Lab: Penguin Jigsaw

Adapted from The Science Teacher by Constible, Sandro & Lee

(MAKEUP VERSION)

Background: At the global level, strong evidence suggests that observed changes in Earth's climate are largely due to human activities (IPCC, 2007). At the regional level, the evidence for human-dominated change is sometimes less clear. Scientists have a particularly difficult time explaining warming trends in Antarctica – a region with a relatively short history of scientific observation and a highly variable climate (Clarke et al. 2007). Regardless of the mechanism of warming, however, climate change is having a dramatic impact on Antarctic ecosystems. This activity highlights the ecosystem-level changes observed on the western Antarctic Peninsula.

Air temperature data indicate that the western Antarctic Peninsula has warmed by about 3^{o}C in the last century (Clarke et al. 2007). Although this relatively short-term record is only from a few research stations, other indirect lines of evidence confirm the trend. The most striking of these proxies is a shift in penguin communities. Adélie penguins, which are dependent on sea ice for their survival, are rapidly declining on the Antarctic Peninsula despite a 600-year colonization history. In contrast, chinstrap penguins, which prefer open water, are increasing dramatically. These shifts in population appear to be the result of a decrease in the amount, timing, and duration of sea ice. Why is sea ice so important to Adélie penguins? First, sea ice is a feeding platform for Adélies. Krill, the primary prey of Adélies on the Peninsula, feed on microorganisms growing on the underside of the ice (Atkinson et al. 2004). For Adélie penguins, which are relatively slow swimmers, it is easier to find food under the ice than in large stretches of open water (Ainley 2002). Second, sea ice helps control the local climate. Ice keeps the Peninsula cool by reflecting solar radiation back to space. As air temperatures increase and sea ice melts, open water converts radiation into heat and amplifies the upward trend in local air temperatures (Figure 2; Wadhams 2000). Third, ice acts as a
giant cap on the ocean, limiting evaporation. As sea ice declines, cloud condensation nuclei and moisture are released into the atmosphere, leading to more snow. This extra snow often does not melt until Adélies have already started nesting; the resulting melt water can kill their eggs (Fraser and Patterson 1997).

Prelab Questions:

1. How are Adélie penguin populations and chinstrap penguin populations differing in their reactions to rising temperatures in Antarctica?
2. What makes the Adélie penguins dependent on sea ice for their survival?
3. Krill is a very important organism in the southern ocean. What do krill feed on?
4. Name two other creatures that feed on krill (answer not given above).
5. How does snowfall affect Adélie penguin nesting?

What We Did in Class:

Each student became one of the following specialists to analyze relationships in the Antarctic ecosystem:

Ornithologist: A scientist who studies birds. Uses visual surveys (from ship or on land), diet analysis, and satellite tracking to collect data on penguins.

Oceanographer: A scientist who studies the ocean. Uses satellite imagery, underwater sensors, and manual measurements of sea ice thickness to collect data on sea ice conditions and ocean temperature.

Meteorologist: A scientist who studies the weather. Uses automatic weather stations and visual observations of the skies to collect data on precipitation, temperature, and cloud cover.

Marine ecologist: A scientist who studies the relationship between organisms and their ocean environment. Uses visual surveys, diet analysis, and satellite tracking to collect data on organisms, including penguins.

Fisheries biologist: A scientist who studies fish and their prey. Collects data on krill during research cruises.

What You Need to Do:

CHOOSE ONE of the specialist categories from the list above. Answer the prelab questions 1-5 above, then graph the data (upper left corner) and answer questions 6-10 from the specialist page of your choosing, then answer the postlab questions 11-15 at the end.

FIGURE 5

Ornithologists: Adélie penguin dataset.

