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The Case of the Missing Penguins!

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Grade Level
7th Grade

Subject Area
Life Science

VA SEA is a collaborative project between the Chesapeake Bay National Estuarine Research Reserve, the Virginia Institute of Marine Science's Marine Advisory Program, and Virginia Sea Grant. The VA SEA project is made possible through funding from the National Estuarine Research Reserve System Science Collaborative, which supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is funded by the National Oceanic and Atmospheric Administration and managed by the University of Michigan Water Center.

Title: The Case of the Missing Penguins!

Focus: Gather and graph data to examine patterns in Adélie penguin populations in the Western Antarctic Peninsula and determine potential drivers for these patterns.

Grade Level: 7th Grade Life Science

VA Science Standards

LS.1 The student will demonstrate an understanding of scientific and engineering practices by

a) asking questions and defining problems
   - ask questions and develop hypotheses to determine relationships between independent and dependent variables

b) interpreting, analyzing, and evaluating data
   - identify, interpret, and evaluate patterns in data construct, analyze, and interpret graphical displays of data compare and contrast data

d) constructing and critiquing conclusions and explanations

LS.8 The student will investigate and understand that ecosystems, communities, populations, and organisms are dynamic and change over time. Key ideas include

a) organisms respond to daily, seasonal, and long-term changes;

b) changes in the environment may increase or decrease population size; and

c) large-scale changes such as eutrophication, climate changes, and catastrophic disturbances affect ecosystems.

LS.9 The student will investigate and understand that relationships exist between ecosystem dynamics and human activity. Key ideas include

a) changes in habitat can disturb populations;

b) disruptions in ecosystems can change species competition; and

c) variations in biotic and abiotic factors can change ecosystems.

(Additional relevant learning standards can be found in Appendix C.)

Learning Objectives

Students will:

- Collect data on penguin populations, penguin stomach contents, and sea ice coverage in the Western Antarctic Peninsula.
- Create line graphs of penguin populations and penguin stomach contents over time and analyze a line graph of sea ice coverage over time.
- Analyze and make predictions about potential drivers for the trends experienced in Adélie penguin populations.
- Come up with their own suggestions about what could be affecting Adélie penguin populations in the Western Antarctic Peninsula.

Total Length of Time Required

Initial preparation of materials: 30 minutes, only needs to be done once.

Total time for lesson: 45-60 minutes, or one class period. Class discussion may lengthen this estimate.

Vocabulary

- Abiotic factors: Nonliving components of an ecosystem
- Abundance: The number of individual objects or animals in a sample
- Anthropogenic: Caused by humans
- Biotic factors: Living components of an ecosystem
- Climate Change: Long-term change in the Earth's average temperature and weather patterns, either natural or caused by humans
- Community: All of the organisms living and interacting in one particular location
- Ecology: The study of how organisms interact with each other and with their environment
- Ecosystem: A group of organisms that interact with each other within their environment
- Habitat: The natural home or environment of an organism
- Ice-Obligate: A species that must spend a significant part of its life on and around polar sea ice
- Polar: Regions at latitudes greater than 66.5 degrees North or South
- Population: A group of individuals of the same species living in one location
- Sea Ice: Frozen seawater that floats on the surface of the ocean
- Trend: A general direction in which data are moving over time

(Bilingual resources and extended Spanish glossary can be found in Appendix B.)

Background Information

This mystery unfolds in the Western Antarctic Peninsula, a region in Antarctica that is known for being very productive, having large amounts of krill, and having abundant penguins and other large animals like whales and seals. Even though it is such a productive region with so much life, it is very vulnerable to the warming effects of climate change, which can alter the physical landscape, by melting ice and altering currents, and the biological landscape as well. The Western Antarctic Peninsula is a particularly special place to study the effects of climate change because warming can be seen along a spatial gradient, which means that some parts are warming faster than others so it is easy to compare changes between locations. At the Palmer Long Term Ecological Research Station (PAL-LTER), scientists have been studying the region's ecology for 30 years to better understand how the ecosystem is changing over time and how these changes affect the populations and processes in the area.

