

Using Long-Term Data From Antarctica to Teach Ocean Acidification

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INTRODUCTION

There is a mystery to be solved! This lesson plan asks students to identify the Who, What, When, Where, Why, and How of ocean acidification (OA). Global oceans have absorbed approximately a third of the CO₂ produced by human activities, such as burning of fossil fuels, over the past decade (Sabine et al. 2004). This accumulation of CO₂ in the ocean has lowered average global ocean pH and decreased the concentration of carbonate ions (CO₃²⁻) (Fabry et al. 2008). As a result of this OA, the carbonate chemistry of the global ocean is rapidly changing and affecting marine organisms (Orr et al. 2005). Pteropods (open-ocean snails) are considered bioindicators of OA due to the vulnerability of their aragonitic shells dissolving under increasingly acidic conditions from a changing climate (Figure 1) (Orr et al. 2005; Bednaršek et al. 2014). This lesson plan can be found at: <https://www.vims.edu/research/units/centerspartners/map/education/profdev/VASEA/lessons.php>.

The Southern Ocean is particularly vulnerable to OA because it is more chemically sensitive to increases in anthropogenic CO₂ and is projected to become completely undersaturated with aragonite by 2100 (Doney et al. 2009). The ongoing Palmer Antarctica Long-Term Ecological Research (PAL LTER) study, which began in 1993, monitors how environmental changes, such as OA are significantly affecting the marine ecosystem including pteropods (Figure 2; Thibodeau et al. 2019). Students will utilize real long-term data collected by the PAL LTER to learn about OA.

OA is a pertinent topic when discussing the general concepts of seawater chemistry as well as broader topics including climate change and human impacts. Hence, this lesson plan uses OA as a method to apply more traditional chemistry concepts (i.e., solubility, acids-bases) within the context of global climate change. The lesson focuses on a case study in Antarctica and the potential effects of OA on an open ocean plankton, the pteropod (tero-pod) species *Limacina helicina antarctica*, whose shell is easily dissolved in ocean acidification conditions. With this lesson plan, students will be able to: 1.) outline ocean chemistry processes; 2.) identify key points of Antarctic geography and biology of polar species; 3.) synthesize scientific information from the internet and reproduce in their own words; 4.) record and graph real scientific data using excel; and 5.) interpret graphs and make predictions about future trends based on graphical information.

The lesson plan is approximately 135 minutes or three, 45-minute classes. The different components of the lesson plan can be easily differentiated and function independently as mini-lessons if the full 135 minutes is not available. Content is intended for grades 9-12 but can be modified for use in grades 6-8. The lesson achieves Next Generation Science Standards including 1.) Earth and Space Science standards HS-ESS2-2 Earth's Systems, HS-ESS2-4 Earth's Systems, and HS-ESS3-6 Earth and Human Activity; 2.) Life Sciences standards HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics and HS-LS4-6 Biological Evolution: Unity and Diversity; and 3.) Physical Sciences standards Chemical Reactions HS-PS1-5 and HS-PS1-6.

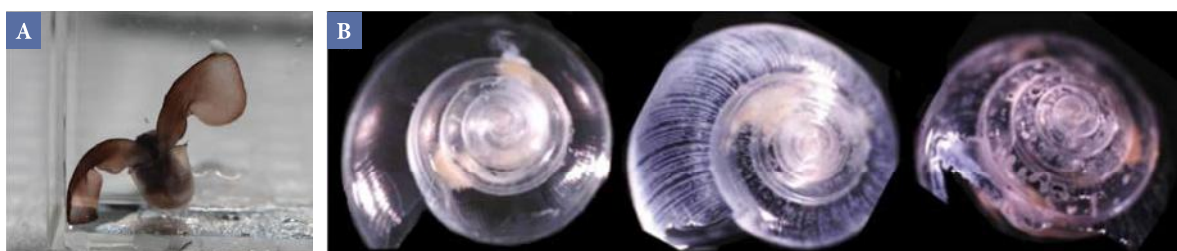


FIGURE 1. *Limacina helicina antarctica* collected along the Western Antarctic Peninsula as part of the Palmer Antarctica Long-Term Ecological Research program (A). Courtesy of Kharis Schrage; and (B). adapted from Busch, D.S., Maher, M., Thibodeau, P., McElhany, P. (2014). Shell condition and survival of Puget Sound pteropods are impaired by ocean acidification conditions. *PLoS ONE* 9(8): e105884. <https://doi.org/10.1371/journal.pone.0105884>