Year	# Breeding pairs of Adélie penguins
1975	15,202
1979	13,788
1983	13,515
1986	13,180
1987	10,150
1989	12,983
1990	11,554
1991	12,359
1992	12,055
1993	11,964
1994	11,052
1995	11,052
1996	9,228
1997	8,817
1998	8,315
1999	7,707
2000	7,160
2001	6,887
2002	4,059

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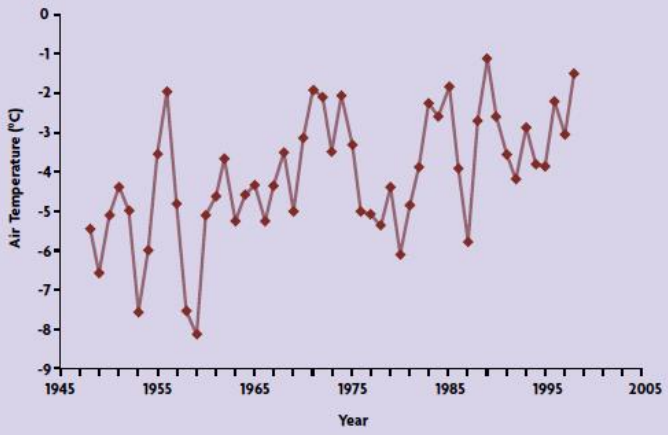
- Adélie penguins spend their summers on land, where they breed. They spend winters on the outer extent of the sea ice surrounding Antarctica, where they molt their feathers and fatten up.
- Adélies are visual predators, meaning they need enough light to see their prey. Near the outer part of the pack ice, there are only a few hours of daylight in the middle of the winter. There is less sunlight as one moves further south (closer to land).
- On the western Antarctic Peninsula, Adélie penguins mostly eat krill, a shrimplike crustacean.
- Several countries have been harvesting krill since the mid 1960s.
- Adélie penguins need dry, snow-free places to lay their eggs. They use the same nest sites each year and at about the same time every year. Heavy snowfalls during the nesting season can bury adult Adélies and kill their eggs.
- Female Adélies lay two eggs, but usually only one of those eggs result in a fledged chick (fledged chicks have a good chance of maturing into adults). The two most common causes of death of eggs and chicks are abandonment by the parents (if they cannot find enough food) and predation by skuas (hawklike birds).
- In the water, Adélies are eaten mostly by leopard seals and killer whales.
- Adélies can look for food under sea ice because they can hold their breath for a long time. They are not as good at foraging in the open ocean, because they cannot swim very fast.
- Adélie penguins have lived in the western Antarctic Peninsula for at least 644 years.

Data source: Smith, Fraser, and Stammerjohn 2003.

FIGURE 4

Climatologists: Air temperature data set.



Data source: Palmer LTER Data Archive *(http://pal.lternet.edu/data/dataset_catalog.php)*, supported by NSF Grant No. OPP-96-32763.

Chinstrap and Adélie penguins.

Chinstrap penguins *(Pygoscelis antarctica)* are primarily found on the Antarctic Peninsula and in the Scotia Arc, a chain of islands between the tip of South America and the Peninsula. Their name comes from the black band running across their chins. Adult chinstraps stand 71–76 cm tall and weigh up to 5 kg.

Adélie penguins *(Pygoscelis adeliae)* breed on the coast of Antarctica and surrounding islands. They are named after the wife of French explorer Jules Sébastien Dumont d'Urville. Adult Adélies stand 70–75 cm tall and weigh up to 5 kg.

Option One – Ornithologists – Graph # Breeding Pairs (y-axis) vs. Time (x-axis)

Specialist Questions:

6. How do the lifestyles of Adelie penguins change from summer to winter?
7. What threats do Adelie penguins face?
8. How has the number of Adelie penguins changed since 1975?
9. What are some possible explanations for the changes in the Adelie penguin population?
10. What further information would you need to determine whether you were correct in question 9?

FIGURE 6

Year	Area of sea ice extending from the Antarctic Peninsula (km^2)
1980	146,298
1981	136,511
1982	118,676
1983	88,229
1984	85,686
1985	78,792
1986	118,333
1987	142,480
1988	90,310
1989	44,082
1990	79,391
1991	111,959
1992	110,471
1993	94,374
1994	103,485
1995	95,544
1996	86,398
1997	100,784
1998	73,598
1999	79,223
2000	79,200
2001	69,914

Oceanographers: Sea ice dataset.

