rate.

The 2006 Tracking Narwhals in Greenland Exploration is directed toward obtaining profiles of salinity, temperature, and depth in Baffin Bay; a region that is directly involved with processes that drive the deep ocean THC. These profiles are among the most fundamental pieces of information used by biological and physical oceanographers, but extreme cold, six-month nights, and ocean areas blocked by sea ice have made these measurements impossible in Baffin Bay during the 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.

The environmental, social, and economic consequences of Arctic climate change are a primary concern of an intergovernmental group known as the Arctic Council. Members of the Arctic Council include all of the nations whose territory includes the Arctic region: Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden, and the United States. In addition, the Council also includes six international organizations that represent many indigenous peoples of the Arctic: Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Conference, Russian Association of Indigenous Peoples of the North, and Saami Council. Environmental monitoring and assessment is a key element of the Council's activities, which are carried out by five expert Working Groups. A closely related activity is the Arctic Climate Impact Assessment (ACIA), an international project of the Arctic Council and the International Arctic Science Committee to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation in the Arctic and the consequences of these changes. The full ACIA scientific report (1042 pages) can be downloaded from http://www.acia.uaf.edu/pages/scientific.html.

Because winter oceanographic conditions in Baffin Bay have never been studied, the work of the Tracking Narwhals in Greenland Exploration is crucial to international efforts to monitor the impacts of Arctic climate change and prepare for the consequences of these impacts. This lesson is intended to provide an introduction to the larger context of this exploration. While many people still think of the Arctic as a remote part of Earth with little connection to human communities in temperate regions, the reality is that Arctic climate change will have major global impacts. To better understand these impacts, students will use very recent information produced by the Arctic Council to investigate some of the anticipated social, economic, and environmental consequences of Arctic climate change.

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 for an overview of the expedition and background information. Students are expected to draw primarily upon reports prepared by the Arctic Council's Working Groups

and the ACIA to complete their assignments. You should review "ACIA Highlights" (http://amap.no/acia/Highlights.pdf), and may also want to review the Working Group reports listed below. If students will not be using the internet to complete their assignment, you will also need to download and copy these documents for student use.

Note: Because the resource materials to be used by students in this lesson contain substantial amounts of information, student reports have the potential to be fairly long. For this reason, and because this topic can be readily linked to numerous other curriculum elements, you may want to consider treating this lesson as a long term assignment extending over several weeks.

2. Briefly review the geography of the Arctic Ocean and the deep ocean THC, highlighting the importance of cold, dense water formation in the Arctic as a driving force of the THC. Point out that the climate of the Arctic is rapidly changing, and briefly discuss the implications of these changes to the THC. 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, and 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 investigate Arctic climate change and prepare reports about some of the social, economic, and environmental consequences that are expected to result from this change. Assign one of the following topics to each student group:
   - Climate trends in the Arctic region
   - Indigenous peoples and traditional knowledge
   - Arctic marine pollution
   - Environmental emergencies and risk management in the Arctic
   - Ecosystem-based approaches for conserving Arctic biodiversity

   Because the individual reports relevant to these topics contain different amounts of information, you may want to adjust the size of student groups to reflect the quantity of material to be reviewed.

   Tell each group to review general information on Arctic climate change and answer questions in Part A of the "Impacts of Arctic Climate Change Worksheet" before beginning work on their specific topic. Tell students that the Guide Questions in Part B of the worksheet are intended to help focus on key topics, but that they should include other information in their reports that they believe is relevant or important. You may also want to have students include graphs and other images that are available on the Ocean Explorer and ACIA Web sites.