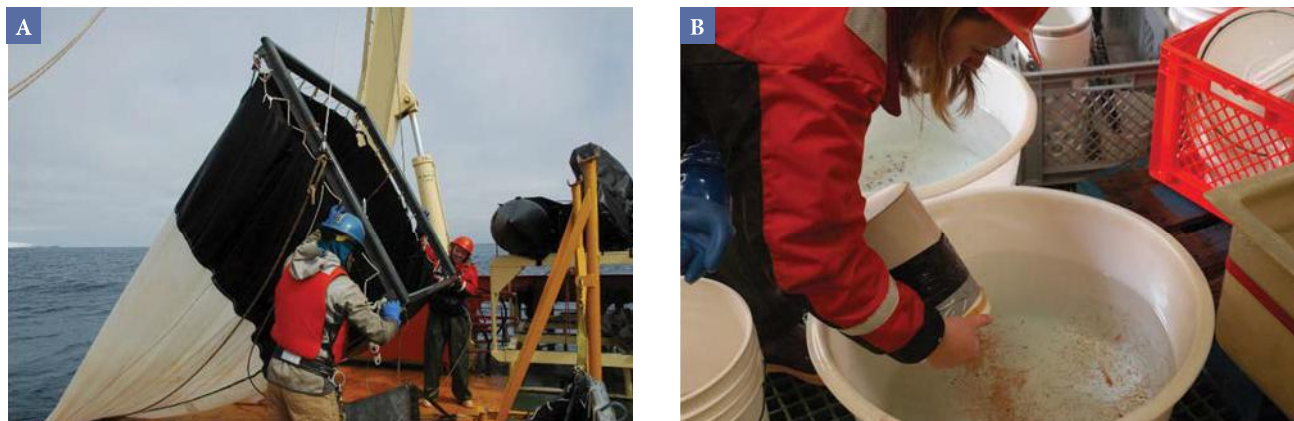


FIGURE 2. Scientists recovering the net used to collect pteropods and other plankton on board the *R/V Laurence M. Gould* in Antarctica as part of the Palmer Antarctica Long Term Ecological Research Program (A). Contents from the net tow used to collect pteropods and other plankton being poured into a bucket to determine its contents. (B). The pink organisms are Antarctic krill and small black dots in the tub are the pteropods. Courtesy of Patricia S. Thibodeau

The class will begin with an OA gallery walk in which students work in pairs or small teams to scan QR codes with iPads/iPhones. Students will be directed to visit specific websites and record their findings on a provided worksheet and then report their findings as a class. This starter activity will cover the “What is ocean acidification?” (Figure 3). This activity is suitable for grades 6-12.

The teacher will then show a presentation to review the concept of OA (*What and When*) and explain Why OA is happening. The presentation also discusses OA in Antarctica and how it could affect a species of pteropod, *Limacina helicina antarctica* (*Where and Who*) (Figure 4).

The major component of the lesson plan is a data nugget activity in which students will answer the question, “How is OA happening?” (Figure 5). For higher level classes, students can graph these data on their own using the provided teacher’s guide. For lower level classes, teachers can provide students with the premade graphs available within the lesson plan for them to interpret. Data are sourced from the PAL LTER publicly available data archive: <http://pal.lternet.edu/data>.

Class will conclude by students reviewing the 5 W’s of OA with a think-pair-share activity (Figure 6). By learning about important scientific concepts related to oceans and utilizing real scientific data, students will better understand the processes governing our oceans and be prepared in answering important scientific and societal questions.