- In the winter (August), sea ice covers over 18 × 106 km^2, or 40%, of the Southern Ocean (an area larger than Europe). In the summer (February), only 3 × 106 km^2 (about 7%) of the ocean is covered by sea ice.
- Sea ice keeps the air of the Antarctic region cool by reflecting most of the solar radiation back into space.
- Open water absorbs solar radiation instead of reflecting it and converts it to heat. This heat warms up the atmosphere.
- Sea ice reduces evaporation of the ocean, thus reducing the amount of moisture that is released to the atmosphere.
- As sea ice melts, bacteria and other particles are released into the atmosphere. These particles form condensation or freezing nuclei, which grow into rain or snow.
- Rain helps to stabilize the sea ice by freezing on the surface.
- Sea ice can be broken up by strong winds that last a week or more.
- An icebreaker is a ship used to break up ice and keep channels open for navigation. Icebreakers were first used in the Antarctic in 1947.

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Data source: Palmer LTER Data Archive *(http://pal.lternet.edu/data/dataset_catalog.php)*, supported by NSF Grant No. OPP-96-32763.

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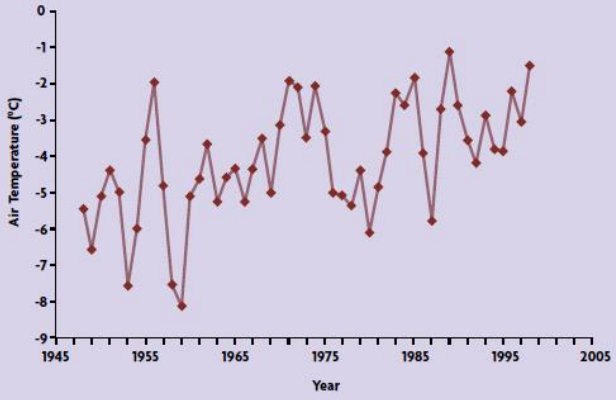

Data source: Palmer LTER Data Archive *(http://pal.lternet.edu/data/dataset_catalog.php)*, supported by NSF Grant No. OPP-96-32763.

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Adélie penguins *(Pygoscelis adeliae)* breed on the coast of Antarctica and surrounding islands. They are named after the wife of French explorer Jules Sébastien Dumont d'Urville. Adult Adélies stand 70–75 cm tall and weigh up to 5 kg.

Option Two - Oceanographers - Graph Area of Sea Ice (y-axis) vs. Time (x-axis)
Specialist Questions:

6. How does sea ice coverage change from summer to winter?
7. How does sea ice coverage affect atmospheric temperatures?
8. How has the area of sea ice coverage changed since 1980?
9. What are some possible explanations for the changes in sea ice coverage since 1980?
10. What further information would you need to determine whether you were correct in question 9?

FIGURE 7

Meteorologists: Winter snow dataset.

Year	% of precpitation events that are snow
1982	49
1983	67
1984	72
1985	67
1986	81
1987	80
1988	69
1989	69
1990	68
1991	72
1992	70
1993	70
1994	83
1995	77
1996	74
1997	81
1998	81
1999	83
2000	77
2001	90
2002	82
2003	76

