



Education and Research: Testing Hypotheses

Lesson Plan—*Are Adélie Penguins Getting the “Cold Shoulder”?*

(Katie Lodes, Jeff Robbins, Tara Sain, and Miriam Sutton)

Summary

Scientists have been collecting Long-Term Ecological Research (LTER) Data along the West Antarctic Peninsula (WAP) annually since 1974. The Palmer LTER project is one of 26 LTER sites that are also found throughout the US, Puerto Rico, and Tahiti. Palmer LTER is focused along the West Antarctic Peninsula and based out of the Palmer Station on Anvers Island (-64.77417°S, -64.05450°W).¹ The information generated from decades of annual data collection has allowed scientists to observe short and long-term changes in the ecological dynamics along the WAP. This activity focuses on the changes observed between 1975 and 2010 in the population dynamics between three species of penguins found along the WAP: Adélie, Chinstrap, and Gentoo. The impact of changing ocean temperatures along the West Antarctic Peninsula is also investigated using a supporting graphics and a second LTER dataset to analyze the relationship between climate change, the Antarctic food web, and penguin population dynamics.

¹ “Welcome to Palmer Station Antarctica LTER A Member of the Long Term Ecological Research Network.” *Palmer Station Antarctica LTER*, LTER Network, 20 July 2017, pal.lternet.edu/.

[TAGS: Climate Change impacts; ecosystem; predator-prey relationships; Antarctica; penguins; LTER; Food web]

Background

Changes in Earth’s climate are also generating changes in our oceans. These changes vary in different parts of the globe. Antarctica is experiencing varying amounts of change to its ice shelves that are adjacent to the Antarctic Circumpolar Current. This current flows at a rate from 100-150 Sverdrups (1 Sv=10⁶ m³ s⁻¹) pushing between 125 x 10⁶ m³/s and 140 x 10⁶ m³/s volume of water around the Southern Continent.^{2, 3} Using a plethora of data collection instruments, scientists have recorded variations and anomalies within the layers of seawater that surround Antarctica. These variations are currently theorized to be the cause of fluctuations observed in the amount of ice remaining in the peninsula region of Antarctic’s western ice sheets. These fluctuations are also affecting the food web and penguin nesting regions in this part of the continent. The impacts of a changing climate are reducing the amount of sea ice in the West Antarctic Peninsula (WAP) region and, thereby reducing the ice habitats used by krill. Krill are large zooplankton that forage beneath the ice shelf and sea ice for other microscopic forms of plankton. Larger marine organisms in the WAP, including three species of penguins that rely on krill as a food source, are also being affected by these changes to the sea ice.

² Ryan Smith, Melicie Desflots, Sean White, Arthur J. Mariano, Edward H. Ryan. "The Antarctic CP Current." *Ocean Surface Currents*. University of Miami (2013). <http://oceancurrents.rsmas.miami.edu/southern/antarctic-cp.html>.

³ NOWLIN, WORTH D., JR., and JOHN M. KLINCK. "The Physics of the Antarctic Circumpolar Current." *REVIEWS OF GEOPHYSICS* 24.3 (1986): 469-91.] *The Physics of the Antarctic Circumpolar Current - Center for Coastal Physical Oceanography*. Center for Coastal Physical Oceanography - Old Dominion University, Aug. 1986. Web. 15 Nov. 2016. <http://www.ccpo.odu.edu/~klinck/Reprints/PDF/nowlinRevGeo86.pdf>.

Key Concepts

Major concepts addressed in this lesson:

- Population Dynamics: Changes to three species of penguin populations
- Environmental Impacts: Relationship between West Antarctic Peninsula sea ice and the Antarctic Food Web

NGSS Disciplinary Core Ideas

Practices: Analyzing and interpreting data

Crosscutting Concepts: Cause and effect

Life Sciences:

LS2.A. Interdependent Relationships in Ecosystems

LS2.C. Ecosystem Dynamics, Functioning, and Resilience

LS2.D. Social Interactions and Group Behavior

LS4.C. Adaptation

Earth and Space Sciences:

ESS3.D. Global Climate Change

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-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

Objectives

Students will be able to:

1. Manipulate a "clean" dataset (Penguin Population Data (*“Adélie – Chinstrap – Gentoo Trends”* XCel Spreadsheets: Student version and Teacher version) extrapolated from the Palmer Station Long Term Ecological Research website and database to investigate changes observed in the population dynamics of 3 species of penguins along the West Antarctic Peninsula.
2. Generate 3 graphs illustrating changes in penguin populations along the West Antarctic Peninsula since 1974 using computers with XCel spreadsheet software or Chromebooks using Google Sheets..
3. Interpret graphics to explore variables relevant to penguin population dynamics along the West Antarctic Peninsula including: thermodynamics, hydrologic, and food web.
4. Access the PAL-LTER data portal to download Penguin Diet Composition data to a spreadsheet and generate a graph illustrating the composition of the Adélie penguin diet.
5. Analyze 2 data sets and supporting graphics to communicate cause and effect and feedback relationships driving changes in penguin populations along the West Antarctic Peninsula.

