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Penguin Dynamics Along the West Antarctic Peninsula

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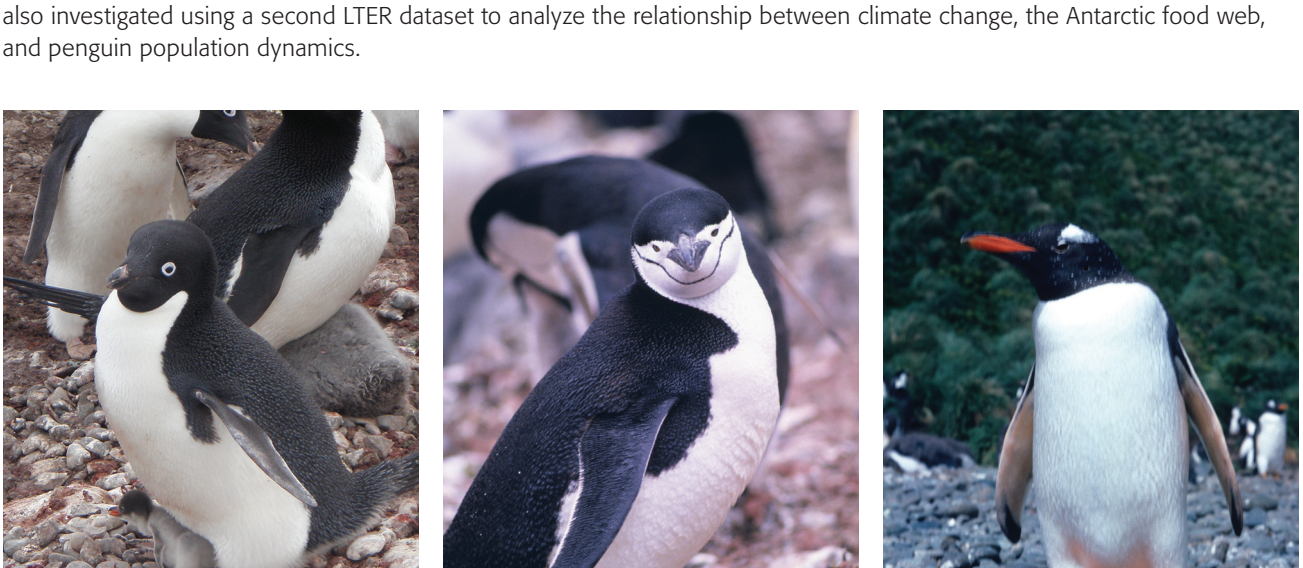
ABSTRACT

This activity incorporates the use of real scientific data to explore ecosystem dynamics among three Antarctic penguin species. Students will analyze two Long-Term Ecological Research (LTER) data sets and supporting graphics to cause and effect and feedback relationships driving changes observed in Adelie, Chinstrap, and Gentoo penguins between 1975 and 2010 along the West Antarctic Peninsula. The penguin population datasets were collected from the Palmer Station Study region, which is part of the Long-Term Ecological Research program. The LTER program began in 1974 and has been collecting annual data in this region (as well as numerous other regions in Antarctica) on a variety of ecological interactions.

INTRODUCTION

Scientists have been collecting Long-Term Ecological Research (LTER) Data along the West Antarctic Peninsula (WAP) a nnually since 1974.[1] The Palmer LTER project is one of 26 LTER sites that are also found throughout the U.S., 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 penguin population 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: Adelie, Chinstrap, and Gentoo. The impact of changing ocean temperatures along the West Antarctic Peninsula is also investigated using a second LTER dataset to analyze the relationship between climate change, the Antarctic food web, and penguin population dynamics.



Left to right: Adélie, Chinstrap, and Gentoo penguins. Courtesy of Renee Koplan, Lieutenant Philip Hall, and Dr. Robert Ricker

OBJECTIVES

1. Students will manipulate a "clean" dataset (created for this activity) extrapolated from the Palmer Station Long Term Ecological Research website and database to investigate changes observed in the population dynamics of three species of penguins along the West Antarctic Peninsula.
2. Students will generate three graphs illustrating changes in penguin populations along the West Antarctic Peninsula since 1974.
3. Students will interpret graphics to explore variables relevant to penguin population dynamics along the West Antarctic Peninsula, including thermodynamics, hydrologic conditions, and food web.
4. Students will access the PAL-LTER data portal to download Penguin Diet Composition data to a spreadsheet and generate a graph illustrating the composition of the Adelie penguin diet.
5. Students will analyze two data sets and supporting graphics to identify cause and effect and feedback relationships driving changes in penguin populations along the West Antarctic Peninsula.