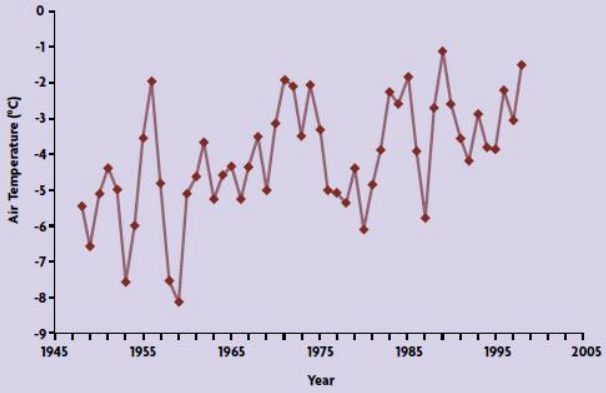
- In the winter, most of the precipitation in the western Antarctic Peninsula occurs as snow. There is an even mix of snow and rain the rest of the year.
- It is difficult to accurately measure the amount of snowfall in the Antarctic because strong winds blow the snow around.
- The Antarctic Peninsula has a relatively warm maritime climate, so gets more rain and snow than the rest of the Antarctic continent.
- Most of the rain and snow on the Peninsula is generated by cyclones from outside the Southern Ocean. Cyclones are areas of low atmospheric pressure and rotating winds.
- When there is less sea ice covering the ocean, there is more evaporation of the ocean and therefore more moisture in the atmosphere.
- As sea ice melts, bacteria and other particles are released into the atmosphere. These particles form condensation or freezing nuclei, which grow into rain or snow.

LUKE SANDRO

Data source: Antarctic Meteorology Online, British Antarctic Survey (*www.antarctica.ac.uk/met/metlog/*).

FIGURE 4

Climatologists: Air temperature data set.



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Option Three – Meteorologists - Graph % of Precipitation Events (y-axis) vs. Time (x-axis)

Specialist Questions:

6. How does precipitation in the western Antarctic Peninsula change from summer to winter?
7. How does sea ice coverage affect precipitation in the Antarctic?
8. How has the percentage of precipitation events that are snow changed since 1982?
9. What are some possible explanations for the changes in percentage of precipitation events that are snow since 1982?
10. What further information would you need to determine whether you were correct in question 9?

FIGURE 8

Marine ecologists: Chinstrap penguin dataset.

Year	# of breeding pairs of chinstrap penguins
1976	10
1977	42
1983	100
1984	109
1985	150
1989	205
1990	223
1991	164
1992	180
1993	216
1994	205
1995	255
1996	234
1997	250
1998	186
1999	220
2000	325
2001	325
2002	250

- Chinstrap penguins breed on land in the spring and summer and spend the rest of the year in open water north of the sea ice. The number of chinstraps that successfully breed is much lower in years when the sea ice does not melt until late spring.
- Chinstraps mostly eat krill, a shrimplike crustacean.
- Whalers and sealers overhunted seals and whales, which also eat krill, until the late 1960s.
- Chinstraps primarily hunt in open water, because they cannot hold their breath for very long.
- The main predators of chinstraps are skuas (hawklike birds), leopard seals, and killer whales.
- Chinstraps will aggressively displace Adélie penguins from nest sites in order to start their own nests, and may compete with Adélies for feeding areas.
- Although chinstrap penguins have occupied the western Antarctic Peninsula for over 600 years, they have become numerous near Palmer Station only in the last 35 years.

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Data source: Smith, Fraser, and Stammerjohn 2003.

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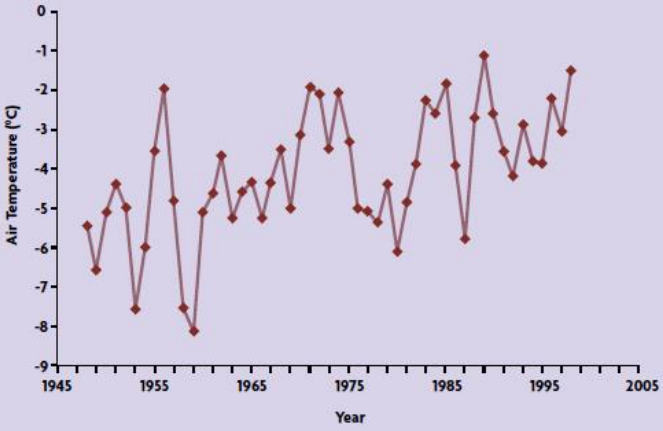
Climatologists: Air temperature data set.