Adélie penguin *(Pygoscelis adeliae)* populations, while once extremely abundant in the Western Antarctic Peninsula, have declined approximately 90% since the 1970s. Studies are being conducted in this region, both by scientists at the PAL-LTER and others, to monitor these penguins and the environment to determine the root cause for their intense decline. This lesson uses data collected at the PAL-LTER from the 1990s to 2020 to look at how the abundance of Adélie penguin breeding pairs has changed over this thirty-year period and discover potential trends in krill abundance in penguin stomachs and sea ice coverage—the two leading hypotheses for the cause of the decline of these penguins.

Krill make up an important part of Adélie penguins' diets, so decreases in krill abundance or shifts in the range for these organisms could be a driver for the decline in these penguins' populations. Studies conducted at the PAL-LTER have monitored both water-column abundances for krill and the stomach contents of sea birds to determine if there have been any significant changes in their populations. Krill also depend on sea ice for a portion of their life cycles, which may link them to the effects of climate change and warming that the Western Antarctic Peninsula is experiencing.

Adélie penguins are also an ice-obligate species, meaning that they depend on and will spend large portions of their lives on the sea ice that surrounds the Western Antarctic Peninsula. Because the Western Antarctic Peninsula is experiencing warming at faster rates than almost any other area on the planet, the extent and duration of sea ice cover in this area are changing in response. Because of their need for ice, it is possible that decreased sea ice cover is the reason for the decrease in penguin populations.

Despite the ongoing work at the Palmer Long Term Ecological Research Station, scientists are still working to determine the cause of such an intense decline in Adélie penguin populations in the Western Antarctic Peninsula. Current research is pointing toward sea ice retreat as the most probable cause, but more data and investigations are necessary to rule out other possibilities. As Adélie penguins have declined, others have come to take their place, namely the subpolar Gentoo *(Pygoscelis papua)* and Chinstrap *(Pygoscelis antarcticus)* penguins, who tend to favor warmer, less icy conditions than the Adélies. As scientists continue

to unravel the mystery of these missing penguins all the way in Antarctica, your class will help further the mission with today's activity.

Materials & Supplies

- One Case File for each group. Each case file will need:
  - 1 manila folder to hold contents
  - 6 Penguin Census envelopes (or baggies). Each Penguin Census envelope will need:
    - 1 envelope for each 5-year period, labeled with the years
    - Blue beads corresponding with penguin pair counts for each 5-year period*
  - 6 Stomach Contents envelopes (or baggies). Each Stomach Contents envelope will need:
    - 1 envelope for each 5-year period, labeled with the years
    - Red beads corresponding with krill counts for each 5-year period*
  - 1 Sea Ice envelope (or baggie). The Sea Ice envelope will need:
    - 1 printout of the Sea Ice table*
    - 1 printout of Sea Ice Change graph*
- Graphing paper (optional if not printing out worksheets)

*See Appendix A for Instructor Key.

Teacher Preparation

- Divide students into groups of 4-6 students each, depending on class size.
- Case files should be prepped in advance. These only need to be made once, as they can be stored and reused.
- Each group of students will receive a case file and worksheets. If not printing the worksheets, ensure students have graphing paper or something else to draw their graphs on. Worksheets with entirely blank graphs are located in Appendix A (pg. 14-19), for more advanced graphers.