This activity includes: Student data sets, Teachers data sets (including answer keys), and Tutorials for accessing and utilizing the LTER database all accessible online at https://static1.squarespace.com/static/5b4cecfde2ccd188cfed8026/t/5d5a24756b419900019c6356/1566188675833/Penguin-Dynamics-Along-The-West-Antarctic-Peninsula-Resources.pdf.

The Investigation: (A lab sheet is provided for this activity and serves to guide students through their investigation of penguin population dynamics. Encourage students to develop a hypothesis for the investigation question presented in the activity.)

How are penguin populations responding to changes in climate along the West Antarctic Peninsula (WAP)?

USING REAL DATA

The initial dataset provided for this activity was extrapolated from Adelie, Chinstrap, and Gentoo penguin population data provided by Dr. William Fraser, (Polar Oceans Research Group; Sheridan, Montana) and collected between 1974 and 2010 along West Antarctic Peninsula.[2] Students can work independently or in teams to generate graphs to illustrate the population count changes observed in the three penguin species. The data is available in three separate spreadsheet files (one file for each species) and in one file containing all three species datasets (Figures 1 and 2).

Percent of Population Remaining in the Study Region[∞]

	% Penguin Population Remaining		
YEAR	ADELIE	CHINSTRAP	GENTOO
1975	100	0	0
1976	97	1	0
1977	96	3	0
1978	93	3	0
1979	90	3	0
1980	90	4	0
1981	89	4	0
1982	89	5	0
1983	88	6	0
1984	88	7	0
1985	88	8	0
1986	87	9	0
1987	68	10	0
1988	78	10	0
1989	87	11	0
1990	77	12	0
1991	81	9	0
1992	80	10	0
1993	79	12	0
1994	73	11	1
1995	73	14	2
1996	61	13	2
1997	58	14	3
1998	56	11	1
1999	52	12	6
2000	48	18	11
2001	29	18	25
2002	38	17	25
2003	36	17	30
2004	32	6	30
2005	27	13	36
2006	22	14	39
2007	18	12	44
2008	17	15	62
2009	18	17	95
2010	16	20	95

[∞] Fraser, William. Palmer LTER Network. Palmer Station Antarctica LTER Transformational Science. National Science Foundation: Office of Polar Programs. http://pal.lternet.edu/research/transformational-science

FIGURE 1. Percentage of population remaining in the study region. Courtesy of Fraser, William. Palmer LTER Network. Palmer Station Antarctica LTER Transformational Science. National Science Foundation: Office of Polar Programs

ANALYZING PENGUIN POPULATION DYNAMICS

Penguin Population Graph Analysis:

a. Adelie penguin population trends represent an 85% decline between 1974 and 2010 for the study region (Figure 3).
b. Chinstrap penguin populations have increased between 1974 and 2010 (Figure 4).
c. Gentoo penguin populations between 1974 and 2010 have shown a dramatic increase since 1998 (Figure 5).

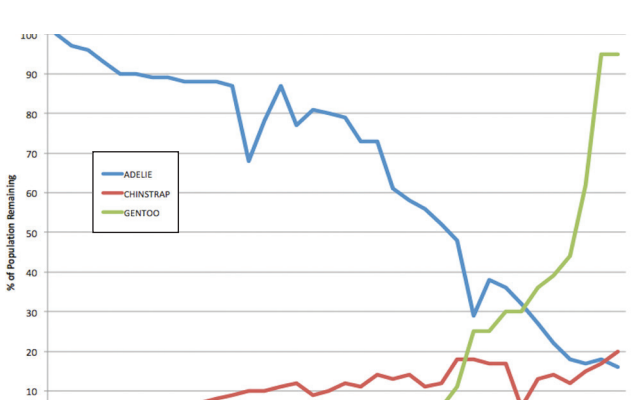


FIGURE 2. Comparison of penguin populations (Palmer Station Study). Courtesy of Miriam Sutton

