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Weaving a science story: Narratives and language as tools in the science classroom

Claudia Moncada
Virginia Institute of Marine Science, camoncada@vims.edu

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<u>Advisory Team:</u>

Deborah Steinberg
Janice McDonnell

<u>Capstone Products</u>:

Sofia, Aman, and the Coldest Continent
The Case of the Missing Penguins! 7th Grade Life Science Lesson Plan
The Case of the Missing Penguins! PowerPoint
Fishing for… Plankton? 7th Grade Life Science Lesson Plan
Fishing for… Plankton? PowerPoint

Lesson PowerPoints can be found under Additional Files

The Case of the Missing Penguins! can be found at:
https://www.vims.edu/research/units/centerspartners/map/education/profdev/VASEA/lessons.php

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Capstone Summary

The Standards of Learning (SOL) for Virginia public schools, and other national standards, set expectations for student achievements throughout the school year for many subjects, including science. Because educators must prepare their students for end-of-course exams based on the SOL, classroom discussion and deeper understanding of topics can be lessened. Middle school students show declines in motivations and attitudes toward science, and challenges are greater for English-learning (EL) students. Incorporating storytelling into science classrooms can be helpful to EL and non-EL students because it presents challenging topics and vocabulary in a simpler and more engaging way than traditional textbooks. This project seeks to provide middle school educators with tools to incorporate science stories into classrooms without sacrificing important SOL topics.

Virginia Standards of Learning

The Standards of Learning (SOL) for Virginia Public Schools establish minimum expectations for what students should know and be able to do at the end of each grade or course in English, math, science, history and social science, and other subjects (Virginia Department of Education, 2020). The science SOL place emphasis on students developing and using communication, collaboration, critical thinking, and creative thinking skills and on understanding how civic responsibility plays a role in the applications of science (Virginia Department of Education, 2018). Similar goals have been set nationally by the Next Generation Science Standards (NGSS) and Ocean Literacy Principles, indicating that scientific literacy is essential for the success of students and graduates across the United States.

The Virginia SOL describe the state's expectations for both students' and teachers' achievements, though they can sometimes lead to a narrow field of focus and a tendency to omit topics that may not apply directly to the SOL or end-of-course exams (Grogan, 2001). In a study conducted to assess teachers' and principals' responses to the challenges in preparing high school students to pass Virginia SOL exams, Grogan (2001) found that teachers felt rushed to cover all of the topics required by the SOL. For example, teachers could not spend as much time on class discussion as they would have liked and felt that the end-of-course exams required rote memorization of content rather than deeper understanding. Because this study was conducted in nine teachers' classrooms and covered biology as well as English and algebra, and Virginia SOL are part of students' experience during their whole academic careers, it can be concluded that similar challenges are being faced in science classrooms at all different grade levels (Grogan, 2001). Despite these obstacles, the Virginia SOL and other similar educational frameworks are the standard for public schools in the state and beyond. It is the educators' and teachers' responsibility to find ways to engage their students while meeting these standards to ensure students' success once they leave the classroom.

Challenges for middle school science students

Science is a difficult subject for students to grasp, particularly for students entering secondary or middle school, where they are faced with new, linguistically complex text and a shift toward more abstract thinking (Crocetti & Barr, 2020). A study by Osborne et al. (2003) on the attitudes of students toward science showed that in most countries, students enter middle school with a positive attitude toward and interest in science, but that their experience in science classrooms erodes their interest in the subject. Indeed, middle school is a grade level where there is an observed decline in both motivations and attitudes toward science, affecting both scientific literacy in and beyond the classroom as well as career choice post-secondary school (Crocetti & Barr, 2020). Middle school students are learning an entirely new set of skills for observing and explaining the world, and many students are struggling to understand and apply science concepts in their daily lives. Difficult-to-handle texts and the sometimes discussion-limiting nature of SOL and other educational frameworks make it hard for students to be engaged with and motivated to learn science.

These challenges are even greater for English-learning (EL) students and students from lower socioeconomic backgrounds, whose linguistic and communication skills may not be as developed as those of their peers (Crocetti & Barr, 2020). EL students have a well-established first language other than English but can have varied levels of English language development, which can lead to difficulties grasping scientific content or communicating their findings (Lee et al., 2013). Typical science education for bilingual students is delivered monolingually in the school's majority language. Because of this, many bilingual students are unable to use all of their language skills in the classroom and their academic achievements are lower than their monolingual counterparts (Ünsal et al., 2018). In a world where it is becoming increasingly more common to be bilingual rather than monolingual, it is important to consider these students' experiences and provide them with tools they can use to succeed in the classroom and beyond.

Reading and science

Observation, investigation, and inquiry are just a small subset of the skills that science requires, but in order to communicate the conclusions and findings that are generated by these investigations, science also relies heavily on language—often written. Most likely, students will see dense science texts in the form of their required textbooks, dry and often boring or difficult avenues for students to engage with and understand new science topics. These texts are challenging for students because they cover content and vocabulary that are not relevant in their daily lives and use vocabulary and language that they have often never experienced before (Fang & Wei, 2010). If students do not find educational texts helpful or relevant, it is harder for them to practice and apply the skills that are taught within these texts.

For EL students, chances for success with these texts are further diminished. More so than their English-speaking peers, EL students find the content presented in science texts inaccessible and extremely difficult to deal with (Tretter et al., 2019). These students are not only grappling with the complex vocabulary and topics that the entire class is learning, but also contending with the fundamental language these texts are written in. Science classrooms are a place where students—regardless of their first language—shift from using everyday language to describe experiences and phenomena to using more formal scientific language gleaned from their lessons (Ünsal et al., 2018). Fang and Wei (2010) assert that for all students, reading and science are impossible to separate from one another and that basic literacy is the backbone of scientific literacy, however special attention must be paid to students grappling with language barriers on top of the existing challenges surrounding new science content.