Procedure

- See slides 1-5 to introduce the region and animals studied in this lesson.
- On slide 6, direct the students to create K-W-L charts.
    - Allow 5 minutes (timer provided) for solo thinking about the Know section.
    - Have students share with their groups (or with the class) and come up with 3 questions for the Want to Know section.
- After introducing part 1 of the activity on slide 7, hand out pre-prepared case files to students and activity sheet 1.
    - Allow 5-10 minutes for counting and graphing penguin census data.
    - Introduce the idea of trends, ask the students if they see a trend in the penguin census data.
- On slide 8, ask the students if they can think of any reasons why Adélie penguin populations are decreasing.
    - Have students base their answers off what they may already know about Antarctica, penguins, climate change, and community interactions.
    - Encourage the students to come up with multiple hypotheses.
- See slides 9-12 to introduce the hypotheses being tested by Palmer scientists and part 2 of the activity.
    - Discuss how changes in abiotic and biotic factors could affect communities in the Western Antarctic Peninsula.
    - Introduce krill as an important food source, opportunity to speak about food webs and energy transfer if relevant to the class.
    - Introduce sea ice as an important habitat, opportunity to delve deeper into climate change and sea ice retreat.
    - Allow 10-15 minutes for counting, graphing, and investigating krill and sea ice data,
- On slide 13, ask the students if they saw any trends in krill or sea ice and if they think either of the two hypotheses could explain the decrease in Adélie penguin populations.
    - Class discussion on drawing conclusions from data analysis if time permits.
- On slide 14, tell the students that scientists have not come to a conclusion yet based on the data they have collected.
    - Revisit the question from slide 7 now that they know it might not be related to krill or sea ice coverage.
    - Connect the students to Antarctica by asking how their actions at home might affect or help these penguins.
        - Discuss climate change and individual environmental stewardship.
- On slide 15, have students complete their K-W-L charts.
    - Allow 5 minutes for students to complete their Learned section (timer provided).
    - Have students share with their groups (or the class).
- Optional: Further discussion on climate change and human impacts or independent research project on other species/ecosystems affected by climate change.

Name: _____ Date: _____

Part 1: The Missing Penguins

Open your case files and locate the envelopes labeled Penguin Census.

For each envelope, note the years it represents and count the number of beads inside. These beads represent the total number of Adélie penguin pairs in the Western Antarctic Peninsula for that 5-year period.

Fill in this table to keep track of your data.

Years	Penguin Pairs
1991-1995	
1996-2000	
2001-2005	
2006-2010	
2011-2015	
2016-2020	

Bonus: Each of the beads actually represents 10 penguin pairs. See if you can calculate the number of penguin pairs and individual penguins represented in the data.

Total number of penguin pairs: _____

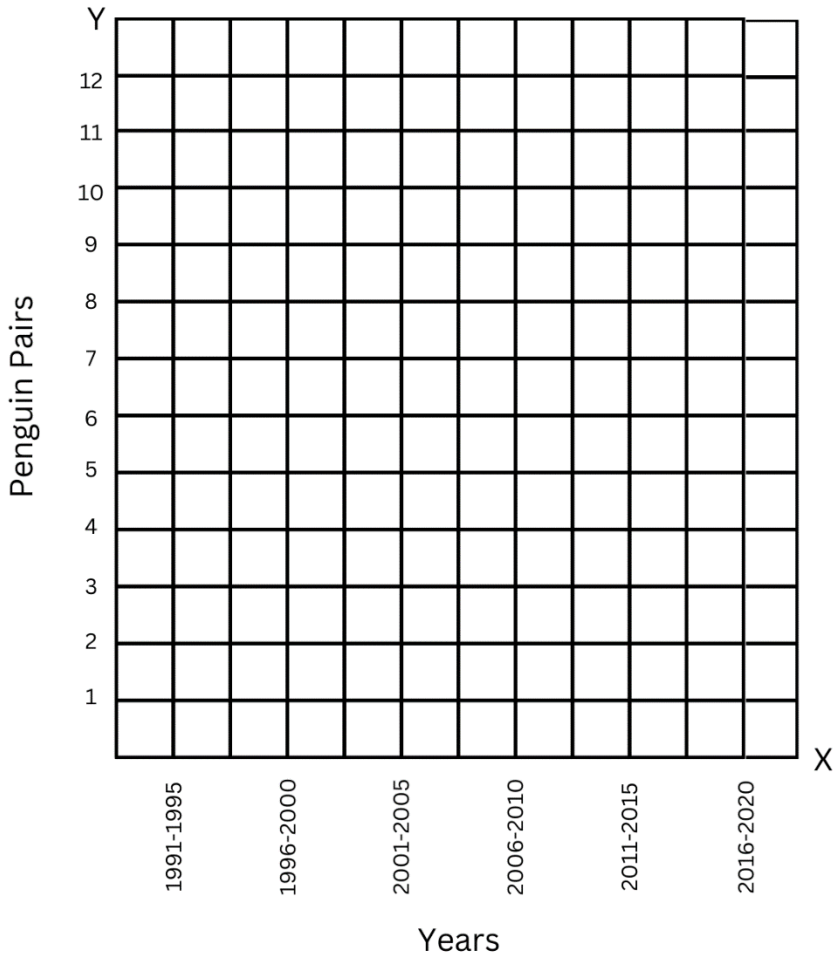
Total number of individual penguins: _____