FIGURE 3. Changes in Adelie population. Courtesy of Miriam Sutton

A CLOSER LOOK AT THE PROBLEM

The Percent of Penguin Population data (see Figure 1) reveals an 85% decline in Adelie penguin populations along the Palmer Station study region while Chinstrap and Gentoo penguin populations are on the rise. Facilitating a class discussion encourages possible causes for the changes observed in the data. Student concerns relevant to climate change, sea-level rise, and predator-prey relationships are addressed using a series of graphics that address each area of concern. Allowing students to work in teams facilitates open discussions as they make interpretations and inferences based on each graphic. The Student Lab Sheet (see online access link on page 28) provides space for observations of each data set and for each of the graphics.

Adelie penguins are far more dependent on sea ice than are Chinstrap or Gentoo penguins. The latter two species prefer nesting sites along rocky outcrops that are free of ice. Annual sea ice has continued to decline with changes in climate and sea surface temperatures. Sea ice forms when ice freezes at the surface. Sea ice is responsible for increasing the Southern Continent's frozen surface area by 14-16 square kilometers (5-6 square miles) during the winter months[3] (Figure 6).

West Antarctic Peninsula Analysis

It is important to differentiate between the decrease in the sea ice season observed along the West Antarctic Peninsula as compared to the remainder of the Southern Continent (Figure 7). Increases in annual sea ice have been recorded in the regions south of the peninsula and throughout East Antarctica.[4] Scientists are continuing to research the discrepancies observed between East Antarctica and the West Antarctic Peninsula sea ice to define the key variables driving this variance.