Storytelling in the classroom

How can we get students to engage with scientific topics through reading, while keeping the SOL in mind and making the content more accessible and enjoyable? Storytelling has been woven into human life for generations as a tool used for sharing information and making connections with others. Research suggests that narratives are easier to understand and are more engaging than typical communication methods, making them an excellent tool for science communication with non-expert audiences (Dahlstrom, 2014). People also read narrative passages faster, comprehend them better, and remember the information presented within them better than with their expository counterparts such as textbooks (Glaser et al., 2009). Science narratives, then, can promote learning and also increase students' motivation to engage with new content by presenting the information in a format they can relate to.

Fang and Wei (2010) assert that one effective strategy to increase students' background knowledge about science is to expose them to science trade books—books intended for general readership rather than strictly educational texts—despite the fact that students in middle school and beyond actually engage very little with reading in classrooms. Their study compared classrooms where students were engaging with an inquiry-based science plus reading (ISR) curriculum, where students received once-a-week reading instruction in class and participated in an at-home science trade book reading program, with those who were engaging in only inquiry-based science curriculum (IS) to see how reading affected scientific literacy. Results showed that ISR students outperformed IS students in both fundamental and derived scientific literacy, which refers to skills that apply to all reading and the knowledge of science content, respectively. The at-home reading program was deemed helpful to the ISR students because the science trade books were more engaging, in-depth, and were written at more varied reading levels than the traditional science texts, while the in-class reading instruction provided them with awareness of and the ability to use reading skills that apply widely to science such as predicting, analyzing, and problem solving.

Strategies for storytelling in the science classroom are also applicable for EL students. Particularly for these students, learning science begins with discussing topics in everyday English before moving onto converting those same concepts into more advanced scientific language (Lee et al., 2013). This practice could be conducted using science stories, which already have the goal of presenting information in a simpler, more engaging way. Visually enriched resources are especially useful for EL students, bypassing language barriers or enriching text-based resources (Tretter et al., 2019). Narratives, when used in combination with supplementary language resources such as extended glossaries, can help EL students learn and be confident in English and the language of science. Two studies integrating English literacy and science show that EL students can improve both science and English vocabulary skills by combining them in one curriculum (Tretter et al., 2019). Science stories can employ all of these tactics to give EL students a better chance at having a positive experience in the classroom.

Classroom applications of science stories

Science stories have the potential to be incredibly useful in promoting student success with challenging content. By writing these stories and incorporating topics or vocabulary that are pertinent to the SOL framework, it is possible to present students with a different introduction to the content and teachers with more options to guide their students through state standards. However, integrating reading into secondary science classrooms is a difficult task in many regards.

In general, middle schools are larger and less personal than elementary schools, with teachers seeing more students and specializing in their subjects rather than employing a more cross-curricular approach (Fang & Wei, 2010). Particularly when considering teachers' existing struggles to cover all SOL materials during the school year and helping their students prepare for end-of-course exams, it is likely that reading could compete with these responsibilities or take up time that could be used for other instruction. Additionally, while many teachers have no qualms with integrating reading with science, they may not have the knowledge, resources, or support systems in place to make it possible (Fang and Wei 2010). This is why ensuring that the content of science stories reflects what must be covered in class and making these tools available to teachers is the first step. Giving teachers the opportunity to work with these materials in their classrooms and see the positive effects they can have on students opens the door for professional development and other training opportunities. Such opportunities would give teachers the confidence they need to practice their new skills with students.

One suggestion for integrating stories into science classrooms could be to start small: sending students home with short passages to read as homework or starting off their class with bell-ringer-style reading assignments. Seeking out and making trade books or short science stories available to students who may want them as supplementary materials is another strategy that may address the concern that reading might take away classroom time from important SOL instruction.

It is important to acknowledge the potential financial strain that providing extra materials may have on teachers. A solution for this financial pressure could involve school and local public libraries offering more targeted science trade books that teachers or individual students could check out. Additionally, schools where cross-curricular collaboration can occur or is encouraged would be an excellent place for science stories to help students thrive. Crocetti and Barr (2020) make the important connection that English teachers play fundamental roles in helping students access language and literacy across texts and disciplines, not just in the English classroom. It is clear that no matter how science stories are integrated into traditional science curricula, if these resources do not exist or are not made accessible to educators, science education and students' negative attitudes toward it will not change.

Conclusion

Because narratives and language can be useful tools for increasing understanding and improving attitudes toward science in middle school classrooms and among EL students, this project seeks to provide an access point for teachers to integrate them in their classrooms.

Sofia, Aman, and the Coldest Continent is a short story that follows two middle school students as they research their proposal to win a trip on a civilian cruise to Antarctica. The narrative sees Sofia and Aman research the area and come up with a project to pursue, as well as their experience on the cruise and the connections they keep up after their adventure is over. The hope is that students can see themselves reflected in the characters, while also gaining exposure to vocabulary and science topics they may not have encountered yet. Self-publishing of *Sofia, Aman, and the Coldest Continent* will be pursued post-graduation, as well as professional illustrative work, to make this science story available to anyone who may find it useful.