1. Analyze the date you have collected. What years had the highest number of penguin pairs? The lowest?

   Is there a big difference between these numbers?

Now that we know how many penguin pairs were present in the Western Antarctic Peninsula during each of our 5-year periods, let's graph the data to get a better idea of how they have changed over time. In the space below, fill in the axes and plot each of the data points. Once you have all of your points on the graph, connect them with a line to make a line graph.

2. What is the independent variable?
   What is the dependent variable?



3. Patterns in data over time called trends help scientists determine what their data are doing. Trends can be positive (increasing), negative (decreasing), or there can be no clear trend.

   Can you identify any trends in your Adélie penguin data? Describe them using the information you gathered from the case file.

Name: _____ Date: _____

Part 2: Why are their populations declining?

Now that you've confirmed that Adélie penguin populations have decreased over time, continue to the next section to see if you can determine why this is happening. Look inside your case file for some possible evidence.

1. Even though Adélie penguins eat different kinds of fish, krill make up a very important part of their diet. How could differences in the abundance of krill in the Western Antarctic Peninsula over time explain the decline of Adélie penguin populations?

In your case files, you will find envelopes labeled Stomach Contents. Each envelope has beads that represent the number of krill inside the stomach of an average Adélie penguin during each 5-year period. Count the number of beads and record your data in the table below.

Years	Krill Abundance
1991-1995	
1996-2000	
2001-2005	
2006-2010	
2011-2015	
2016-2020	

Bonus: As before, each bead represents 10 krill. See if you can calculate the total abundance of krill represented in the data.