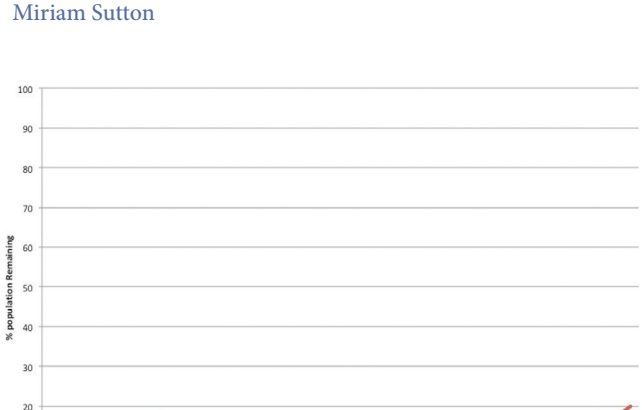


FIGURE 4. hanges in Chinstrap population. Courtesy of Miriam Sutton

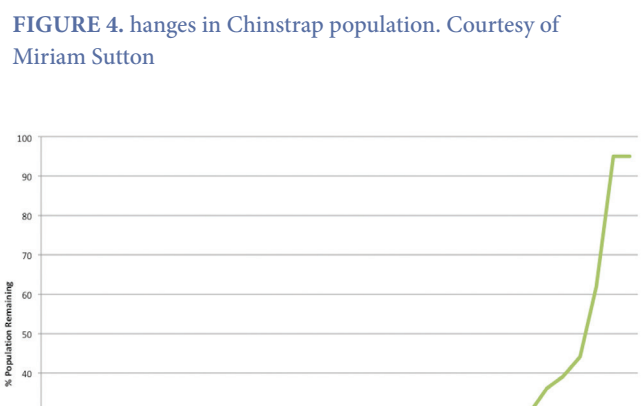


FIGURE 5. Changes in Gentoo population. Courtesy of Miriam Sutton

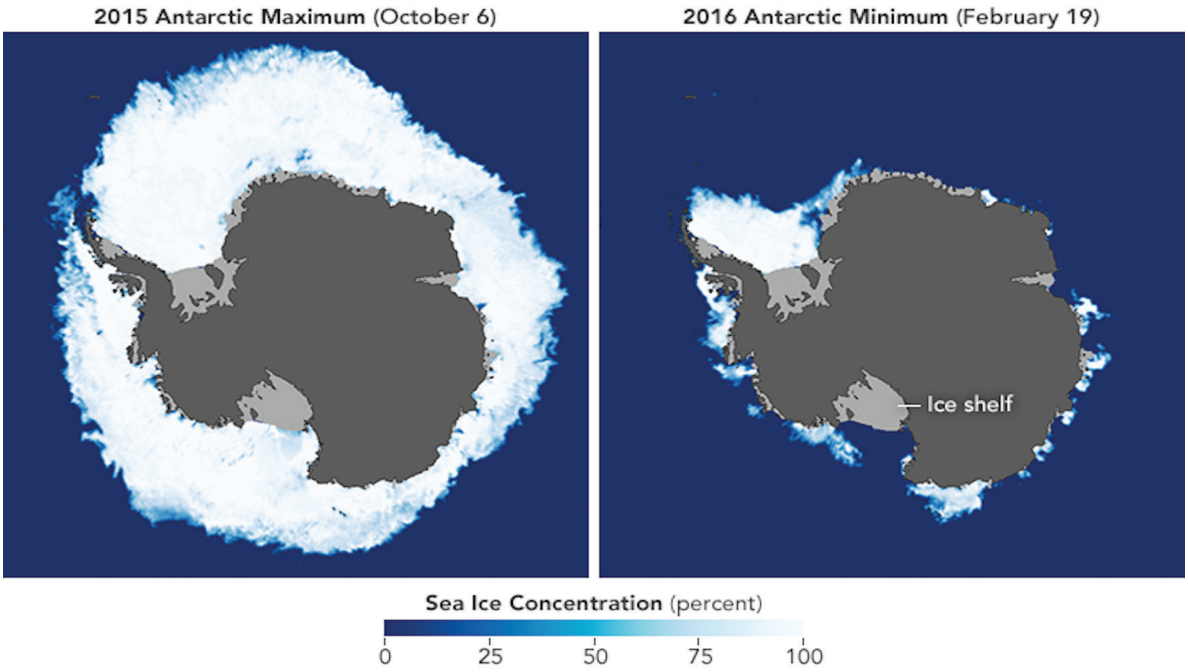


FIGURE 6. Sea ice concentration. Courtesy of Joshua Stevens. AMSR2 data supplied by GCOM-W1/JAXA. Antarctic Sea Ice. NASA: Earth Observatory

Adelie penguins are moving farther south in search of more sea ice. A comparison of six study sites shown on the map indicates an increase in Gentoo penguin nests and a decrease in Adelie penguin nests between 1975 and 2014 (Figure 8); most particularly noted at the Biscoe Point site.[5]

Antarctic Food Web Analysis

Large predators such as penguins, seals, and whales characterize the marine food web along the west Antarctic Peninsula. (See figures of Antarctic food webs online at http://pal.lternet.edu/research/transformational-science and http://polardiscovery.whoi.edu/antarctica/ecosystem.html.) This aquatic food web is sustained by upwelling that supports high productivity and large krill populations.[6] The base of this aquatic food web is the algae that grows beneath the sea ice and supports the plethora of microfauna that the krill (*Euphausia superba*) feed upon, from diatoms to copepods. As a result, krill are highly dependent on sea ice for survival in their first year.[7]

Fluctuations in sea ice can affect the Antarctic food web (see figures of sea ice and krill online at https://www.nature.com/articles/ncomms5318/figures/4). The positive (+) and negative (-) episodes indicate differences that can occur along the Western Antarctic Peninsula each winter. Negative episodes of the Southern Annular Mode (-SAM, left panel) result in increases in winter sea ice, followed by spring and summer

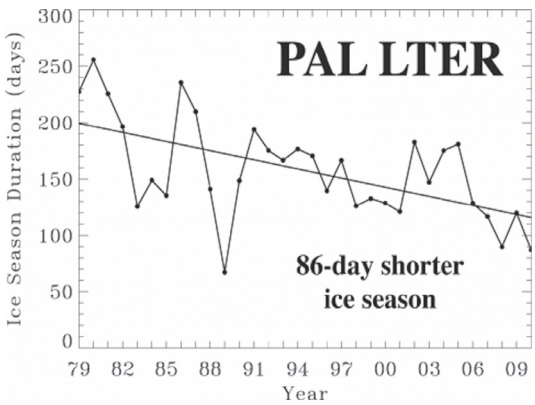


FIGURE 7. West Antarctic Peninsula (WAP) Sea Ice at Palmer Station. Courtesy of Sharon Stammerjohn. University of Colorado, Boulder

conditions that encourage more algae growth. Positive SAM episodes (+ SAM, right panel) result in a reversal of the -SAM conditions.[8]