Two lesson plans with hands-on components were created to accompany this story, which draw directly from the topics discussed in *Sofia, Aman, and the Coldest Continent*. *The Case of the Missing Penguins!* introduces students to the declining population of Adelie penguins in the Western Antarctic Peninsula. Students are challenged to analyze and interpret real-world data before they are asked to formulate their own hypotheses. Data for this lesson plan were adapted from the Palmer Long-Term Ecological Research (PAL-LTER) study area in the Western Antarctic Peninsula. *Fishing for… Plankton?* tasks students with designing and testing tools they can use to collect Antarctic plankton, giving them a platform to become engineers and scientists. Real-world data adapted from PAL-LTER are also analyzed and interpreted in this lesson. These lessons are collaborative and give students the chance to investigate an ecosystem that is likely very far from their homes, while also targeting specific SOL, NGSS, and Ocean Literacy Principles that allow teachers to feel confident that their students are gaining practical knowledge. In both lessons, an extended glossary in Spanish and access to glossaries in other languages are provided, allowing EL students to engage with English-language content while providing them access to supplementary materials in their first language. Combined, these products offer teachers and students the chance to explore storytelling in their classrooms without sacrificing important SOL topics.

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Sofia, Aman, and the Coldest Continent

By Claudia Moncada

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Chapter 1

On a Wednesday in third period science class, I decided I would go to Antarctica.

Now, you might be wondering, “Sofia. You’re just a normal kid, how on Earth are you going to get to Antarctica?” And you would be right. Not a lot of people get to visit Antarctica, and for those that do, not many of them are middle schoolers.

But, I had a plan.

You see, my science teacher Mrs. Sanchez told us about a contest. Polarsci, a science travel company, was offering spots on an expedition to Antarctica. If we won, we’d have a seat on a gigantic ship that would take regular folks, just like you and me, to the South Pole where we would volunteer with the scientists who live and work there.

“Just like in the real science world, you have to come up with your own experiment,” Mrs. Sanchez said as she handed out the flyers she'd printed out for us. *Win a once-in-a-lifetime Antarctic experience!* it said in big, bold letters at the top. “The scientists will pick the top five proposals and those students will hitch a ride to Antarctica.”

Not a lot of kids in my class seemed super excited. I could hear them murmuring about how weird it would be to go on vacation and basically do homework in the cold, but it sounded awesome to me!

Honestly, it did sound like a lot of work, even for a once-in-a-lifetime experience. It couldn’t be so simple to come up with an experiment and carry it out, but the possibility of seeing penguins and icebergs with my own two eyes made me giddy.

The thing that really made the choice for me, though, was a small line near the bottom that said *Group proposals accepted.*

Almost as if we’d seen the text at the same time and our brains linked, I looked across the classroom and locked eyes with my best friend Aman, and that was it.

Oh yeah. We were doing this.

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“What do you even know about Antarctica?” asked my brother Manuel when I came home and showed the flyer to everyone in my family who would listen. He looked skeptical, and that irked me.

I thought about it for a second, turning the paper over in my hands. “Well... It's cold. And there's lots of ice and glaciers, obviously.” I paused. “There are definitely penguins, the jury is still out about polar bears though.”

“Polar bears are in the *North* Pole,” Manuel said. He rolled his eyes as if that was the most common knowledge in the world.

“That's what all the research I'm going to do is for!” I said, laughing despite feeling a little annoyed at my brother. “And anyway, Aman and I decided we'd do it together and there's more room for great ideas if we work as a team. He's bound to know stuff I don't.”

Aman and I had met in preschool, more of a thing of convenience for our moms than any real friendship at first. His mom always had to work right when school let out, and we lived right down the street from the Osmans, so it was pretty common for my mom to snag us both at the same time.

Even though at first we didn’t have a lot in common, we were inseparable before we knew it. He knew all about stuff I didn’t, and I knew all about stuff he didn’t, so we were constantly trying new things.

We came up with all of our best ideas when we were together, like that time we did a science fair project investigating the best dyes to make natural markers or when we convinced our parents to let us raise chickens when the price of eggs was crazy high.

The Antarctica contest would be no different, we were confident we could come up with something to really impress those scientists.

Chapter 2

“Let's just start with a basic search, yeah?” Aman was sitting at one of the computers in the school library, typing out *Antarctica* into the search bar and hitting Enter. This brought up hundreds of thousands of results, with frequently asked questions such as, “Can people live in Antarctica?” and “How to go to Antarctica?” and “Are there polar bears in Antarctica?”

I laughed, pointing at that last one. “I can tell you for sure there aren't,” I said. “Manuel was pretty stubborn about it when I was telling him about the penguins.” Aman let out a big breath, he knew exactly how my little brother could be about certain things. “Click on that first link, the one to the Wikipedia page.”

Aman did as I asked, and we started scrolling through the page. I read over his shoulder while he mouthed the words silently to himself.

Very quickly, we realized that settling on just one idea to follow for our project was going to be harder than we thought. The Wikipedia page just kept going. And going. And going! There was so much to learn about our coldest continent.

Here's two of the things we thought were the coolest during that first search.

- Antarctica is the southernmost *and* least-populated continent.

Talk about record-setting. We wondered if there were any year-round residents, or if scientists took turns visiting. We added that to our list of things to look into later.

- The food web down there is super short.

We'd learned about food webs in class before, so we thought we knew what to expect.

Plants usually make up the bottom level of the food web, making all of the energy through photosynthesis that then travels through the food web. These are called the primary producers.

Primary consumers come next, eating those primary producers and taking some of that energy for themselves. Then secondary consumers, and so on up the food web until you make it to the top predators, the ones without anything hunting them because they’re so big or powerful.