Procedure

Overview of the West Antarctic Peninsula, Palmer Station Research Station, and LTER

1. Use a map of Antarctica to review the unique geography and the variations in ice dynamics between East and West Antarctica. The Transantarctic Mountain range separates East and West Antarctica and responses to climate change vary widely across the continent. Ice accumulation along East Antarctica continues to remain relatively stable while annual ice recordings along the West Antarctic Peninsula (WAP) show declines in sea ice and ice sheet volume. Various research stations from different countries are found throughout Antarctica, including a U.S. Station known as Palmer Station. (Antarctica Map: http://www.nationsonline.org/oneworld/map/antarctica_map.htm)
2. Provide students with an overview of Palmer Station, found along the West Antarctic Peninsula (WAP). Reference the webcams, weather station, other information found on this website to assist student understanding of the research station and surrounding areas: (<https://www.usap.gov/videoclipsandmaps/palwebcam.cfm>)
3. Review the **Lab Sheet** for this activity and facilitate students in forming a hypothesis for the investigation of **Penguin Dynamics Along the WAP**.

Analyzing and Interpreting LTER Data and Graphics

1. **PAL-LTER DATASET #1:** Use the PAL-LTER Datasets (provided in XCel) to generate three graphs illustrating changes in Population Percentages of Adélie, Chinstrap, and Gentoo penguin populations along the WAP between 1974 and 2010. Use the **XCel Tutorial** to assist you in the layout of your graphs.
2. **WAP and PENGUIN ECOSYSTEM GRAPHICS:** Use the **Graphics for Penguin Dynamics Handout** to assist in identifying variables affecting changes in penguin populations along the WAP:
 - a. Use the “*Comparison of Adélie and Gentoo Ranges and Nests*” Map to observe the historical nesting data for Adélie and Gentoo Penguins along the WAP.
 - b. Use the “*West Antarctic Peninsula Sea Ice at Palmer Station Graph*” to observe changes in sea ice along the WAP since 1979.
 - c. Open this website interactive to explore summer and winter seasonal changes in the Antarctic Food Web: <http://polardiscovery.who.edu/antarctica/summer.html>.
 - d. Use the “*Antarctic Food Web and Biological Pump*” Graphic to observe the relationship between sea ice, the biological pump, and the aquatic food web found along the WAP.
 - e. Use the “*Effects of Changing Sea Ice on Food Web*” Graphic to observe the relationship between sea ice and the aquatic food web found along the WAP.
2. **PAL-LTER DATASET #2:** Use the Palmer **LTER Data Tutorial** to access the PAL-LTER Portal to assist you in downloading the data and generating a pie chart illustrating the Adélie Penguin Diet Composition.

Drawing Conclusions and Communicating Findings

1. Facilitate a class discussion as students are forming their conclusions from their investigation of **Penguin Dynamics Along the WAP** and completing their lab sheet.
2. (Optional) Students may work in teams to create a poster or slide presentation to communicate their findings from their investigation.

Assessment

- **Performance**—Students will download and manipulate real scientific data from Palmer Station’s LTER Program to analyze and interpret changes occurring along the West Antarctic Peninsula and communicate their findings in writing and through class discussions.
- **Product**—Students will successfully complete the provided Lab Sheet to demonstrate their understanding of Penguin Dynamics Along the West Antarctic Peninsula.
- **Assessment rubrics that you would use in the classroom are also helpful**

Lab Investigation Assessment – Written and Oral Assessment

5	4	3	2	1
Lab sheet and oral discussion demonstrates knowledge gained through scientific writing and communication skills used to describe all key concepts and relationships explored in each dataset and graphic. Student demonstrates a comprehensive understanding of the relationship between climate change and the WAP ecosystem.	Lab sheet and oral discussion demonstrates knowledge gained through scientific writing and communication skills used to describe some of the key concepts and relationships explored in each dataset and graphic. Student demonstrates significant understanding of the relationship between climate change and the WAP ecosystem.	Lab sheet and oral discussion demonstrates some knowledge gained through scientific writing and communication skills used to describe some of the key concepts and relationships explored in the data and graphics. Student demonstrates some understanding of the relationship between climate change and the WAP ecosystem.	Lab sheet and oral discussion demonstrates minimal knowledge gained through scientific writing and communication skills used to describe one of the key concepts and relationships explored in the data and graphics. Student demonstrates minimal understanding of the relationship between climate change and the WAP ecosystem.	Lab sheet and oral discussion demonstrates no knowledge gained through scientific writing and communication skills used to describe any of the key concepts and relationships explored in the data and graphics. Student demonstrates no understanding of the relationship between climate change and the WAP ecosystem.