FIGURE 3. Example of a QR-code students will scan (A). A subset of the QR-code gallery walk worksheet students will complete as an introductory activity for the lesson plan (B).

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.



FIGURE 4. Example slide from the presentation a teacher presents to students to review the concept of ocean acidification.

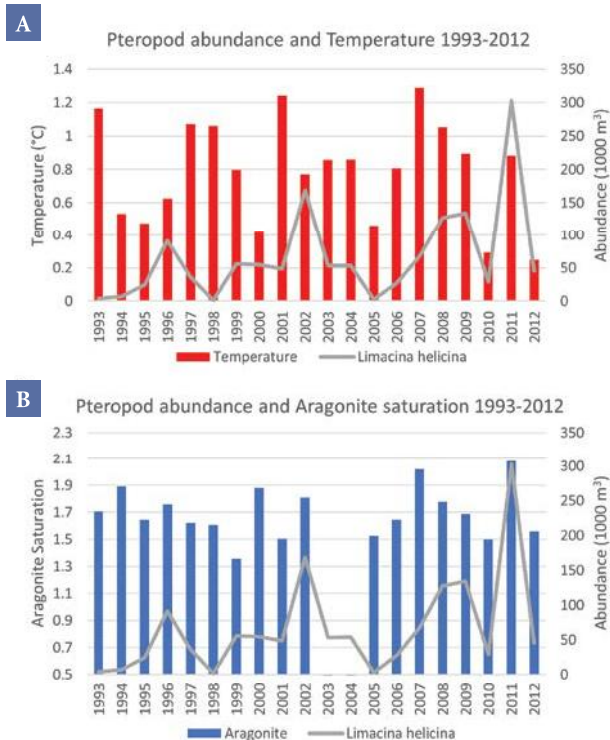


FIGURE 5. A graph generated as part of the data nugget activity. Temperature (left y-axis) and pteropod abundance (right y-axis) both oscillate overtime (x-axis) with moderate summertime temperature ($\sim 1^{\circ}\text{C}$) corresponding to higher pteropod abundance (A). Aragonite saturation (left y-axis) and pteropod abundance (right y-axis) also oscillate overtime (x-axis) with high aragonite saturation corresponding to high pteropod abundance (B). We would expect to see this positive relationship between aragonite saturation and pteropod abundance because aragonite is the building block of pteropod shells.

Appendix 6. Discussion questions and answers

Guiding questions for analyzing data:

Choose questions based on students' abilities, differentiation

a. Describe the data table, what are the variables?

Introduce some of these words in the teacher graphing demo: oscillating, varying, variability. These are common vocabulary to describe trends in time-series data. Students should identify years of high/low pteropod abundance in relation to the graphing variable.

b. What could be your independent and dependent variables? Why?

Discuss why pteropod abundance and the environmental variable are both dependent variables (answer: they're both varying as a function of time, the independent variable). To expand upon this question and add a higher order of thinking, ask students how they would interpret a graph of pteropod abundance vs. environmental variable (answer: pteropod would be dependent variable because we're assuming that the environmental variable may be controlling pteropod abundance in some way). This concept could also be expanded to address correlation by asking students to graph these variables against each other, graph a trend line, and calculate a correlation coefficient.

c. AP LEVEL ONLY: What ways could you graph these data? What type of graph best shows the data? Why?

This question is getting at the type of graphs used to interpret data. Ask students why they were asked to make a combination plot of the variables rather than two bar graphs or two-line plots (answer: want to show data as clearly as possible, when two lines are used it can be difficult to parse apart the two variables, especially if they are highly variable). To expand upon this question, ask students to play around with different graphing options and make a 'better' graph than the original one presented. What makes it better? Is there one right way to present data graphically (answer: no!).

FIGURE 6. Subset of differentiated discussion questions from the Teacher's Guide with suggested answers in red. Discussion questions can be shared with students as a class or as a think-pair-share activity.

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