What we weren’t so sure about, though, was how big food webs usually are.

Some of them could be really huge! Aman described connections between members of food webs like big bowls of spaghetti with all the noodles mixed up. Those got really complicated and had so many layers and levels that it made our heads spin.

But in Antarctica it was weirdly simple, and plankton played a big role.

Plankton, we found, are tiny drifting organisms that can't swim against a current. There are two kinds: phytoplankton are the plant kind and zooplankton are the animal kind. Zooplankton can be microscopic or observable with the naked eye, and spend either part of or their whole life or as plankton.

But back to the food web thing.

Phytoplankton are at the base of the Antarctic food web, making their own energy through photosynthesis just like any other plant. Those get eaten by tiny zooplankton, which are then eaten by bigger zooplankton *and* much larger animals like fish, penguins, seals, and even whales.

"Where do we go from here?" Aman asked, scrolling and scrolling and scrolling through all the webpages that the internet spit back out at us. "I'm overwhelmed just thinking about how to start this project. The stakes are pretty high!"

"Well," I said, thinking hard, "experiments are supposed to help answer questions, right?" Aman nodded. "Let's see what kinds of questions need answering, then!"

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Just like picking a single path to follow to start this project, answering Antarctica's questions proved way harder than we thought. I guess that's why scientists spend years and years asking the same questions in different ways, picking away at the answers even if they don't feel like they're making any progress.

After a while, Aman wrote "Climate change" at the top of his notebook and underlined it twice.

"Mrs. Sanchez said a changing environment can affect basically everything, right?" he asked, jotting down a few notes as he spoke. "With ice and cold being such an important part of Antarctica, I bet warming would drive things bonkers crazy down there."

I nodded. "And our warming climate is a huge issue in the world right now. I bet they'd build a statue of us if it were two middle schoolers that solved climate change!" That made Aman laugh.

In class, we'd learned that climate change is a people problem, something that we humans caused and only we humans can fix. Mrs. Sanchez had used the word *anthropogenic* to wrap that all into one word. We thought about all the planes, trains, and cars that burn fossil fuels to carry people all over the world and the factories that made everything around us.

But, what about the bus we took to get to school or the planes my parents and I take to visit family in Colombia? The new clothes we bought after a growth spurt? Were the little things we were doing in our small town affecting life in Antarctica?

"We're thinking too big here," Aman said, his brow furrowed. "Rather than trying to solve climate change, let's go back to the warming part. You were thinking about the ice, let's follow that."

"Yeah!" I said, scooting my chair closer so I could reach the keyboard. "Let's see if there have been any effects of climate change on the poles so far." I typed that into the search bar and hit Enter, knowing that it was okay if we got results for the Arctic as well as for Antarctica. Any information would be helpful!

The results came back and, just like we thought, the ice at both poles was melting due to climate change and hotter temperatures. Sea ice, or large sheets of ice that float in the ocean, is particularly sensitive to warming and melts if the ocean and the air around it get too hot.

We clicked on a website called **polar-ice.org** and looked through the *About* section to see if it was reliable. Mrs. Sanchez had done a lesson on digital resources a while back and told us to always back our sources to make sure they were correct.

The website was put together by a team of scientists and educators who wanted to connect the world with its poles. They were clear about where they got all their information from, there were links to lessons based on real data, and they even had professional published research on display.

Deciding we'd landed on a reliable source, we forged ahead.

"Antarctica is experiencing the fastest warming of anywhere on Earth," Aman said slowly, reading from the screen. He looked over at me, eyes wide. "How is that possible?"

We read on to find out that the Western Antarctic Peninsula, the part of Antarctica closest to South America, has become the fastest winter-warming area on Earth. The surface air temperatures in the winter there have increased by 6°C, which is over five times faster than the global average! Most of the glaciers have been melting, or retreating, too—the website cited 87%.

“This is serious,” I muttered, tapping the end of my pencil on the table. “If Antarctica loses all its ice, that will affect the entire ecosystem!”

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Armed with our newly acquired knowledge about Antarctica, Aman and I set out to figure out just what in the world our experiment would be.

I was really into the whales, just like almost everyone in our class that I asked. How could I not be? They’re so huge and beautiful, and I really loved how they used songs to talk to one another. The weirdest fact was that even as the biggest animals, they somehow ate zooplankton called krill, some of the smallest animals!

Aman wasn’t so on board.

“Do you really think they’ll let us work with whales?” he asked, throwing up his hands in annoyance. This was the third time I’d brought up the subject during our lunchtime. “I was watching videos on how they do some of this science, Sofia, and I don’t think that ‘Let a seventh grader shoot a harpoon’ is on the scientists’ to-do list.”

I almost spit out my sandwich. “A harpoon?” I cried. “I thought they were studying these whales, not hunting them!”

“They’re not, like, shooting arrows at them,” Aman clarified. “That’s just the safest way to attach whatever tags or trackers scientists need for their studies.” I guess I had never thought about it that way, but it did make sense. “Although, there are still indigenous populations in other places that hunt whales since it’s a special cultural thing for them.”

“Really?” I was surprised, I thought that wasn’t allowed anymore.

Aman smiled through a bite of his lunch. “Yup. They’ve been given special permission to hunt certain whales because it’s an important part of their history. I looked it up, it’s called aboriginal or indigenous whaling. Here in the U.S., it’s mostly a practice in Alaska.”

“Well, what do you want to study, then?” I popped a chip in my mouth and waited for his answer, watching the way Aman’s eyebrows scrunched as he thought.