   Depending upon students' internet research skills, you may want to provide the following links, or simply say that students should refer to resources provided by the Arctic Council and ACIA. As noted above, these resources contain extensive amounts of information, so it is important to specify the approximate length and level of detail expected in students' reports. Key references and links are:
   - "ACIA Highlights" (http://amap.no/acia/Highlights.pdf)
   - Indigenous Peoples Secretariat (http://www.arctic-peoples.org/aboutIPS/participants.html)
   - "Understanding Arctic Marine Pollution" (http://www.pame.is/sidur/uploads/AMAPunderstanding%20Science.pdf)
   - "Environmental Emergencies and Risk Management" (http://www.pame.is/sidur/uploads/environmentalemergenciesandriskmanagment.pdf)
   - "Ecosystem-based Approaches for Conserving Arctic Biodiversity" (http://www.pame.is/sidur/uploads/ecosystembasedapproaches.pdf)

4. Have each student group present an oral report on their research findings, then lead a discussion of these results. Key points include:

Background Review Questions

- The overall extent of Arctic sea ice has decreased by 5% in the last 20 years (8% in the last 30 years). In some areas, sea ice thickness has decreased by 40%.
- Ice in the Greenland Ice Sheet contains enough water to raise global sea levels by 7 meters.
- Sea ice is melting at an increasing rate over the Greenland Ice Sheet.
- Global average sea level has risen by about 8 cm during the past 20 years.
- Rising sea level and reduced sea ice allow stronger waves and storm surges to reach shore, increasing coastal erosion; particularly where melting permafrost has weakened the soil structure.
- Ultraviolet radiation in the Arctic is increasing due to depletion of stratospheric ozone.
- Glaciers are shrinking throughout the Arctic region.
- Woody plants and scrub vegetation are becoming more widely distributed and are replacing tundra-type vegetation.
- Net oceanic primary productivity has declined by more than six percent globally in the last two decades. Students may find reports indicating that the increase in terrestrial vegetation results in an increase in primary production of about the same magnitude as the decrease in oceanic primary production. Be sure students understand that these changes do not "balance each other out," because marine food webs cannot substitute terrestrial primary production for decreased oceanic primary production.
- Permafrost is thawing at an increasing rate, causing unstable ground conditions that damage roads, pipelines, and building foundations.

Climate Trends in the Arctic Region

- In general, the Arctic climate is warming more rapidly than elsewhere on Earth. Reasons for this include:
  - Reduced surface reflectivity caused by snow- and ice- melt allows more solar energy to be absorbed by the Earth's surface;
  - More of the trapped energy goes directly to warming rather than to providing heat for evaporation;
  - Less heat is required to warm the atmosphere over the Arctic because the Arctic atmosphere is thinner than elsewhere;
  - With less sea ice, the heat absorbed by the ocean in summer is more easily transferred to the atmosphere in winter; and
  - Changes in atmospheric and oceanic circulation can cause heat to be retained in the Arctic region
- Current global temperature trends coincide with a rise in atmospheric concentrations of greenhouse gases over the last 200 years.
- The melting trend on the Greenland Ice Sheet was interrupted in 1992 when ash from the Mt. Pinatubo volcano reduced the amount of sunlight reaching the Earth's surface, resulting in a short-term global cooling event.
- Changes in snow, ice, and vegetation lower the reflectivity of Arctic land and ocean surfaces, causing more solar energy to be absorbed and thus accelerate global climate change.
- While warmer temperatures were the trend for most of the Arctic region between 1966 and 1995, a cooling trend took place in the northernmost portions of the Arctic during this period. Arctic climate systems are complex, and are strongly influenced by circulation in the atmosphere and ocean. Since this circulation is driven primarily by temperature differences, changes in temperature would be expected to alter circulation patterns, and could isolate some parts of the Arctic region from warmer conditions elsewhere.
- Warmer climates could cause significant quantities of water, methane, and carbon dioxide to be released from the Arctic. The result of these releases would be rising sea level, and increasingly warm temperatures

due to the "greenhouse effect" of methane and carbon dioxide (see the "Burp Under the Ice" lesson [www.oceanexplorer.noaa.gov/explorations/05arctic/background/edu/media/05arctic_burp.pdf] for more about the potential consequences of methane releases).