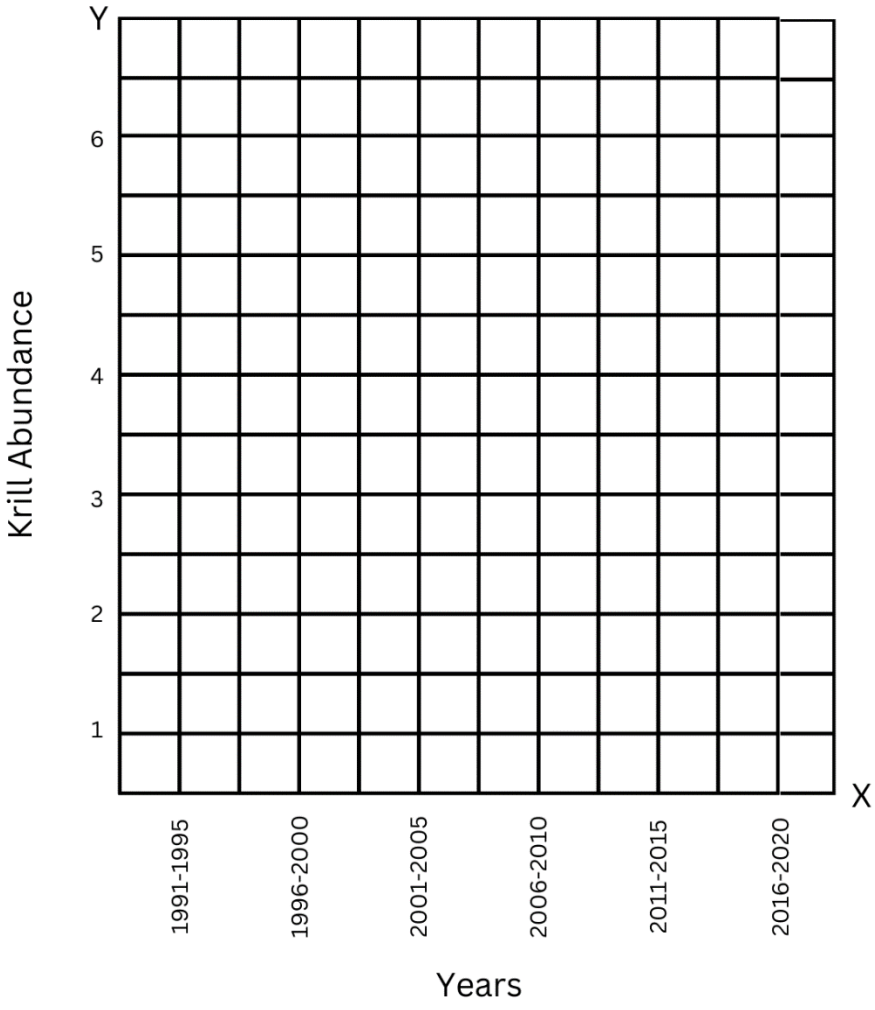
Total krill: _____

2. Analyze the data you have collected. What years had the highest krill abundance? The lowest?

   Is there a big difference between these numbers?

In the space below, fill in the axes and plot each of the data points. Once you have all of your points on the graph, connect them with a line to make a line graph.

3. What is the independent variable?
   What is the dependent variable?



4. Can you identify any trends in your krill data? Describe them using the information you gathered from the case file.

5. Adélie penguins are an ice-obligate species and must spend a large amount of their lives on or around sea ice. Since sea ice is an important habitat for them, how might differences in the amount of sea ice in the area affect penguin populations?

In the envelope labeled Sea Ice, you will see a table showing you the actual area (km^2) covered by sea ice in the Western Antarctic Peninsula in the same 5-year periods and a graph of these data. The dark line is a trendline, which will help you see any possible trends in the data.

6. Can you identify any trends in your sea ice data? Describe them using the information you gathered from the case file.

7. Now that we have compared two variables (krill and sea ice coverage), which of these two, if any, do you think could be the reason why penguin populations have decreased?

   Why? Explain your reasoning using what you've learned throughout this lesson.

Name: _____ Date: _____

Part 3: Drawing Your Own Conclusions

Despite the conclusions you made in Part 2, scientists aren't actually sure about why Adélie penguin populations have decreased so much over time! Today, you've investigated the two main hypotheses scientists are testing: krill abundance and sea ice coverage.

Other topics that scientists are researching in the Western Antarctic Peninsula include how the base of the food web affects the entire ecosystem and how other changes to the environment might affect the entire community. For example, while the Adélie penguin populations are decreasing, Gentoo and Chinstrap penguin populations are increasing—and scientists are curious as to why!

1. Using what you learned during this lesson and what you might already know about Antarctica and its ecosystem, come up with your own hypothesis for why these penguins may be disappearing. What are some potential causes that have not been investigated in this lesson?