Appendix

DATA SOURCES:

- Penguin Data: Ducklow, H. W., K. Baker, D. G. Martinson, Q. L.B., R. M. Ross, R. C. Smith, S. E. Stammerjohn, M. Vernet, and W. R. Fraser. 2007. Marine pelagic ecosystems: the West Antarctic Peninsula. *Philosophical Transactions of the Royal Society of London* 362:67-94. <https://lternet.edu/node/157>.
- Krill Data: Frasier, William. Polar Oceans Research. Adélie Penguins diet studies, collected at Palmer Station Antarctica research area. 1991 - present. <http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets?action=view&id=89>.

REFERENCES:

- Palmer LTER Network. Palmer Station Antarctica LTER Transformational Science. National Science Foundation: Office of Polar Programs. <http://pal.lternet.edu/research/transformational-science> (PDF Version: http://pal.lternet.edu/sites/default/files/files/PALLTER_TransformationalScience.pdf)
- Powell, Hugh and Chris Linder. On the Antarctic Peninsula, Scientists Witness a Penguin Revolution. All About Birds. The Cornell Lab of Ornithology: Cornell University; Ithaca, NY. January 26, 2016. <https://www.allaboutbirds.org/on-the-antarctic-peninsula-scientists-witness-a-penguin-revolution/>
- Frasier, William. “Adélie Penguin Diet Composition.” Palmer Station Antarctica LTER. *Datazoo*, Ocean Informatics - Scripps Institution of Oceanography, UCSD, 2019, <https://oceaninformatics.ucsd.edu/datazoo/catalogs/pallter/datasets/89>.
- “Antarctica’s Ecosystem.” *Polar Discovery*. Woods Hole Oceanographic Institution, 2006, <http://polardiscovery.whoi.edu/antarctica/ecosystem.html>. (Woods Hole Oceanographic Institution provides two interactive graphics for the summer and winter Antarctic food webs allow students to explore how the different species in Antarctica interact.)
- Trivelpiece, Wayne Z.; et.al. “*Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica.*” *Proceedings of the National Academy of Sciences of the USA*. May 3, 2011. <http://www.pnas.org/content/108/18/7625.full.pdf> (An article on the change in krill, and shows how availability has changed over time, includes graphs showing trends.)
- Pickett, Erin P., et.al. “Spatial Niche Partitioning May Promote Coexistence of Pygoscelis Penguins as Climate-Induced Sympatry Occurs.” *Wiley Online Library: Ecology and Evolution*. September 11, 2018. <http://onlinelibrary.wiley.com/doi/10.1890/11-1588.1/full> (A scientific paper is based on a multi year study of multiple sites, it contains multiple links to other studies, shows location, graphs of change in population, discussion and suggestions for further study.)
- Thathan, Phil N., Lynch, Heather J., and Frasier, William R. “Changes in Penguin Distribution over the Antarctic Peninsula and Scotia Arc.” *Antarctic Environments Portal*. Emerging Issues: Version1. May 13, 2016. <https://www.environments.aq/emerging-issues/changes-in-penguin-distribution-over-the-antarctic-peninsula-and-scotia-arc/> (An article that includes information on the change in the number and type of penguins and the location of the survey sites.)

SPECIES RESOURCES:

- *Adélie Penguins*:
 - “Adélie penguins.” Australian Antarctic Division: Leading Australia’s Antarctic Program. Australian Government: Department of the Environment and Energy. March 20, 2018. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/adelie-penguins>.
 - “Adélie Penguins of Paulet Island, Antarctica.” YouTube Video: 9EbdyGTQQ. Tennessee Aquarium. December 30, 2011. <https://www.youtube.com/watch?v=9EbdyGTQQ> (A 5-minute video on Adélie penguins.)
 - Emmerson, Louise and Southwell, Colin. “Adélie Penguin Population Dynamics: 18 Years in a Colony.” Australian Antarctic Magazine: Issue 17, November 20, 2009. <http://www.antarctica.gov.au/magazine/2006-2010/issue-17-2009/science/adlie-penguin-population-dynamics-18-years-in-a-colony>.
 - Southwell C, Emmerson L, McKinlay J, Newbery K, Takahashi A, Kato A, et al. (2015) Spatially Extensive Standardized Surveys Reveal Widespread, Multi-Decadal Increase in East Antarctic Adélie Penguin Populations. PLoS ONE 10(10): e0139877. <https://doi.org/10.1371/journal.pone.0139877>, <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0139877> and <http://www.antarctica.gov.au/news/2015/adelie-penguin-population-almost-doubles-in-east-antarctica>. (Article noting the Adélie penguin populations in East Antarctica have almost doubled over the past 30 years.)
- *Chinstrap Penguins*:
 - “Chinstrap penguins.” Australian Antarctic Division: Leading Australia’s Antarctic Program. Australian Government: Department of the Environment and Energy. March 20, 2018. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/chinstrap-penguins>.
- *Gentoo Penguins*:
 - “Gentoo penguins.” Australian Antarctic Division: Leading Australia’s Antarctic Program. Australian Government: Department of the Environment and Energy. August 12, 2010. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/gentoo-penguins>.

PENGUIN DYNAMICS NOTES:

- Adélie **Nesting and Diet**: Adélie penguins build nests out of the pebbles they find on dry land. Local meals (those within 20 km of the colony) consist mostly of fish, amphipods and ‘crystal krill’ (*Euphausia crystallorophias*), while offshore meals consist of mainly ‘Antarctic krill’ (*Euphausia superba*). <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/adelie-penguins>
- **Chinstrap Nesting and Diet**: Chinstraps spend the winter north of the pack ice zone and return to their colonies in early October through to November. The two eggs are laid in late November. Both males and females take part in the 33-36 day incubation period. Breeding success is lower in years when extensive sea-ice persists close to colonies, as this restricts access to the sea for foraging adults. Although chinstrap penguins forage at sea throughout the day and night, diving effort is concentrated near midnight and noon. Chinstrap penguins feed

mainly on krill and fish and are considered near-shore feeders, feeding close to their breeding colonies. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/chinstrap-penguins>

- **Gentoo Penguin Nesting and Diet:** Gentoos build nests on beaches or amongst tussocks, and keenly defend their turf. Each year the location of their breeding colony is slightly different. While Adélie penguins, for example, often return year after year to the same nest sites, Gentoos may occupy a new area near to that of the previous year. They occupy their islands generally all year round. Gentoo penguins are opportunistic hunters, the diet of gentoos is quite varied. The composition of their diet varies with season and location but is usually a mix of crustaceans, small fishes and squid. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/penguins/gentoo-penguins>

Additional Activities

Exploring the Antarctic Food Web

1. Facilitate student groups as they access and review the following articles using a guided format similar to the format suggested below the list of articles:
 - a. “Salps.” Australian Antarctic Division: Leading Australia’s Antarctic Program. Australian Government: Department of the Environment and Energy. March 20, 2018. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/salps>. (This article discusses the role of salps and krill in the Antarctic food web.)
 - b. “Warming Oceans May Threaten Krill, a Cornerstone of the Antarctic Ecosystem”. http://www.nytimes.com/2015/10/20/science/australia-antarctica-krill-climate-change-ocean.html?_r=0 (This article discusses the relationship with climate and fluctuations in krill populations and the subsequent impact to the Antarctic Food Web.)
 - c. “Antarctic Krill.” Australian Antarctic Division: Leading Australia’s Antarctic Program. Australian Government: Department of the Environment and Energy. February 07, 2018. <http://www.antarctica.gov.au/about-antarctica/wildlife/animals/krill>.
 - d. “Diatoms,” Miracle: Microfossil Image Recovery and Circulation for Learning and Education, England: University College London, <https://www.ucl.ac.uk/GeolSci/micropal/diatom.html>.
 - e. “Phytoplankton Population Drops 40 Percent Since 1950”. <http://www.scientificamerican.com/article/phytoplankton-population/> (This article reviews the role of phytoplankton in biogeochemical cycles and the Antarctic food web.)
2. The “Antarctica Food Web Game” allows students to experience the predator-prey relationships occurring throughout the Antarctic Food Web. (<http://coseenow.net/antarctica/Act%2020%20Lesson%20and%20Activity.pdf>)

Extensions

- Explore the caloric differences between Krill and Silverfish
- Explore the minimum weight for an Adélie chick to survive and reproduce
- Explore the distance required to travel for food and survivability