Increases in sea ice yield increases in algae (phytoplankton) growth, which raises the productivity to support krill growth and survival. Sea ice reduction lowers productivity and reduces the biomass of krill along the West Antarctic Peninsula.

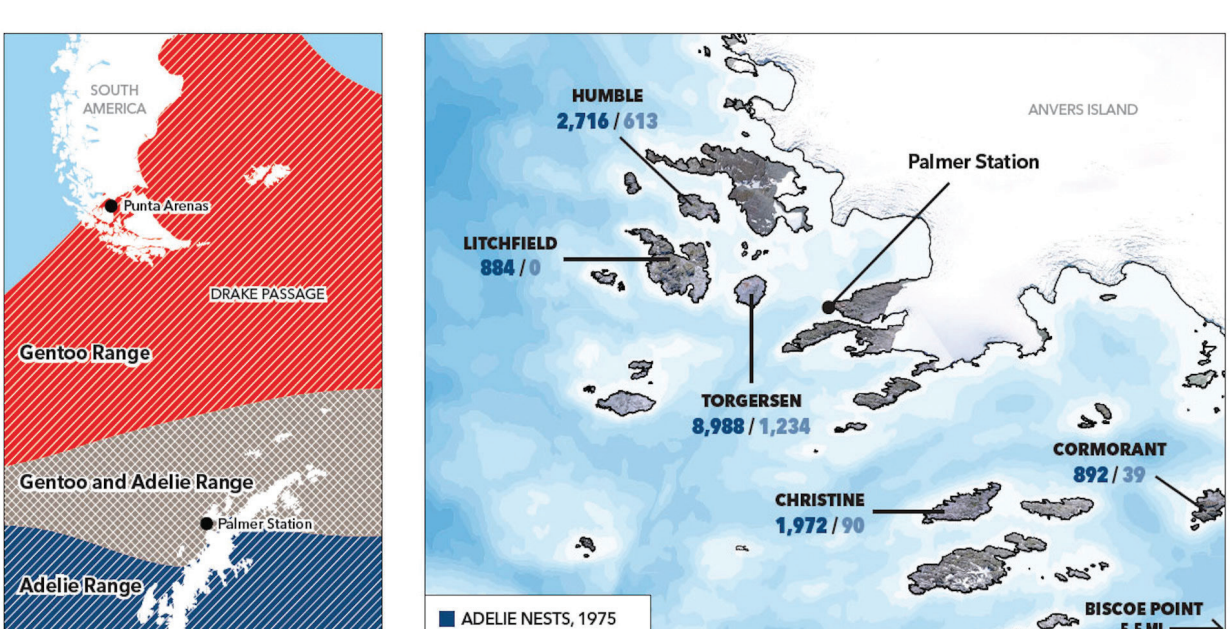


FIGURE 8. Comparison of Adelie and Gentoo ranges and nests. Courtesy of Hugh Powell. "On the Antarctic Peninsula, Scientists Witness a Penguin Revolution." All About Birds. The Cornell Lab of Ornithology

Adelie Penguin Diet Graph Analysis

Why does the decline in sea ice impact Adelie penguins and not the Chinstrap and Gentoo penguins? The previous analysis of the Antarctic food web reveals the key role krill play in penguin diets. This section looks at the diet composition of Adelie penguins using real data collected at PAL-LTER between 1992 and 2015. A step-by-step tutorial is provided to assist students in accessing real data from the Palmer LTER portal (see online access link on page 28).