“I like the little guys,” he said softly. “Plankton are the base of everything that goes on in Antarctica—the world, really. It would be really sad if something happened, and they couldn’t survive.” As I watched him, he looked really beat up just thinking about plankton disappearing.

I thought for a second about the research we had done the day before. “Remember the temperature differences along the Western Antarctic Peninsula?”

We’d learned that there’s a gradient of temperature changes there, and that scientists can use that gradient to see how increased warming in the future might change the landscape of Antarctica without having to actually wait all that time for it to happen. “How about we look at how warming along that gradient affects plankton?”

Aman’s eyes lit up; I knew he’d be interested. “Maybe we’ll even figure out something to help combat climate change!” he said, his voice hopeful even though he’d laughed at the idea before.

Maybe we would, maybe we wouldn’t. That was part of the fun, not really knowing what we might find.

Chapter 3

"We want to study how warming affects the plankton in Antarctica," I finished. We had just explained our whole thought process for the contest to Mrs. Sanchez. Aman and I stood on the other side of her desk, waiting for her to tell us how great of an idea this was.

Only, she didn't immediately gush over it.

"I think that's an interesting idea," she started, clasping her hands on the top of her desk, "but don't you think that's a little broad?" The smile on Aman's face fell.

Broad? We'd picked one part of the food web to study, how was our idea broad?

Mrs. Sanchez seemed to have read my mind because she kept going. "Why don't you pick just one or two plankton to study?" she offered. I glanced back at Aman; Mrs. Sanchez was making a brilliant point. We'd just picked plankton and run with it, but even beyond phytoplankton and zooplankton, there were so many possibilities to follow.

"Antarctic krill are zooplankton, right?" Aman asked. I nodded, unsure of where his thought process was going. "Well, Sofia was really interested in whales, and whales eat krill. So, why not focus on them?"

What a genius! Not only were krill and whales directly related in the food web and ecosystem, but they also both fell into categories of things we were both interested in. It was the perfect compromise.

"Plus," he continued, "krill are zooplankton that need ice and cold waters to survive, so they would be a perfect organism to study along the temperature gradient there." I smiled wide and nodded my head enthusiastically. I was loving the direction our project was going in.

"That's a great idea," Mrs. Sanchez said, smiling at both of us. "I think you might have a winning idea here. I can't wait to read through your full proposal."

From there, we decided it was time to actually write the proposal. Well, at least jot down all the things we wanted to do, and then later we'd put it into the formatting that the scientists wanted. They had said it didn't need to be perfect, our lead scientist would help flesh out the specifics.

"We'll have to use a plankton net," I said, thinking about the tools scientists use to collect plankton from the water. It's like a butterfly net—all mesh—that gets towed through the water behind the boat.

All the plankton that are small enough to go through the mesh get left in the water, free to drift another day. Those that are big enough to be trapped by the mesh get swept into the end of the net, called the cod end. There's a jar on the cod end that concentrates the plankton in one place, and that's the sample!

"Do you think we should still try to connect it to whales?" Aman asked. I was so happy he'd come around to the idea but thinking back to Mrs. Sanchez's advice to refine our project, I wasn't so sure we should take it that far.

I thought for a moment. "How about we leave that for later? There has to be some data we can compare our own to, either some studies on whales that have happened in the past or maybe one will happen on this expedition. Someone might be willing to share their data."

The polar-ice website we'd visited linked to a 30-year-long study happening on the Western Antarctic Peninsula, called long-term ecological research. There were tons of data that were free to use and examine, and it was just a matter of knowing what we were looking for.

If we won the contest, this would be at least a year-long project for the scientists that took it on. No doubt they would be interested in combining or comparing our data with an existing set!

"And we're of course sampling at different stops along the temperature gradient," Aman continued. He pulled out the map of the Western Antarctic Peninsula that he'd printed and looked at it. "I don't know where would be good. Maybe the real scientists might know?"

I gasped, pretending to be shocked. "Aman! We *are* real scientists. The ones you're talking about just have more experience."

We spent a few more days polishing up the idea and typing it up properly. I even had my mom and dad read through it to be sure there weren't any mistakes or typos before we sent it in.

After that, it was all in the hands of the science gods.

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Every day after school Aman and I would check the mailbox, hoping, *praying* that there was a big fat envelope from Antarctica with our names on it.

It was torture, waiting on it. "The best rewards come to those who wait," my mom kept saying. She would laugh every time I came inside with my shoulders sagging, but I knew she was getting antsy too.

And then, one blazing hot afternoon, it arrived.

“I can’t open it,” I said, covering my eyes with one hand and thrusting the envelope into Aman’s lap with the other. We were sitting on the floor in the kitchen, escaping the late summer heat on the cool white tiles.

“What makes you think I can?” Aman retorted. He tossed the envelope onto the floor like it had burned him. “It was your idea to enter this contest, you do it.”

Before I could even reach for it, Manuel came through the kitchen like a high-speed jet and snatched up the envelope. “I’ve got it!” he shouted, running around the dinner table waving it in the air. Manuel ripped it open, and any protests I had died on my lips. I watched him read it to himself, carefully sounding out the words with his lips.

“Well?” I cried, impatient. Aman rocked back and forth on his heels, brimming with excitement.

Manuel looked up at us and cracked a grin. “Bring me back a souvenir,” was all he said.

Aman and I shrieked with joy—we were going to Antarctica!

Chapter 4

We spent the next few months planning, packing, and preparing. As it turns out, the work involved in trips like this one starts months in advance!