Indigenous Peoples and Traditional Knowledge

- The Arctic indigenous organizations participating in the Arctic Council are:
  - Aleut International Association representing Aleuts on the Russian and American Aleutian Islands;
  - Arctic Athabaskan Council representing Athabaskans in Canada and the U.S.;
  - Gwich'in Council International representing Gwich'in in Canada and the U.S.;
  - Inuit Circumpolar Conference representing Inuit in Greenland (Denmark), Canada, Alaska, and Chukotka (Russia);
  - Russian Association of Indigenous Peoples of the North representing 30 different peoples of the North, Far East, and Siberian regions of the Russian Federation; and
  - Saami Council representing Saami people of Norway, Sweden, Finland, and Russia
- Traditional knowledge is the knowledge of indigenous peoples built up over generations and often passed from generation to generation by word of mouth. It is a combination of knowledge about the local environment, spiritual beliefs, and social customs and philosophies.
- Persistent toxic substances are a key issue among indigenous peoples of the Arctic because studies have found toxic chemicals in the body tissues of many people living in the Arctic.
- Over many generations, Arctic indigenous peoples have selected diets that meet the specific nutritional needs of humans living in the Arctic climate. Switching to imported foods could pose significant health risks, as well as financial hardships since imported foods are almost certain to be more expensive than traditional foods. In addition, a drastic change in diet would have spiritual and cultural impacts, since a deep attachment to the land and the food it provides are central elements of indigenous Arctic cultures.
- The Stockholm Convention on Persistent Organic Pollutants commits nations that ratify the treaty to work toward elimination of 12 of the world's most dangerous chemicals whose health effects include cancer, reproductive disorders, immune system deficiencies and reductions in cognitive function. The compounds targeted by the Convention are:
  Aldrin
  Chlordane
  Dieldrin
  Dioxins
  DDT
  Endrin
  Furans
  Heptachlor
  Hexachlorobenzene
  Mirex
  Polychlorinated biphenyls (PCBs)
  Toxaphene

The significance of the Convention to indigenous peoples of the Arctic region is primarily that there is a formal commitment to eliminate the use and production of dangerous chemicals that have found their way from other parts of the world into the Arctic. Actual implementation of the Convention may require years, however, and there are many other sources of contamination that pose serious threats to Arctic ecosystems.

- Impacts of Arctic climate change on indigenous peoples of the region include:
  - Changes in reindeer grazing pastures
  - Reduction in polar bear populations because of habitat loss
  - Appearance of new insect species
  - Damage to buildings, pipelines, and roads because of coastal erosion and unstable

soils resulting from melting permafrost
- Increasingly dangerous conditions on traditional ice and water transportation routes due to thinning ice and altered water flows
- Major shortages of traditional foods due to continued reduction of sea ice and altered vegetation in the Arctic

Arctic Marine Pollution

- The four major categories of contaminants found in the Arctic are:
  - Persistent organic pollutants
  - Heavy metals
  - Artificial radionucleides
  - Polycyclic aromatic hydrocarbons (PAHs)
- Most contaminants originate with agricultural and industrial activities elsewhere on Earth. Some of the contaminants that enter global air and water circulation are eventually carried to the Arctic.
- Mercury, cadmium and lead are the heavy metals of greatest concern. Fossil fuel combustion is the primary anthropogenic source of mercury. Production of nonferrous metals such as zinc is the primary anthropogenic source of cadmium and lead, although combustion of leaded gasoline was the primary source of lead prior to the widespread ban on lead additives in gasoline.
- Brominated flame retardants and perfluorinated alkanes used to make clothing stain resistant are two relatively new sources of persistent organic pollutants.
- Nuclear weapons testing has historically been the greatest source of radionucleide contamination.
- Contaminants may enter the Arctic marine environment via
  - inflowing ocean currents
  - atmospheric deposition
  - north-flowing rivers
  - runoff from land
  - direct disposal into the ocean
- Springtime mercury depletion events occur at the time of polar sunrise when a combination of chemical reactions cause gaseous elemental mercury (Hg0) to be converted into a gaseous ionized form (Hg2+) that is much more reactive and as a result is readily deposited onto various surfaces. When reactive mercury is deposited onto snow it may be carried by snow melt into marine and aquatic environments where it is transformed into methyl mercury which accumulates in food chains and eventually concentrates in marine mammals.
- Bioconcentration is the process in which a contaminant passes through cell membranes directly into an organism from the surrounding water. The concentration of the contaminant inside the cells may become much greater than the concentration in the water. This process is particularly significant in zooplankton and phytoplankton. In larger organisms, consumption of contaminated prey is the primary way in which contaminants enter the organism. Once the contaminant is ingested, the only way the organism can get rid of it is through excretion or metabolism. Bioaccumulation occurs when the rate at which a contaminant is ingested exceeds the rate at which the organism is able to get rid of the contaminant. Biomagnification occurs when the concentration of a contaminant increases with each step in the food chain. For example, if a plankton feeder must consume 10 grams of plankton to produce 1 gram of biomass, a contaminant in the plankton could be increased ten-fold in the plankton feeder (assuming the plankton feeder was unable to get rid of the contaminant).
- Hexachlorocyclohexanes (HCHs) are the most common persistent organic pollutants in Arctic seawater. There are eight different HCH isomers, one of which (gamma-HCH, commonly known as lindane) is manufactured as an insecticide. Lindane produces a variety of toxic effects in humans, including death. All HCH isomers are likely to cause cancer.