Students will generate a pie graph to illustrate the Adelie penguins diet composition, which is comprised predominantly of two species of krill (*Thysanoessa macrura; Euphausia superba*). Chinstrap and Gentoo diets also include krill. In addition, Gentoo penguins also forage on small fishes and squid.[9] Their food resources are not sea ice-dependent species and can be found in many regions along the West Antarctic Peninsula. The dietary restrictions of the Adelie penguins create a more sea ice-dependent species.

PULLING IT ALL TOGETHER

This activity allows students to explore the interdependency between climate change, sea ice, and the Antarctic food web along the West Antarctic Peninsula. The diet composition of Adelie penguins is predominantly two species of krill; whereas, Chinstrap and Gentoo penguin diets are more diverse and less sea ice-dependent. Changes in annual sea ice are decreasing along the West Antarctic Peninsula, whereas, other regions of the Southern Continent continue to show increases in annual sea ice. Less accumulation of sea ice in the study region is creating a decline in productivity leading to reductions in krill concentration. This reduction in krill for this region presents a burden for Adelie penguin populations, requiring greater energy expenditures in search of a scarcer food source. As a result, Adelie penguin populations have been observed moving farther south along cooler peninsula regions harboring more sea ice.[10]

The plight of the Adelie, Chinstrap, and Gentoo penguin population dynamics is marked by the displacement of the Adelie population as the Chinstrap and Gentoo populations adapt to environmental changes impacting the West Antarctic Peninsula's ecosystem. Reductions in sea ice conditions have increased available nesting sites for Chinstrap and Gentoo species, which are less sea ice-dependent than Adelie penguins. This activity demonstrates how competition and predator-prey relationships drive evolution processes as each species strives to adapt to changes in the environment around them.

Comparison of Classroom Data Distribution for Graphing Activity

Single Species Data Set	Composite Species Data Set
STEP 1a: Pairs/Teams of students generate an Adelie Penguin Graph **STEP 1b:** Pairs/Teams of students generate a Chinstrap Penguin Graph **STEP 1c:** Pairs/Teams of students generate a Gentoo Penguin Graph	**STEP 1:** Pairs/Teams of students generate a single graph of the three penguin species
STEP 2: Each team analyzes their single species graph and draws their conclusion based solely on their single species	**STEP 2:** Each team analyzes their composite species graph and draws their conclusion based on changes observed in each species of penguin
STEP 3: Each team presents their findings of their single penguin species to the class for comparison and discussion	**STEP 3:** Each team presents their findings of their composite species graph to the class for comparison and discussion
Note: The "blind study" technique used with the Single Species Data Set provides an easier graphing exercise for younger students and also generates a livelier discussion among students as each team discovers the positive and negative variance revealed in the separate datasets.	**Note:** The Composite Species Data Set method requires less class time to complete once graphing is completed. Students who are unfamiliar with generating three graphs in one chart may find this method challenging.

ENDNOTES

[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/.

[2] Fraser, William. Palmer LTER Network. Palmer Station Antarctica LTER Transformational Science. *National Science Foundation: Office of Polar Programs*. http://pal.lternet.edu/research/transformational-science

[3,4] "Antarctic Sea Ice." NASA: Earth Observatory. September 16, 2016. https://www.earthobservatory.nasa.gov/features/SeaIce/page4.php

[5] 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/

[6] Heifetz, I., Rutgers University. *Palmer LTER Network. Palmer Station Antarctica LTER Transformational Science*. National Science Foundation: Office of Polar Programs. http://pal.lternet.edu/research/transformational-science

[7] Schaafsma, F.L., et.al. "Sea Ice: An Important Food Source for Young Antarctic Krill." Wageningen University and Research. Wageningen, Netherlands. September 29, 2017. https://www.wur.nl/en/newsarticle/Sea-ice-an-important-food-source-for-young-Antarctic-krill.htm

[8] Saba, Grace; et.al. "Winter and Spring Controls on the Summer Food Web of the Coastal West Antarctic Peninsula." *Nature Communications*, 5, Article #4318. July 07, 2014. https://www.nature.com/articles/ncomms5318

[9] Australian Antarctic Data Centre. *Taxon Profile:* Pygoscelis papua. Commonwealth of Australia, Australian Antarctic Division. 2019. https://data.aad.gov.au/aadc/biodiversity/taxon_profile.cfm?taxon_id=66969

[10] 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.

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