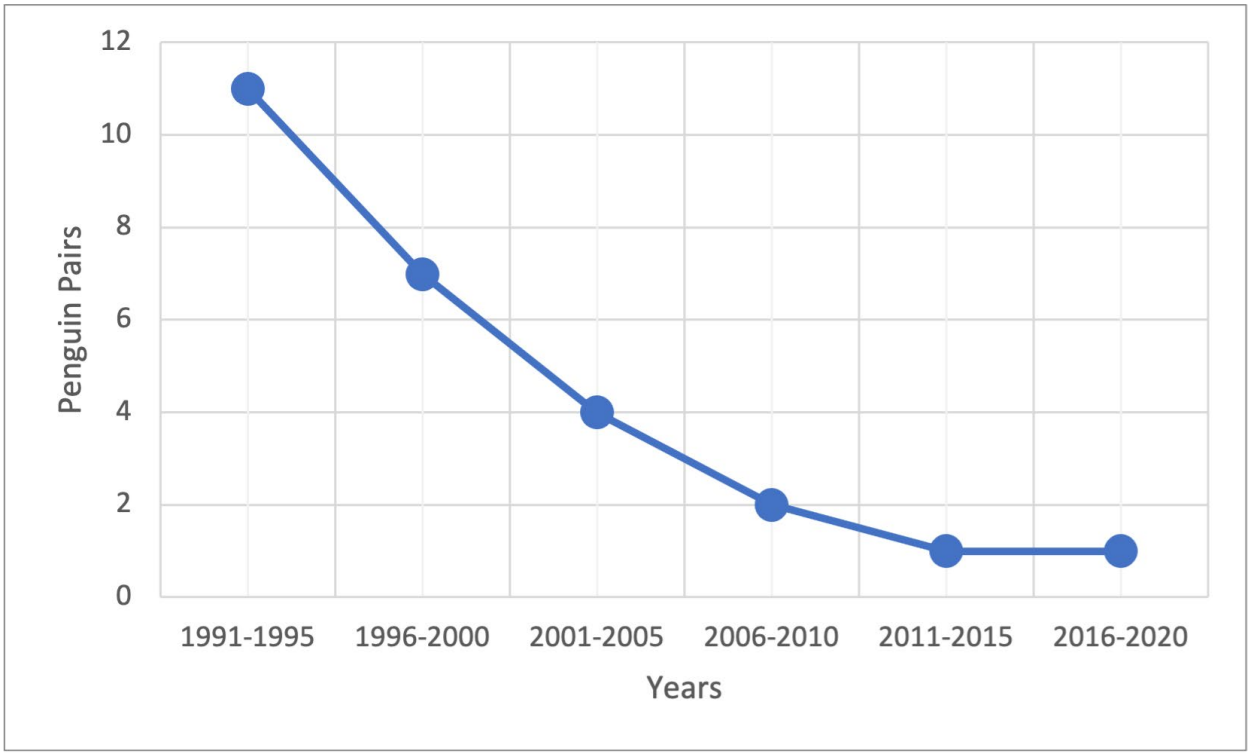
   Share your hypothesis with your group and discuss similarities or differences in your hypotheses.

2. Anthropogenic or human-driven climate change is responsible for much of the warming that is causing polar sea ice to melt. Things like burning fossil fuels, agriculture, and deforestation are causing Earth's climate to warm.

   Even though you might not live in Antarctica, there are ways you can help these penguins. List some ways you can be responsible for reducing the impacts of anthropogenic climate change.

Table of Adélie penguin pairs over time.