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Option Four - Marine Ecologists - Graph # Breeding Pairs (y-axis) vs. Time (x-axis)
Specialist Questions:

6. How do the lifestyles of chinstrap penguins change from summer to winter?
7. What threats do chinstrap penguins face?
8. How has the number of chinstrap penguins changed since 1976?
9. What are some possible explanations for the changes in the chinstrap penguin population?
10. What further information would you need to determine whether you were correct in question 9?

FIGURE 9

Biologists: Krill dataset.

Year	Density of krill in the Southern Ocean (no./m²)
1982	91
1984	50
1985	41
1987	36
1988	57
1989	15
1990	8
1992	7
1993	22
1994	6
1995	9
1996	31
1997	53
1998	46
1999	4
2000	8
2001	31
2002	8
2003	3

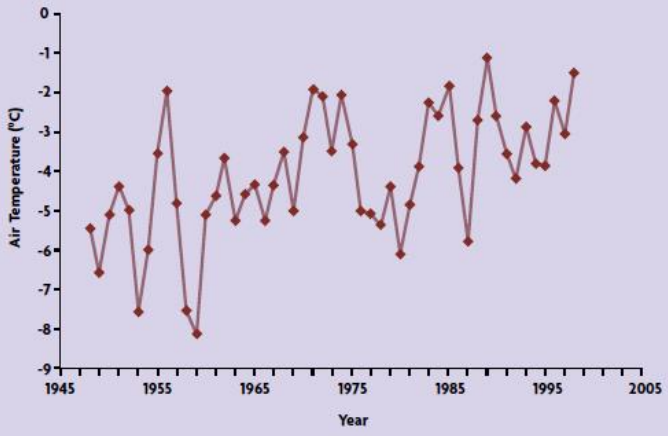
- Krill are a keystone species, meaning they are one of the most important links in the Antarctic food web. All the vertebrate animals in the Antarctic either eat krill or another animal that eats krill.
- Krill eat mostly algae. In the winter, the only place algae can grow is on the underside of sea ice.
- Several countries have been harvesting krill since the mid 1960s.
- Ultraviolet radiation is harmful to krill, and can even kill them. Worldwide, ozone depletion is highest over Antarctica.
- Salps, which are small, marine animals that look like blobs of jelly, may compete with krill for food resources. As the salt content of the ocean decreases, salp populations increase and krill populations increase.

RICHARD E. LEE JR.

Data source: Atkinson et al. 2004

FIGURE 4

Climatologists: Air temperature data set.



