Climate Change and Arctic Ecosystems

Key Concepts:
- Albedo
- Ecosystem
- Sea ice

WHAT YOU WILL LEARN

1. You will analyze Arctic temperatures and the ways in which they affect sea ice.
2. You will calculate changes in sea ice area and predict the year when the sea ice will disappear.
3. You will analyze polar bear population data and the influence of sea ice on these numbers.
Engage Your Thinking

Many scientists today are discussing climate change and asking questions about the effect of climate change on different geographic regions of the Earth. In this activity you will learn about the Arctic ecosystem: how climate change is affecting the Arctic ecosystem? How is this change in the arctic ecosystem impacting polar bear populations?

In this activity you will analyze maps of Arctic sea ice, temperature graphs, and polar bear population data to answer these questions about the impact of climate change on the arctic ecosystem.

1. How is climate change affecting the Arctic ecosystem?

2. How is climate change affecting the polar bear?

Explore and Explain

The Earth’s Polar Regions include the Arctic in the Northern Hemisphere and Antarctica in the Southern Hemisphere. The Arctic consists mostly of frozen ocean (i.e., the Arctic Ocean) surrounded by land, while Antarctica is an ice-covered land mass, a continent, surrounded by ocean. The Arctic region borders on the northern boreal forest and the southern boreal forest (Figure 1). Thus, most of the Arctic ecosystem exists on ice (frozen ocean water) with a small portion on land.

Albedo

Albedo is the ability of an object to reflect the sun’s energy (light). The higher the albedo, the more sun light an object reflects and the less heat it absorbs. Light objects reflect more sunlight than dark objects. Thus, light objects radiate less heat than dark objects.
Although the central part of the Arctic Ocean is frozen all year, the overall area and the extent of the ice changes with the seasons. During the summer months, the outer edges of the ice melt away from North America and Eurasia and the frozen ocean becomes open water filled with drifting sea ice. During the winter, this open ocean water freezes and the ice expands again outwards toward North America and Eurasia.

How does the Arctic receive warmth? In fact, land and open water warm the Arctic atmosphere more than do snow and ice. Because snow and ice are so white, they reflect much of the sun’s energy (known as albedo) back into the atmosphere. Therefore, land and water absorb and transfer more heat to the atmosphere than do snow and ice. The more open land and water there are, the warmer the atmosphere becomes; this increases melting. Also important to the freezing of ocean water is its salinity content. The “saltier” the water, the lower the freezing point. Arctic Ocean water tends to freeze at about -2°C (28°F).

Global warming is expected to be greater in the Polar Regions than in other areas of the world. As more snow and ice melt, more land and ocean water are exposed to the sun’s energy. If more ocean water and land are exposed to the sun, they absorb more energy (heat), causing the Arctic atmosphere to warm more than the atmosphere in other regions of the world. The observed change in Arctic temperature since 1900 is shown in Figure 2. The purple bars show the change in temperature above normal and the blue bars show the change in temperature below normal. The last 50 years have seen a 3-4°C increase in the winter temperature for Alaska and Western Canada.
3. Based on the data in Figure 2, what has happened to the Arctic temperature in the last 100 years?

4. Based on the data in Figure 2, what has happened to the temperature in the last 20 years?

5. How might this change in Arctic temperature impact the Arctic ecosystem?
Using the two images of Arctic summer sea ice in Figure 3 below and the transparent grid, determine the impact of global warming on Arctic sea ice and the Arctic ecosystem. Then answer the questions that follow.

6. Using the transparent grid, outline the boundary of the 1979 summer sea ice on the grid and determine how many squares are covered by summer sea ice.

7. Following the same procedure, outline the 2003 boundary and calculate the number of squares covered by summer sea ice.

8. What is the percentage of sea ice remaining in 2003? (Hint: Divide the number of squares for 2003 by the number of squares for 1979).

Figure 3. Images of Arctic summer sea ice 1979 (top) and 2003 (bottom) (Source: NASA)
10. Based on the percentage you calculated in question 6, predict the number of years it will take for all of the summer sea ice to melt. Explain your prediction.