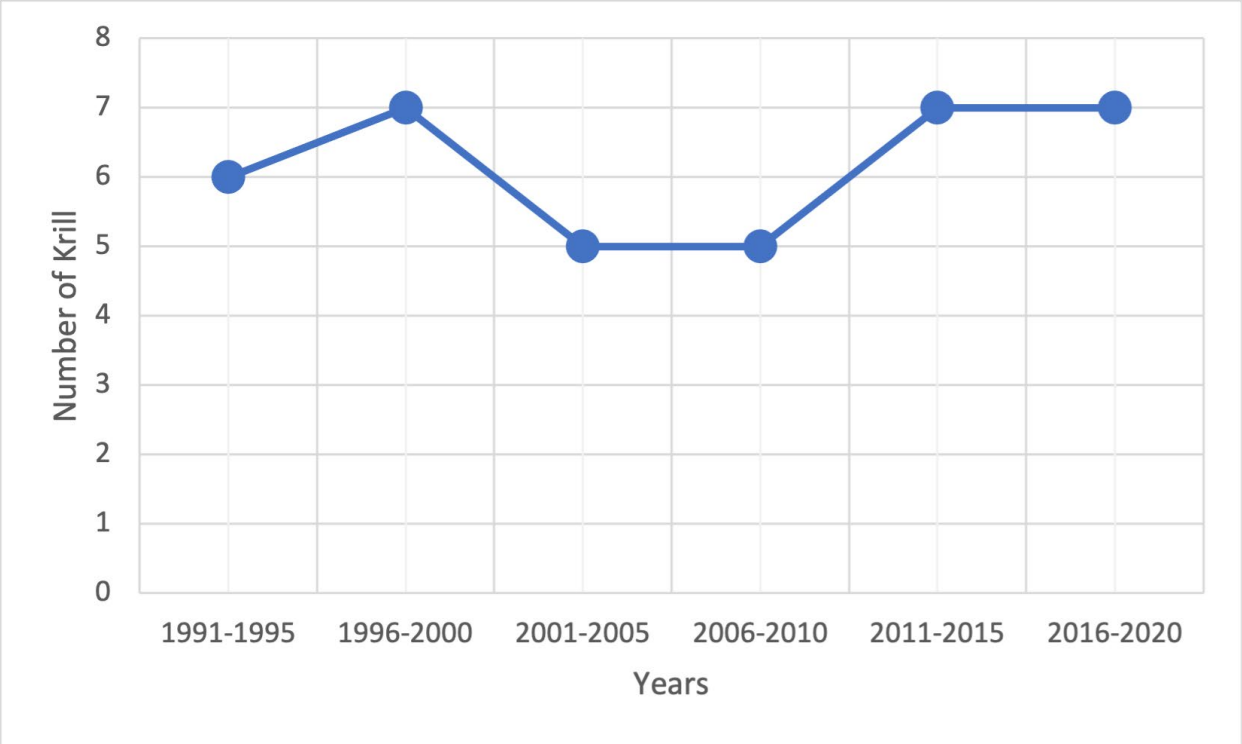
Years	Penguin Pairs
1991-1995	11
1996-2000	7
2001-2005	4
2006-2010	2
2011-2015	1
2016-2020	1



Graph of Adélie penguin pairs over time.

Table of average krill abundance inside Adélie penguin stomachs over time.

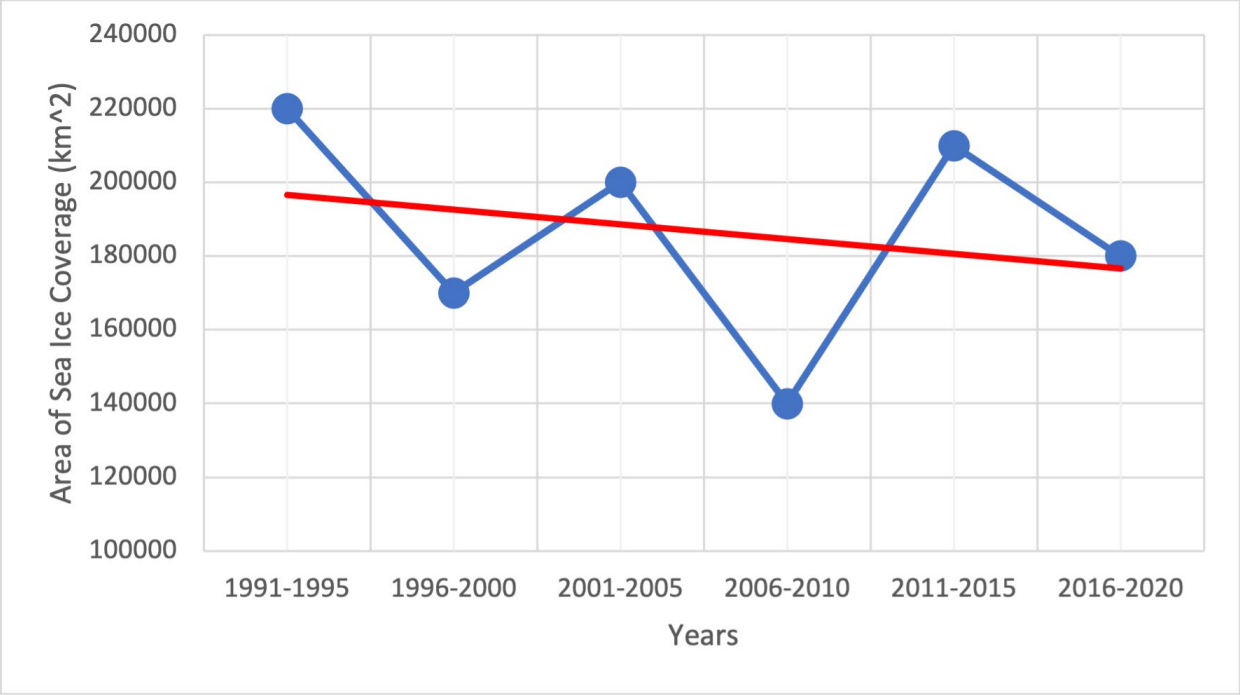
Years	Krill Abundance
1991-1995	6
1996-2000	7
2001-2005	5
2006-2010	5
2011-2015	7
2016-2020	7