The best part was getting to meet our Primary Investigator, or PI, Dr. Nancy Fleming. She'd been working in Antarctica for years on lots of different projects, but her main studies revolved around predator-prey interactions and the role of zooplankton in the ecosystem. Aman and I were able to get on a video chat with her after school soon after we found out we'd been selected as one of the civilian projects.

"I'm looking forward to meeting you two in person," she said, smiling at us from her little box on the screen. Behind her, Aman and I could see pictures of penguins and icebergs and beautiful sunsets.

"We'll take care of all the scientific supplies on our end," she continued, "so don't worry about a thing. Your proposal was very detailed, and we've been able to fill in a few of the gaps to be sure we've got everything. Our crate is starting to come together as we speak, actually! It'll be sent to the ship soon."

"You mean we don't take it all with us when we get onboard?" Aman asked, saying exactly what I had been thinking.

Dr. Fleming laughed. "Oh, no! Big cruises like this require a lot of different tools and equipment. Everything you need gets organized in a big inventory list and it all gets ordered, organized, and packed away in a big crate. The crate makes its way onboard the vessel before most everyone else so it's all ready when we arrive. Anything smaller or important you can bring with you!" She paused for a moment, a weird look on her face. "That is, if all goes well."

"What do you mean?" That sounded way too ominous not to ask about it!

"Well, sometimes folks' crates don't actually make it onboard, which makes it a tad difficult to conduct your experiments!" Dr. Fleming replied. A sense of dread struck my core as I imagined showing up to the boat and not having any of the things we needed. I guess it showed on my face, because Dr. Fleming assured us that it didn't happen often. Even if it did, she said we'd be able to help out with someone else's projects or make do with the things that did arrive.

"But don't worry," she said. "We'll do our best to make sure we've got it all."

We met up virtually a few more times before we were ready to go, mainly to make sure all the things we wanted to do were accounted for and so she could share updates from her end. All in all, by the time December break rolled around, Aman and I were ready to go on our big adventure.

The first step was getting there.

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“Are you sure you packed everything?” my mom asked for like the hundredth time. We’d been packing and unpacking for a week, trying to get everything we could possibly need into one carry-on and one backpack each.

If we were going anywhere else it wouldn’t have been such a big deal. But, when you’re packing a gigantic winter coat to wear in Antarctica, suddenly you have a lot less room in your suitcase!

I sighed, eyeing my suitcase from across the room. “I promise, mom.” Then, I narrowed my eyes at her, mischievously. “And what about *you?* You can be pretty forgetful.”

“Hija, please. When you realize you forgot to pack something and freak out, you’ll be glad to know I already packed it for you,” she said, smiling despite her comment. “Just call me super mom!”

“I’m just checking!” I said, throwing my hands in the air innocently. “Aman should be here any minute now, he said his mom would drop him off at—”

Our brain-link strong as ever, Aman cut me off by ringing the doorbell before I could finish my sentence.

“We’re really doing this,” he whispered gleefully once he was through the door, bags in hand. I nodded my head, grinning wide.

It only took about three suitcase checks—and twenty minutes of my mom’s nervous interrogation about what we’d do if we got separated in the airport—for us to finally be on our way. She said it was different this time than in the past since Aman’s mom was trusting us to keep him safe.

Manuel and my dad stood in the driveway to see us off, waving wildly and reminding us to take plenty of pictures.

Our first leg of the journey was to fly to Punta Arenas, Chile, the southernmost region of South America and the gateway to Antarctica.

I'd been to Colombia before, where most of my family lives, but I'd never been any farther south than that. This was Aman's first time out of the country, too, so this was kind of a big deal!

Thankfully, the most stressful part of the journey was my mom misplacing her reading glasses in the terminal. "Sofia, have you seen my glasses?" she asked, her voice low as she no doubt imagined the rest of the trip filled with headaches and blurry text.

It took me a second to tell if she was being serious or not, because her glasses were actually sitting right on top of her head like they usually are!

A few planes, sprints across airport terminals, and countries later, we checked into our hotel for the night in Punta Arenas. We were set to board the ship that would take us to Antarctica the next day, along with the other contest winners.

Since there were people coming from all over the U.S., PolarSci had arranged for everyone to stay in the same hotel so we could all board together.

While my mom went to sleep early and encouraged us to do the same, Aman and I stayed up late, brimming with excitement and wondering what the journey ahead would hold.

***

"Good morning everyone! My name is Thomas, and it's time for your pre-boarding orientation. This will get you up to speed before you make your way to the *Albatross*."

It was the morning and soon we'd be boarding the ship, a gigantic white and blue vessel called the *Albatross*, so they had rounded up all the contest winners in one of the hotel's conference rooms for a talk about safety and expectations onboard the ship.

My mom had gone to sit with the other chaperones, and I looked around at the other groups. Aside from one other small group of middle schoolers, Aman and I were the youngest kids there. Everyone else seemed to be high school age.

It seemed everyone submitted a group project, which meant the ship should be pretty lively! We were looking forward to meeting everyone and hearing about their projects, and we'd finally get the chance soon.

At the orientation, Thomas ran us through the safety packet and itinerary.

We'd be at sea for about four days, during which we'd cross the infamous Drake Passage—the roughest stretch of water in the world—just thinking about it made me queasy. Once we arrived in Antarctica, we'd be there for ten days. Aside from the planned hours for all of our projects, there were fun excursions on the itinerary like whale watching and walking on the continent with penguins.

Aman nudged me when they mentioned the whales, making an aiming motion with his fingers and reminding me of our harpoon conversation. I rolled my eyes and kicked him in the shin to get him to focus on Thomas again. Out of the corner of my vision I saw him stick his tongue out at me.