11. Describe how the disappearance of summer sea ice would impact the Arctic ecosystem.

Now watch the video that shows the projected (predicted) melting of summer Arctic sea ice. The video shows the number of years it will take before all of the summer sea ice completely disappears. Click for video: Summer sea ice melting.

12. What year did the sea ice completely disappear?

13. How close was your prediction to the video’s prediction?

![Figure 4: Sea ice thickness 1950’s and predicted thickness for 2050 (Source: NOAA)](image-url)
Not only has Arctic sea ice disappeared, but the ice has become thinner (Figure 4). During the decades since the 1960’s, some areas of Arctic sea ice have shown a 40% decrease in thickness.

14. How would you explain the thinning of Arctic sea ice since the 1960’s?

**Extend Your Thinking**

Marine species such as the polar bear, the ringed seal, and the walrus are all dependent upon sea ice for their survival and will likely decline in population as the sea ice disappears. One species of international interest at the current time is the polar bear. Polar bears are the largest bear species on Earth and are the top predators (carnivore) in the Arctic ecosystem. Polar bears are specially adapted for life in the Arctic region. They have paddle-like feet, water repellent guard hairs in their coats, and a dense layer of under-fur to protect them from the cold. Polar bears use the Arctic sea ice as their niche and spend 90% of their time on floating ice and 10% on land. Scientists who study polar bear populations have learned that they live in distinct geographic areas. For this reason, the polar bear populations are divided into groups based on these locations all within the Arctic ecosystem (Figure 5). The main U.S. polar bear populations are the Southern Beaufort Sea group and the Chukchi group. Polar bear populations are hard to determine due to their large range and overlapping territories. One estimate

![Figure 5. Map of polar bear populations (Source: IUCN)](http://www.iclimate.org/ccc)
cites the total polar bear population at 20,000 to 25,000. The population and status for each polar bear group is shown in Table 1.

<table>
<thead>
<tr>
<th>Population</th>
<th>Number (Year of most recent estimate)</th>
<th>Status</th>
<th>Current Trend</th>
<th>Estimated risk of decline (Next 10 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S Beaufort Sea SB</td>
<td>1500 (2006)</td>
<td>Reduced</td>
<td>Declining</td>
<td>No estimate</td>
</tr>
<tr>
<td>N Beaufort Sea NB</td>
<td>1200 (1986)</td>
<td>Not reduced</td>
<td>Stable</td>
<td>No estimate</td>
</tr>
<tr>
<td>Viscount Melville VB</td>
<td>215 (1996)</td>
<td>Severely reduced</td>
<td>Increasing</td>
<td>Very low</td>
</tr>
<tr>
<td>Lancaster Sound LS</td>
<td>2541 (1998)</td>
<td>Not reduced</td>
<td>Stable</td>
<td>Higher</td>
</tr>
<tr>
<td>McClintock Channel MC</td>
<td>284 (2000)</td>
<td>Severely reduced</td>
<td>Increased</td>
<td>Very low</td>
</tr>
<tr>
<td>Gulf of Boothia GB</td>
<td>1523 (2000)</td>
<td>Not reduced</td>
<td>Stable</td>
<td>Lower</td>
</tr>
<tr>
<td>W Hudson Bay WH</td>
<td>935 (2004)</td>
<td>Reduced</td>
<td>Declining</td>
<td>Very High</td>
</tr>
<tr>
<td>S Hudson Bay SH</td>
<td>1000 (1988)</td>
<td>Not reduced</td>
<td>Stable</td>
<td>Lower*</td>
</tr>
<tr>
<td>Davis Strait DS</td>
<td>1650 (2004)</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>Lower</td>
</tr>
<tr>
<td>Baffin Bay BB</td>
<td>1546 (2004)</td>
<td>Reduced</td>
<td>Declining</td>
<td>Very High</td>
</tr>
<tr>
<td>Norwegian Bay NW</td>
<td>190 (1998)</td>
<td>Not reduced</td>
<td>Declining</td>
<td>Higher</td>
</tr>
<tr>
<td>Kane Basin KB</td>
<td>164 (1998)</td>
<td>Reduced</td>
<td>Declining</td>
<td>Very High</td>
</tr>
<tr>
<td>Chukchi Sea</td>
<td>2000 (1993)</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>No Estimate</td>
</tr>
<tr>
<td>Laptev Sea</td>
<td>800-1200 (1993)</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>No Estimate</td>
</tr>
<tr>
<td>East Greenland</td>
<td>unknown</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>No Estimate</td>
</tr>
<tr>
<td>Barents Sea</td>
<td>2997 (2004)</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>No Estimate</td>
</tr>
<tr>
<td>Kara Sea</td>
<td>unknown</td>
<td>Data deficient</td>
<td>Data deficient</td>
<td>No Estimate</td>
</tr>
</tbody>
</table>