- Great skua would be expected to have higher tissue concentrations of persistent organic pollutants than guillemots, because great skua are higher in the food chain and are thus likely to have a greater degree of biomagnification of contaminants.
- The immune, reproductive, nervous, and endocrine systems are known to be significantly affected by persistent organic pollutants.
- Polar bears, the top predator in the Arctic marine ecosystem, have been found to have reduced rates of cub survival that correlate with high tissue levels of persistent organic pollutants.
- Lead is not generally considered to be a major risk to ecosystem health because lead in seawater is typically adsorbed onto particulate matter and is not readily available to living organisms. As a result, lead does not accumulate in organisms and is not subject to biomagnification. Mercury, on the other hand, is converted to methylmercury by microorganisms and is much more available to other living organisms. Methylmercury is also biomagnified in food chains, so animals at the top of a food chain may have tissue concentrations of mercury 1000 - 3000 times higher than the concentration in surrounding seawater.
- The Inuit people have higher exposure to mercury than the Dene people because of their dietary preference for marine mammals, which are higher in the food chain than foods preferred by the Dene.
- The primary strategy for reducing human exposure to persistent organic pollutants and heavy metals in the Arctic has been to suggest that girls and pregnant women limit or eliminate their consumption of species that are likely to have high concentrations of contaminants (such as marine mammals high on the food chain).

Environmental Emergencies and Risk Management in the Arctic

- The Emergency Prevention Preparedness and Response Working Group is primarily concerned with emergencies associated with the spill or release of hazardous materials into the environment, though the Working Group is examining the possibility of expanding its focus to include natural disasters.
- Transportation and storage of oil poses the greatest threat to the Arctic from release of a pollutant.
- Low temperatures, short growing season, and fewer species to degrade contaminants mean that physical and biological processes that degrade contaminants will operate more slowly than elsewhere on Earth, and thus make the Arctic more vulnerable to damage from contamination and other human impacts.
- If current climate trends continue, seasonal sea lanes may appear through historically ice-locked areas of the Arctic by 2015.
- The productivity of Arctic terrestrial, aquatic, and marine systems is likely to increase as a result of increased freshwater flow due to a warmer climate. Winter habitat in streams and rivers for freshwater and anadromous fishes should improve significantly, to the point that commercial fishing industries may become possible.
- Reduction in sea ice due to climate change will make natural resources of the Arctic more accessible. In addition to petroleum, these resources include transportation routes, forestry, mineral resources, fisheries, tourist attractions, and land suitable for urban development. Because exploitation of these resources has the potential to cause environmental damage (though such damage is not inevitable), climate change increases the risk of environmental emergencies in the Arctic.

Ecosystem-based Approaches for Conserving Arctic Biodiversity

- Biodiversity is the amount of variety or variability within a group of organisms. In a given geographic area, biodiversity includes the amount of variability between individuals of each species, between different species, and between different ecosystems.