The trip back to Chile would take about four more days, but there would be a few talks by the scientists and plenty of pictures to sort through to distract us from the fact that the adventure was ending.

***

"It's huge!" Aman cried, staring up at the gigantic vessel that was somehow *floating* off in the distance. The *Albatross* was an impressive ship, shining in the early morning sun.

With our bags rolling behind us and the rest of the group just a ways ahead, Aman, my mom, and I all crossed the gangplank that led onboard the ship. Just like that, our Antarctic adventure was really underway.

A crewmember was standing at the entrance, ready to show us to our rooms, which they called cabins, where we could unpack and settle in before the captain raised the anchors and set sail. We were led down a few sets of stairs and through several low hallways before we made it to our cabin.

The bunk bed had a larger mattress on the bottom, which my mom and I would be sharing, with a smaller one on top for Aman. A dresser took up most of the wall across from the beds and there was a little desk in the middle, right under a small circular window. It was small, but cozy, and pretty much exactly what I was expecting.

"Home sweet home," I said, flopping onto the mattress. Aman scurried up the ladder to his own bed and let out a long sigh, settling in.

My mom laughed. "Don't get too comfortable! Don't you want to get up to the deck to watch us set off?" she asked. Aman and I shot up from where we lay, I couldn't believe I'd almost forgotten!

We ran off to the top deck, retracing our steps from when we'd come to the room.

In the time it took for everyone to make it onboard and for the ship to raise its anchor to set off, Aman and I were able to make friends with the other middle school group and one of the high school groups.

We didn't get to talking too much about our projects, that would come later. Instead, we talked about our different journeys and how excited we were to be here. Between our three groups, we all were from a different corner of the U.S.

Dr. Fleming joined us for a little while on deck, and it was so nice to finally meet her in person rather than on a screen. "We're going to do some really fun science," she said, smiling.

She assured us that everything had made it onboard, and I felt like I could really breathe knowing that everything was going according to plan—so far.

Once the gigantic *Albatross* began moving, we all stood side by side as we watched the land retreat behind us. Smaller and smaller it got until it was just a speck in the distance, and then we were finally, truly on our way to Antarctica.

***

When they told us the Drake Passage was going to be rough, they were *not* kidding.

The ship creaked and lurched, strong winds and even stronger waves battering its hull. My mom and I had to lay down pretty much the entire time and were reliant on anti-nausea medication, sleep, and a nearby trash can for when the medicine wore off.

What made it worse was that Aman was totally unbothered! He was able to walk around the ship and talk to the crew and other passengers while I was feeling sick out of my mind.

Thankfully, in the moments when I was feeling a little better, he would fill me in on what he'd seen and heard.

For example, on the morning of the first day he learned why this leg of the journey was so rough.

Since there's no land in the Drake Passage for currents to run into, water can flow just about as fast as it wants. This means choppy waters and a rough trip for any vessels crossing this area.

He also learned that somewhere along the middle of the Passage, cold water flowing northward meets with warm water to create the Antarctic Convergence. This creates an upwelling zone, where deep ocean water that's high in nutrients rises to the surface and causes phytoplankton 'blooms.' Krill, especially, love this area because phytoplankton are their main food source.

Aman told us all about the Cape petrels and real albatrosses that flew alongside our *Albatross,* regal seabirds that are commonly seen in this region. He said one of the contest groups was doing a seabird census as part of their project and that they'd invited him to sit with them to count.

Two days out of our four-day journey went by like this, me sprawled on the bed with my mom and Aman bringing us news of the outside world. By the time we were out of that part of the journey, and I felt like I could stomach food again, we were only about a day from reaching our destination.

Chapter 5

I actually didn't realize the moment we had made it to Antarctica.

After four days of rocking and swaying, when I woke up one morning it felt like we had stopped moving. We weren't really stopped but compared to the jostling that had been the last few days, I was feeling downright stable. The captain must have dropped the anchor while we slept.

"Aman!" I hissed, nudging his shoulder. I had squeezed past my mom and was standing on the ladder to his bunk, desperately trying to get him to wake up. "We're here!"

At that, Aman's eyes shot open. He jumped down from his bunk and we hurried to pull on our sweaters and cold-weather pants over our pajamas. We were too excited. We couldn't wait another second to see the coldest continent in the world.

Sure enough, once we ran up to the deck, there it was. Antarctica.

There were other groups of people on deck marveling at the sight, too. A few of the contest groups had beat us there and there were some crew members just going about their mornings, but in that moment it could've just been me, Aman, and the ice.

"There it is," I said, my voice hardly above a whisper. Beside me, Aman shivered. Whether he was shaking from excitement or just plain cold, I'd never know.

The morning was bright, the sky was the bluest I'd ever seen, and the wind stung my cheeks a little from just how cold it was, even though it was summer. But it could've been raining or snowing and I wouldn't have cared, because we were finally here.

PolarSci had planned an outing to the continent for the contest winners before we dove into the data collection, so we hurried to have breakfast and get properly dressed.

The inflatable boats they had ready for the five groups were called Zodiacs. After we were all on our Zodiacs, we made the short trip from the *Albatross* to land.

That first step onto the ice was a little shaky, but it was magic. How many people get to say they got to stand on the continent of Antarctica? And how many get to say they did it when they were twelve?

We were a little wet and more than a little cold from the trip over, but Aman and I were about as happy as could be. We did our secret handshake in the snow and ice, laughing all the while.

The PolarSci folks told us we had some time on the ice to explore and take in the moment, but that we shouldn't go too far. Remembering the safety training about leaving at least 50 feet of distance between us and wildlife, Aman and I took off.

