Volume 34 • No. 1 • Winter 2020

Bringing Long-term Ecological Research (LTER) at Palmer Station, Antarctica to your Classroom

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INTRODUCTION TO PALMER STATION, ANTARCTICA, AND LONG-TERM ECOLOGICAL RESEARCH

The growing realization that our planet is warming has profound implications for future generations as they will be forced to adapt and respond to the changes. Therefore, it is critical to entrain, educate, and enable students to become science literate and active in public policy and decision making about these serious environmental concerns around climate change. Meeting this need is a central focus for the Polar-ICE program through focusing student engagement on one of the most rapidly changing places on Earth, the Polar Regions.

The Arctic and Antarctic are extremely sensitive to warming, resulting in sea ice loss. Sea ice in these systems plays a critical role in regulating marine food webs. Warming reduces the amount of sea ice grown during the cold winter months. This decline in sea ice will restructure marine food webs. Unfortunately, as these systems are remote and harsh, there are few sustained studies to observe and understand the degree with which these systems are experiencing change. This need for sustained observations motivated the formation of several time series efforts in the early 1990s, including the Palmer Long Term Ecological Research (PAL) (Ducklow et al. 2007). The program records semiweekly observations of nearshore processes at Palmer Station between October and April, and conducts a regional-scale cruise in January each austral summer. PAL was built on intensive studies of Adelie penguin ecology and feeding behavior carried out since the mid-1970s (Fraser and Trivelpiece 1996). These sustained observations reveal the shifts in penguin species colonies in the region, correlated to sea ice loss and shifting marine food webs.

More broadly, the long-term studies along the west Antarctic Peninsula (WAP) have documented that it is a highly productive marine ecosystem (Schofield et al. 2010) that is experiencing rapid change (Ducklow et al. 2013). The marine ecosystems in the WAP are also exhibiting significant changes associated with large-scale changes in ocean and atmospheric systems (Stammerjohn et al. 2008; Schofield et al. 2018). Atmospheric temperatures have risen during the winter (>1 degree/per decade, Vaughn et al. 2003). The rise in atmospheric temperatures have mirrored increases in summer surface ocean temperatures (>1°C rise since the 1950s). The increase in ocean heat has been associated with the transport of warm deep ocean water (>1.5°C Upper Circumpolar Deep Water) onto the shelf (Martinson et al. 2008; Couto et al. 2018). The changes in the ocean and atmospheric temperatures have altered ocean circulation (Holland and Kwok 2012), which underlies the declines in annual sea ice concentrations (Stammerjohn et al. 2008). In addition, the sea ice-covered season has declined by more than three months (Stammerjohn et al. 2012). The physical changes have been mirrored with alterations in the food web that include the changes in the base of the food web to the high trophic levels.

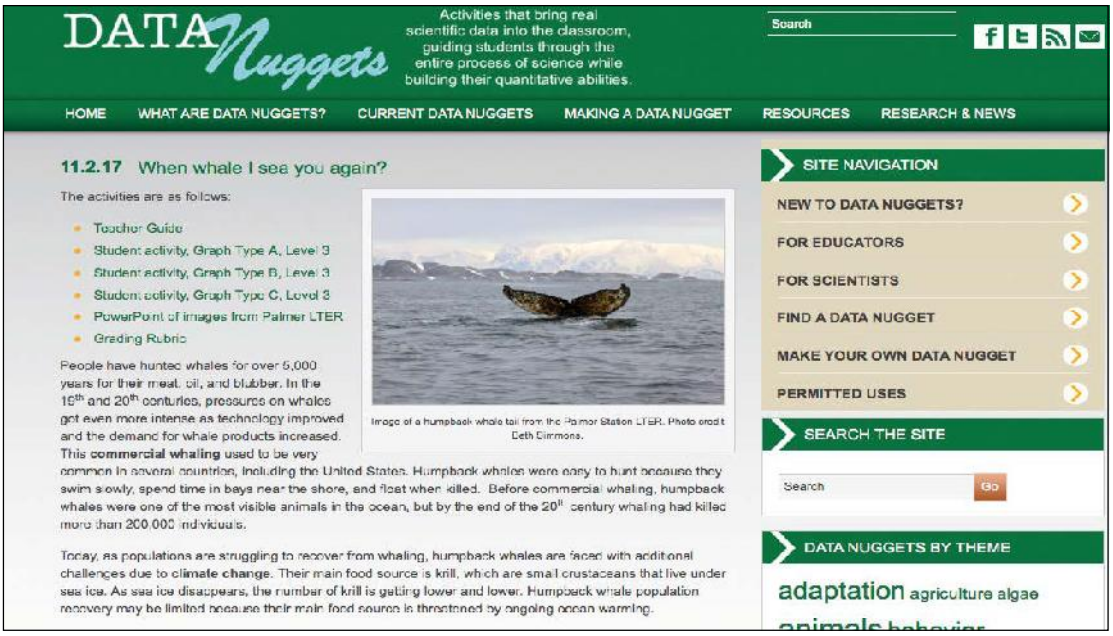
COMMUNICATING CLIMATE CHANGE AT THE FASTEST WINTER WARMING PLACE ON EARTH

In an effort to share the data with broader audiences and communicate the urgent impacts of a warming Western Antarctic Peninsula, a number of education and engagement programs were developed. Examples include:

Data Nuggets (datanuggets.org) are free classroom activities co-developed by research scientists and educators funded by the National Science Foundation through the GK-12 partnership at Michigan State University. They provide a connection to the scientist behind the data and the true story of their research. Each activity seeks to build data literacy, giving students practice working with "messy data" and interpreting quantitative information. Students are guided through the entire process of science, including identifying hypotheses and predictions, visualizing and interpreting data, making evidence-based claims, and asking their own questions for future research.