- An "ecosystem approach" uses the best available knowledge about specific ecosystems and how they work to determine how human activities can contribute to maintaining the health of these ecosystems as well as obtain maximum benefits from these ecosystems on a continuing basis.
- Integrated management is a series of actions that protect natural resources and also ensure that these resources can be used for sustained human benefit. The key concepts are "protection" and "sustained use." Integrated management is distinct from a sole emphasis on conservation, as well as from a sole emphasis on exploitation for human benefit. The idea is to undertake actions that
  (1) provide human benefits from using natural resources, and
  (2) ensure that natural resources are cared for so that these benefits can continue indefinitely.
- To date, the most effective way to conserve marine biodiversity has been to regulate human activities in the marine environment and to set aside areas in which human activity is prohibited or closely controlled.
- The United Nations Convention on the Law of the Sea is the overall framework for conservation and sustainable use of the world's ocean.
- Among the international Conventions that are important to marine conservation are:
  – Global Program of Action for the Protection of the Marine Environment from Land-Based Activities
  – Convention on International Trade in Endangered Species
  – International Whaling Convention
  – Convention on Wetlands of International Importance
  – World Heritage Convention
  – International Migratory Species Convention
  – United Nations Fisheries Agreement
  – Convention for the Prevention of Pollution from Ships
  – Convention on the Protection of the Marine Environment of the Northeast Atlantic
- Among the threats to Arctic marine biodiversity are:
  – Climate change
  – Ozone depletion
  – Environmental changes
  – Threats to the high seas
  – Physical disturbance and habitat fragmentation
  – Chemical disturbance
  – Invasive alien species
  – Overexploitation associated with commercial use
  – Incidental impacts of commercial use
  – Overexploitation associated with subsistance use
  – Aquaculture
  – Commercial shipping and extractive uses
  – Tourism
- Twelve actions to conserve biodiversity that have been recommended for inclusion in the Arctic Council's Arctic Marine Strategic Plan are:
  – Identify ecologically-important marine areas and habitats and ensure their protection
  – Promote an ecosystem approach to Arctic marine and coastal resource use
  – Manage Arctic marine activities to support protection, maintenance, and restoration of biodiversity
  – Incorporate marine biodiversity concerns into decision-making processes
  – Assess the interaction between development activities and biodiversity
  – Identify threats to Arctic marine species and identify appropriate conservation measures
  – Assess impacts of major threats (see above) and develop appropriate strategies to minimize their impact

– Develop and implement programs to monitor Arctic marine biodiversity
– Work with non-Arctic states to improve conservation strategies for migratory and nomadic species
– Encourage participation of Arctic indigenous peoples and other residents and local communities in marine biodiversity conservation activities
– Develop a circumpolar marine policy that recognizes all values of the marine environment
– Consider establishing a circumpolar Arctic Marine Ecosystem Council to coordinate implementation of an Arctic Marine Strategic Plan

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 write a brief essay describing how knowledge of previously unexplored Arctic marine environments (like Baffin Bay) could be personally important. If they have difficulty getting started, suggest that they consider how the Arctic region as a whole is personally important (consider global weather systems) and how climate change in this region may have personal impacts.

Connections to Other Subjects

Biology, Chemistry, English/Language Arts, Geography

Assessment

Student reports prepared in Learning Procedure Step 3 and group discussion in Step 4 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 warming (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 (Chemistry/Biology)

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

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.

Gregg, W. W., M. E. Conkright, P. Ginous, J. E. O'Reily, and N. W. Casey. 2003. Ocean primary production and climate: Global decadal scales. Geophysical Research Letters 30:31-34.

http://www.narwhal.info/ – Web site dedicated to gathering and sharing 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

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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 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
- Geochemical cycles

Content Standard E: Science and Technology
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Personal and community health
- Natural resources
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

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 e.* Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.
- *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 a.* The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
- *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 6.
The ocean and humans are inextricably interconnected.

- *Fundamental Concept e.* Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
- *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.
Please send your comments to:
oceanexeducation@noaa.gov

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Student Handout
Impacts of Arctic Climate Change Worksheet

Part A: Background Review Questions

1. What has happened to Arctic sea ice in the last 20 years?
2. How could water in the Greenland Ice Sheet affect global sea levels?
3. What is happening to sea ice in the Greenland Ice Sheet?
4. What has happened to global average sea level during the past 20 years?
5. How could a warmer Arctic climate affect coastal erosion?
6. What is happening to ultraviolet radiation levels in the Arctic region?
7. What is happening to glaciers in the Arctic region?
8. How are vegetation patterns changing in the Arctic region?
9. How has oceanic primary productivity changed in the last two decades?
10. How are changes in permafrost affecting human activities?