Graph of average krill abundance inside Adélie penguin stomachs over time.

Table of ice coverage area.

Years	Ice Coverage Area (km^2)
1991-1995	220000
1996-2000	170000
2001-2005	200000
2006-2010	140000
2011-2015	210000
2016-2020	180000



Graph of average area of sea ice coverage over time with trend line.

Appendix B: Bilingual Resources

Glosario en español

- Abiotic : Abiótico
  Componentes no vivos de un ecosistema
- Abundance : Abundancia
  El número de objetos individuales o animales en una muestra
- Anthropogenic : Antropogénico
  Causado por humanos
- Biotic : Biótico
  Componentes vivos de un ecosistema
- Climate Change : Cambio climático
  Cambio a largo plazo en la temperatura promedio de la Tierra y los patrones climáticos, ya sea natural o causado por los humanos
- Community : Comunidad
  Todos los organismos que viven e interactúan en un lugar particular
- Ecology : Ecología
  El estudio de cómo los organismos interactúan entre sí y con su entorno
- Ecosystem : Ecosistema
  Un grupo de organismos que interactúan entre sí dentro de su entorno
- Habitat : Hábitat
  El hogar natural o el entorno de un organismo
- Ice-Obligate : Obligado al hielo
  Una especie que necesita pasar una parte significativa de su vida viviendo en y alrededor del hielo marino polar
- Polar : Polar
  Regiones en latitudes superiores a 66.5 grados Norte o Sur
- Population : Población
  Un grupo de individuos de la misma especie que viven en un lugar
- Sea Ice : Hielo marino
  Agua del mar congelada que flota en la superficie del océano
- Trend : Tendencia
  Dirección general en la que los datos se mueven a lo largo del tiempo

For bilingual glossaries in other languages and for other subjects, visit: https://steinhardt.nyu.edu/metrocenter/language-rbern/resources/bilingual-glossaries-and-cognates

Appendix C: Additional Relevant Learning Standards

Next Generation Science Standards

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Polar Literacy Principles

Principle #4: The Polar Regions have productive food webs.

4B: Sea ice cover, water and air temperature change with the seasons

4B-3: Krill serve as food for the higher levels in the Polar food webs.

4C: The Antarctic food web is simple and dependent on ice.

4C-1: Antarctica is home to marine mammals (whales and seals) and sea birds, including penguins. Antarctica is not home to terrestrial mammals. Polar bears do not live in Antarctica.

4C-2: Many Antarctic species (krill, penguins) are dependent on ice cover to survive; they serve major roles in the Antarctic marine food web.

Principle #5: The Poles are experiencing the effects of climate change at an accelerating rate

5C: The Western Antarctic Peninsula (WAP) is the fastest winter-warming region in the world (about 10 times faster than global average.

5C-1: Antarctic ice shelves are floating extensions of the land ice. They are critical to ice stability in Antarctica, forming a buttress to hold back the ice behind them. Antarctica is surrounded by ~45 ice shelves that are susceptible to a warming atmosphere and ocean.

5C-2: The warming Southern Ocean flows close to the WAP, causing melting at the ice shelves and the base of glaciers. This accelerates the WAP glacier melt and collapse.

5C-3: Increased glacial melt affects the WAP food web.