Table 1. Polar bear populations and status (Source: IUCN)
15. Using the polar bear population data in Table 1, identify which polar bear populations are declining.

16. Compare Figures 3 and 5. What is the relationship between the Arctic sea ice and the population of the different polar bear groups? Why are some polar bear groups stable and some declining?

17. Explain how climate change might be causing polar bear populations to decline.

18. The Hudson Bay polar bear group, located in the Western Hudson Bay region (see Figure 5), is perhaps the most studied polar bear population. In 1987, the Hudson Bay polar bear population was 1,200 bears, and in 2004 this number declined to 950. What percent of the Western Hudson Bay polar bear population (2003) is remaining from the 1987 population?

19. Based on your percentage, predict the year the Western Hudson Bay polar bear group will become extinct if climate change continues at its current rate.

Polar bears are highly dependent on sea ice for their survival. The sea ice provides them with food as well as a place to raise their young. In terms of their diet, polar bears use sea ice as corridors to move about and to hunt ringed seals—their primary food source. Polar bear populations are generally dependent on the populations of the ringed seals for survival, although polar bears will also eat harbor seals, bearded seals, harp seals, young walruses, ringed seals, and other food sources. 
Climate Change and Arctic Ecosystems

beluga whales, narwhal, fish, and seabirds and their eggs. The ringed seal, however, is their primary diet. The polar bears hunt and eat the ringed seals in one area, and then move on to another area to find more food.

During the summer, polar bears are often naturally stranded on land because the sea ice regularly recedes and the polar bears cannot swim the distance to the nearest floating ice. During this time, polar bears naturally fast, consuming their body fat until the sea ice forms again in the fall. If the sea ice doesn’t form, the polar bears starve because they cannot find more ringed seals to eat and replenish their muscle and body fat. Also, polar bears need the sea ice to raise their young. Female polar bears and their cubs come out of their dens in spring and use the sea ice for hunting ringed seals. Figure 6 shows the importance of ringed seals to the polar bears survival.

![Graph](http://www.iclimate.org/ccc)

**Figure 6.** The relationship between ringed seal and polar bear populations in Southwestern Greenland. Note: Units for seals are in thousands. (Source: Rosing-Asvid.)

20. Explain the relationship between the ringed seal and polar bear populations as shown in Figure 6.

21. Explain how the decline in Arctic sea ice might impact ringed seal populations.

The diet of polar bears appears to be changing. Although ringed seals are the primary prey of polar bears, polar bears are eating more harbor seals and bearded seals, which are not dependent on sea ice.
22. Explain how the shift in polar bear diet might be caused by climate change.

Apply What You Have Learned

Create a concept map or flow chart that shows the relationship between the Arctic ecosystem, climate change, Arctic sea ice, ringed seals, and polar bears.
Reflect on What You Have Learned

23. How is climate change affecting the Arctic ecosystem?

24. How is climate change affecting the polar bear?

25. Please explain how your ideas and thinking about climate change and polar bears have changed.