



2005 Hidden Ocean Expedition

The Good, The Bad and The Arctic

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 two to six students

Maximum Number of Students

30

Key Words

Arctic Ocean
Canada Basin
Climate change
Indigenous peoples
Traditional knowledge
Marine pollution
Biodiversity
Integrated management

Background Information

The Arctic Ocean is the most inaccessible and least-studied of all the Earth's major oceans. Although it is the smallest of the world's four ocean basins, the Arctic Ocean has a total area of about 14 million square kilometers (5.4 mil-

lion square miles); roughly 1.5 times the size of the United States. The deepest parts of the Arctic Ocean (5,441 m; 17,850 ft), known as the Canada Basin, are particularly isolated and unexplored because of year-round ice cover. To a large extent, the Canada Basin is also geographically isolated by the largest continental shelf of any ocean (average depth about 50 meters) bordering Eurasia and North America. The Chukchi Sea provides a connection with the Pacific Ocean via the Bering Strait, but this connection is very narrow and shallow, so most water exchange is with the Atlantic Ocean via the Greenland Sea. This isolation makes it likely that unique species have evolved in the Canada Basin.

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

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

These realms are linked in many ways, and food webs in each realm interact with those of the other realms.

Sea ice provides a complex habitat for many species that are called sympagic, which means "ice-associated." The ice is riddled with a network of tunnels called brine channels that range in size from microscopic (a few thousandths of a millimeter) to more than an inch in diameter. Diatoms and algae inhabit these channels and obtain energy from sunlight to produce biologi-

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

When sea ice melts, more sunlight enters the sea, and algae grow rapidly since the sun shines for 24 hours a day during the summer. These algae provide energy for a variety of pelagic organisms, including floating crustaceans and jellyfishes called zooplankton, which are the energy source for larger pelagic animals including fishes, squids, seals, and whales. When pelagic organisms die, they settle to the ocean bottom, and become the energy source for inhabitants of the benthic realm. These animals, in turn, provide energy for bottom-feeding fishes, whales, and seals.

A key objective of the 2005 Hidden Ocean expedition is to obtain detailed information about the

living and physical components of Canada Basin ecosystems, including a wide range of organisms from microbes to vertebrates. There is a strong element of urgency about this expedition because the Arctic environment is changing at a dramatic rate. Temperature in the Arctic is increasing at nearly twice the rate of increase as the rest of the world. One visible result is rapid loss of glaciers and sea ice. Less visible are the impacts on living organisms that depend upon glaciers and sea ice for their habitat. These changes are also causing increased coastal erosion and damage to human communities and infrastructure such as building, roads, and pipelines. Potential impacts are not confined to the Arctic: The Greenland Ice Sheet, for example, holds enough water to raise global sea levels by as much as 7 meters. Sea level increases at this magnitude would be sufficient to flood many coastal cities, including most of the city of London.

The 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 is expected to be released in July 2005.

Because the ecosystems of the Canada Basin are virtually unexplored, the work of the 2005 Hidden Ocean expedition 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 the Hidden Ocean expedition. 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, visit the Hidden Ocean expedition's Web page (<http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html>) for an overview of the expedition and background essays. 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, highlighting the location of the Canada Basin and the activities of the Hidden Ocean expedition. Point out that the climate of the Arctic is rapidly changing, and it is essential to understand the present structure of these ecosystems as a baseline against which to measure changes in the future. You may want to briefly mention some of the implications of Arctic climate change, but do not spend a great deal of time on this since one group of student reports will deal specifically with this topic.
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 students that each group should 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 feel 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.arcticpeoples.org/about/IPS/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/environmentalemergenciesandriskmanagement.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:

Climate Trends in the Arctic Region

- 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 warming.
 - 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 oceans. 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 for more about the potential consequences of methane releases).
- 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.

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;
- The Stockholm Convention on Persistent Organic Pollutants commits nations that ratify the treaty to work toward of elimination of twelve of the world's most dangerous chemi-

cals 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
 - Continued reduction of sea ice and altered vegetation in the Arctic is likely to create major shortages of traditional foods.

Arctic Marine Pollution

- The four major categories of contaminants found in the Arctic are:
 - Persistent organic pollutants
 - Heavy metals
 - Artificial radionuclides
 - 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 radionuclide 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 gas-

eous ionized form (Hg^{2+}) 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 conserva-

tion 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 & habitat fragmentation
 - Chemical disturbance
 - Invasive alien species
 - Overexploitation associated with commercial use
 - Incidental impacts of commercial use
 - Overexploitation associated with subsistence 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 warming and the greenhouse effect.

THE “ME” CONNECTION

Have students write a brief essay describing how knowledge of previously unexplored Arctic marine environments (like the Canada Basin) 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

EVALUATION

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

EXTENSIONS

1. Have students visit <http://oceanexplorer.noaa.gov/explorations/05arctic/welcome.html> to keep up to date with the latest 2005 Hidden Ocean Expedition discoveries.
2. Visit http://oceanexplorer.noaa.gov/explorations/02arctic/background/education/media/arctic_lessonplans.html for more lesson plans and activities related to the 2005 Hidden Ocean expedition.
3. 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

<http://oceanexplorer.noaa.gov> – Follow the 2005 Hidden Ocean Expedition daily as documentaries and discoveries are posted each day for your classroom use.

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 site for the Arctic Climate Impact Assessment secretariat

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

FOR MORE INFORMATION

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<http://oceanexplorer.noaa.gov>

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 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 climatic 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?
- 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, a fresh-water 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 Emergencies 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 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 ocean?
- 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 twelve actions to conserve biodiversity have been recommended for inclusion in the Arctic Council’s Arctic Marine Strategic Plan?

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 radionuclide contamination?