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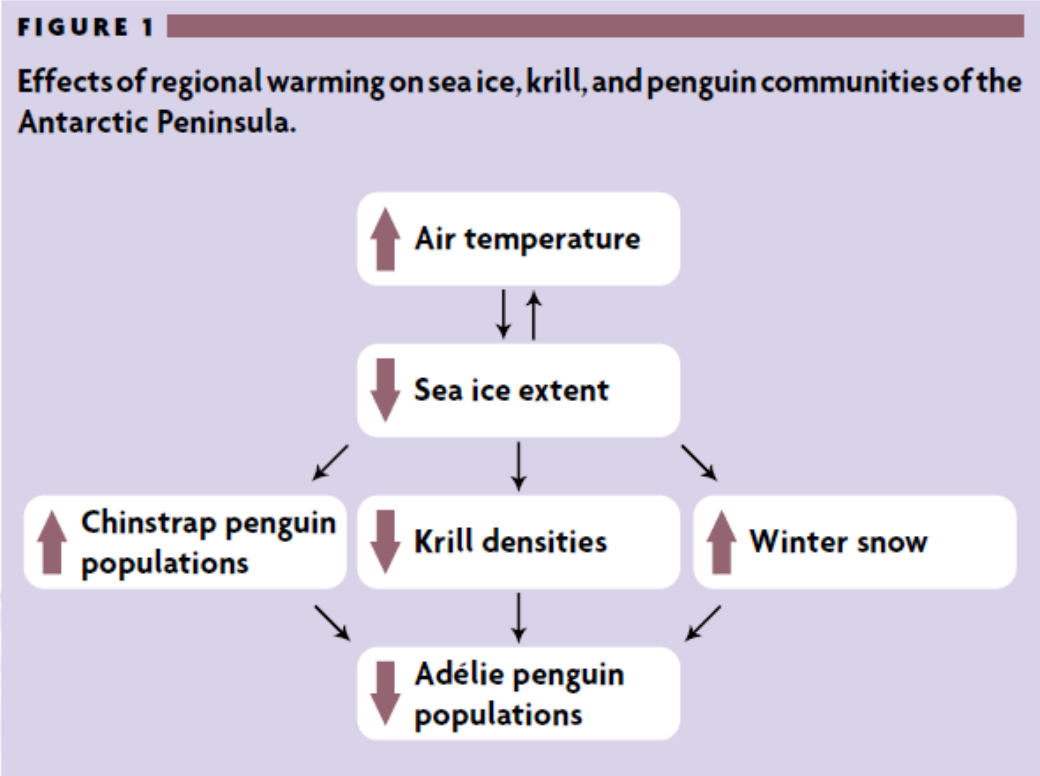
Option Five - Fisheries Biologists - Graph Density of Krill (y-axis) vs. Time (x-axis)

Specialist Questions:

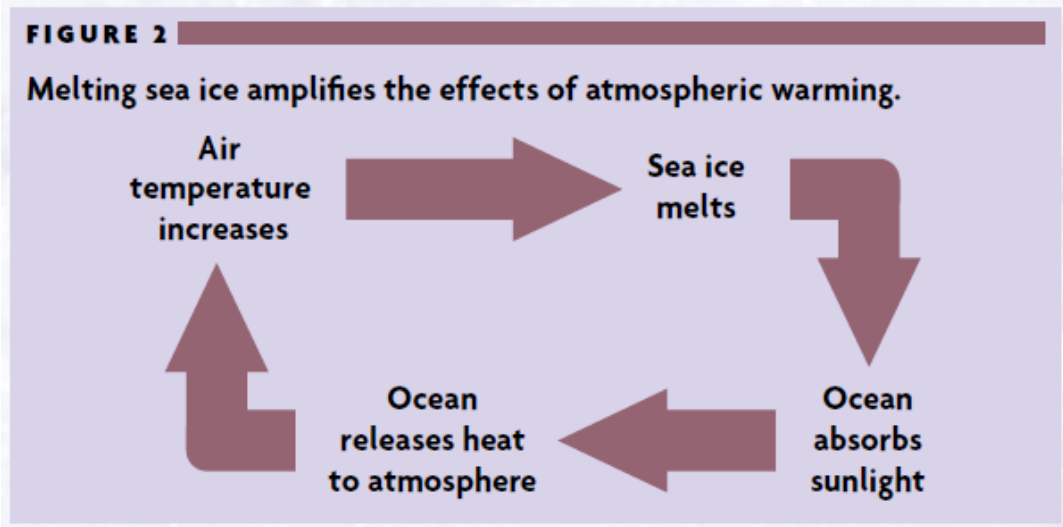
6. How do krill populations change from summer to winter?
7. What threats do krill face?
8. How has the density of krill in the Southern Ocean changed since 1982?
9. What are some possible explanations for the changes in krill density in the Southern Ocean?
10. What further information would you need to determine whether you were correct in question 9?

Postlab Questions:

11. Using the information you accumulated in the larger heterogenous group and the flow chart below, discuss the relationships identified.



12. Discuss the cycle shown below.



13. How has the ecosystem of the Antarctic Peninsula changed in the last 50 years? What are the most likely explanations for these changes?
14. Describe the evidence supporting these explanations. Is this evidence sufficient? Why or why not?
15. What further questions are left unanswered?