Part B: Guide Questions for Research Topics

Topic: Climate Trends in the Arctic Region

- See Review Questions in Part A
- How are climate trends in the Arctic different from similar trends elsewhere on Earth? Why?
- What evidence is there that "greenhouse gases" contribute to the present climatic trends in the Arctic?
- What happened in 1992 that interrupted the pattern of change on the Greenland Ice Sheet?
- How do changes in snow, ice, and vegetation in the Arctic affect global warming?
- Why do climactic trends differ in different parts of the Arctic region?
- Warmer climates could cause significant releases of what substances from the Arctic? What might be some of the consequences of these releases?

Topic: Indigenous Peoples and Traditional Knowledge

- What are the six Arctic indigenous organizations that take part in the work of the Arctic Council, and what peoples do they represent?
- What is "traditional knowledge" and what broad subjects does it include?
- Why are persistent toxic substances a key issue among indigenous peoples of the Arctic?
- Why can't indigenous peoples of the Arctic avoid toxic substances by switching to imported foods known to be free of contaminants?
- What is the significance of the Stockholm Convention on Persistent Organic Pollutants to Arctic indigenous peoples?
- What impacts is Arctic climate change having on indigenous peoples of the region?

Topic: Arctic Marine Pollution

- What four major categories of contaminants are found in the Arctic?
- What is the origin of most of these contaminants?
- Which of the heavy metals are of greatest concern, and what human activities are the primary sources of these metals?
- What chemicals used to treat clothing are relatively new sources of persistent organic pollutants?
- Historically, what has been the greatest source of radionucleide contamination?
- What are the five physical pathways through which contaminants may enter the Arctic marine environment?

- What are springtime mercury depletion events, and how may they lead to an accumulation of mercury in marine mammals?
- What are bioconcentration, bioaccumulation, and biomagnification?
- What are the most common persistent organic pollutants in Arctic seawater?
- Which birds would you expect to have higher tissue concentrations of persistent organic pollutants: guillemots (which feed on small planktivorous fishes) or great skua (which scavenge and prey on other seabirds and sometimes on the carcasses of marine mammals)?
- What are the principal biological systems (organ systems) that can be affected by persistent organic pollutants?
- Is there any evidence that persistent organic pollutants have affected populations of the top predator in the Arctic marine ecosystem?
- Are lead and mercury considered to be major risks to ecosystem health? Why?
- The most popular foods among the Inuit people of Canada are caribou, seal, char (a type of fish) narwhal (a marine mammal), and beluga whale. The most popular foods among the Dene people of the same region are moose, caribou, and freshwater fish. Which group of indigenous people would be expected to have the greater exposure to mercury?
- What steps have been taken to reduce human exposure to persistent organic pollutants and heavy metals in the Arctic?

Topic: Environmental Mmergencies and Risk Management in the Arctic

- What types of emergencies are the focus of the Emergency Prevention Preparedness and Response Working Group?
- What human activity poses the greatest threat to the Arctic from release of a pollutant?
- What are some of the factors that make the Arctic more vulnerable to damage from contamination and other human impacts?
- Based on current trends, how soon might seasonal sea lanes appear through areas of the Arctic that have historically been ice-locked throughout the year?
- How is the productivity of Arctic terrestrial, aquatic, and marine systems likely to change as a result of increased freshwater flow due to a warmer climate?
- How may climate change affect the risk of environmental emergencies in the Arctic?

Topic: Ecosystem-based Approaches for Conserving Arctic Biodiversity

- What is "biodiversity?"
- What is an "ecosystem-based approach?"
- What is "integrated management?"
- To date, what has been the most effective way to conserve marine biodiversity?
- What is the overall framework for conservation and sustainable use of the world's oceans?
- What are some of the international Conventions that are important to marine conservation?
- What are some of the threats to marine biodiversity in the Arctic?
- What 12 actions to conserve biodiversity have been recommended for inclusion in the Arctic Council's Arctic Marine Strategic Plan?