The When Whale I see you again? Data Nugget was developed by Logan Pallin, a graduate student with the LTER whale research team working to understand how humpback whales are recovering after commercial whaling, and how their

FIGURE 1. When whale I sea you again? can be found on the Data Nuggets website by clicking here.



populations are challenged by climate change. Logan partnered with Alex Custer, a high school biology teacher from Princeton High School in Princeton, NJ to develop a lesson exploring: *How do the abundance and/or sex ratio of male and female humpback whales change over the course of the year in the Western Antarctic Peninsula?* This Data Nugget was designed to be part of a high school molecular biology unit and provided a real-world example of scientific tools such as PCR and Gel Electrophoresis to track the recovery of a species population. The lesson has three levels, including a version where students interpret data provided in graphs; a second version where students generate graphs and perform calculations; and a third version where students generate graphs, perform calculations, and generate an interpretation of the data. The lesson includes PowerPoint slides and a grading rubric for student assessment.

VIDEO TELECONFERENCES AT PALMER STATION

The Palmer LTER program conducts Video Teleconferences (VTCs) annually to help students in grades 3-12 connect with the LTER research team. Educators are invited to complete an application process and agree to teach 2-3 lessons prior to their call, with hands-on activities which prepare students for the VTC experiences. Pre-call webinars allow the education and engagement team to provide educators with an overview of the Palmer LTER program, review suggested lesson plans, and test the technology connection. A "web quest" investigative worksheet "Exploring Palmer LTER" was developed to introduce students to the scientific content as well as to help them develop their science questions. Students submit their science questions 24-48 hours in advance of the VTC.

In 2019, 20 educators in 17 schools from 6 states (CA, MI, NJ, NM, NY, OR) and approximately 1500 students spanning grades 3-12 participated in VTCs. Overall the educators ranked the broadcast as highly impactful for both engaging their students in Antarctic science and for impacting their students' identification as scientists (Table 1).

In addition, educators were asked to explain their ratings for the effect of the VTC/Live Video Broadcast on student engagement in science and identification with science. The following trends emerged:

Developing and Asking Scientific Questions: Educators reported that this experience had a strong impact on both engagement and scientific identity. Beyond that, it fostered a sense of efficacy and agency in the students.

> *Sharing their questions in real time with scientists contributed to them feeling they matter and can make a difference concerning climate change.*

> *The VTC allowed my students to become even more excited about the subject matter and provided them with an end goal to their research…Knowing that they would eventually be speaking with and learning from scientists in the field provided a great incentive to learn more on their own. Students wanted to learn*

as much as they could so their questions showed they were knowledgeable about the topics discussed.

Real Science, Real Time: Many educators noted that it was important for students to have the opportunity to meet and talk to a real scientist, with impacts on engagement and identity as well as solidifying what they'd learned.

My students…like that they can see the person that collected the data they are using in the classroom and pair a face to the data. One student commented that they don't need to worry about "fake news" when working directly with a research scientist. They know the information is real and trustworthy, and they feel more connected to the information through the video conference.

CONCLUSION

Palmer LTER scientists and educators will continue to engage students in the on-going science at Palmer and underscore the value of long-term data collection to scientific understanding. Engagement of students in LTER research is of critical importance to supporting Polar Literacy about these critical environments.

REFERENCES

Additional articles, and references and abstracts for all contributions are available on Polar-ICE (https://polar-ice.org/nmea_current/) and NMEA (https://www.marine-ed.org/s/Polar-Ice-Resources-Current.pdf) sites.

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TABLE 1. Educators rated their students experiences with the Palmer LTER VTC program.

Question (n=17)	Rating Average
How would you rate the following components of the VTC/Live Video Broadcast in terms of the impact on your students' engagement in science? (1 = No Impact to 7 = High Impact). We define engagement as students who are persistent, interested and curious in science, and employ strategies to apply science concepts.	
- Students developing questions beforehand to ask the scientists.	6.5
- Students getting to ask their own question.	6.9
- Students receiving responses to their own question from a scientist.	6.9
- Students hearing the questions that other students ask.	6.0
- Seeing scientists at the field station.	6.9
- Learning about science from the scientists in the field.	6.9
How would you rate the following components of the VTC/Live Video Broadcast in terms of the impact on your students' identification with science? (1 = No Impact to 7 = High Impact). We define identification with science as students who describe themselves as having qualities or characteristics of a scientist (think of themselves as a scientist).	
- Students developing questions beforehand to ask the scientists.	6.7
- Students getting to ask their own question.	6.7
- Students receiving responses to their own question from a scientist.	6.9
- Students hearing the questions that other students ask.	6.4
- Seeing scientists at the field station.	6.7
- Learning about science from the scientists in the field.	6.7