The other group of middle schoolers joined us, and the five of us walked in a big circle around the area that the Zodiacs had dropped us off at. We pointed to penguins off in the distance and glaciers bigger than buildings.

In just a few minutes on the continent, we knew our ten days on this expedition would fly by in an instant.

***

Pretty soon after arrival, it was all-hands-on-deck to get the science started. Or, in the case of some of the projects, keep the science going.

"We'll be sampling along a grid that lots of studies in the past have used," Dr. Fleming said. She showed us a map of the Western Antarctic Peninsula like the one Aman had printed, but this one had a grid drawn on top. "This will make sure that our data are consistent with past plankton studies in this region and that we get a thorough coverage of the temperature gradient."

Since our trip was so short, Dr. Fleming assured us that she and her team would continue sampling after we left so that there weren't any holes in the data. We would still have a chance to sample at different locations along the gradient, though, and Aman and I were thankful for that.

"Shall we do a test run of the plankton tow so you all can get a feel for the equipment?" Aman nodded his head vigorously; he'd been waiting for this moment for a long time now.

The net that Dr. Fleming had set up for our sampling was way bigger than I could have imagined! All the ones we had seen online and that she had shown us from her lab were big, sure, but they maxed out at about 3 feet in diameter at the opening and ten long. The one Dr. Fleming motioned to now was attached to a huge crane arm and the opening was as big as a person!

"This is a 2x2 meter net," Dr. Fleming explained. "The mesh size, 700 microns, was picked specifically for your project. We should catch plenty of krill if they're out there!"

“Microns?” Aman asked. We both looked at the net as it swayed in the wind. We had never heard of that unit before.

“Microns, or micrometers, are one-thousandth of a millimeter (or one-millionth of a meter).” Such a small unit was really hard to imagine! “Different mesh sizes are needed to sample for different plankton! 700 microns has been used in other experiments when sampling for krill.”

After explaining this, Dr. Fleming walked us through the process for a plankton tow.

The captain would steer the boat to the location that everyone on the ship’s sampling would take place—it was all mostly coordinated so multiple scientists could do work at once. Operators would help us lower the net into the water, letting out enough rope so that the net would reach our maximum depth for the tow.

“What we’ll be doing is called an oblique tow. This means the net will descend in the water column at an angle and then they’ll pull it back up,” Dr. Fleming explained. “Once the net comes back on board, we’ll empty the cod end and separate the samples for counting later!”

“So, a V-shaped tow?” Aman asked. “Why this way?”

“This way we can catch krill that are at any depth in the water column. We would need much more sophisticated equipment to sample at multiple different depths to make sure we aren’t missing any krill.”

Aman nodded, looking in awe at the net we had. I had no doubt he was wondering what a more sophisticated one would look like, given we weren’t even fully expecting the size of this one. Dr. Fleming continued to explain.

“The sophisticated net that some projects use is called a Multiple Opening/Closing Net and Environmental Sensing System, or MOCNESS for short,” she said.

MOCNESS? Like the Loch Ness monster? I giggled a little at the thought of Nessie swimming around the icy waters.

“It has between 6 and 20 nets that can be opened and closed at discrete depths, so all the samples contain only things found at one depth in the water column. It also has other tools to collect data on the environment at the time of the tow.”

Scientists really seemed to have a tool for everything. Dr. Fleming said that when they didn’t have the right tool, they’d just make something up and see if it worked! Engineering and being a scientist apparently went hand in hand.

Once we finished talking about our plans, we got the go-ahead to conduct our first tow. Since we weren't yet in anyone's sampling locations, this really was just a dry run.

The net was lowered into the water and the ship moved forward slowly. We towed for a few minutes, and after the net was hauled back in by the crew members in charge, the cod end was emptied into a big bucket.

Out poured water with a surprising number of things in it! Most of the plankton in the net were probably too small to see just by looking at the bucket, but there were some gelatinous zooplankton called salps and even one stray jellyfish.

What was most exciting, though, was that we actually caught our first krill! There they were, scuttling their little legs in the bucket of water!

"Look!" Aman cried, pointing at the tiny crustaceans. "This has to be a good sign!"

***

The actual rest of the trip went by in a whirlwind.

We were able to do a few tows in each section of the grid that we had planned on reaching during my and Aman's time onboard the *Albatross.* Thankfully the weather cooperated with us during those few days. We'd heard horror stories from some of the crew about terrible weather sidelining a lot of people's plans.

Dr. Fleming was pleased with the number of krill we were seeing just by emptying out the cod end and storing samples for counting later—we'd have plenty of good data when we were done.

We even started seeing more krill the closer we got to the colder parts of the Western Antarctic Peninsula, just like Aman thought. What was even more interesting was what we saw in the warmer places instead of krill: tons of those jelly, barrel-shaped salps! Dr. Fleming said that there were actually some scientists just starting to investigate that!

Even though we didn't get to participate in the whale tagging that was going on, we were still able to watch with binoculars from the top deck. Next to the backs of these whales, the scientists looked teeny tiny, and that was just one small part of the whales!

It was crazy to think that something so big could survive off of the tiny krill we were collecting.

From the ship we could see their baleen plates, giant broom-like bristles that some whales use to filter zooplankton like krill out of the water. With each giant mouthful, the whales we observed gulped thousands of zooplankton!

When we weren't whale watching or helping with plankton tows, we were able to make a few excursions back to the continent. Aman and I took lots of pictures posing with penguins in the background.

Spirits were high for the entire time we were in the Western Antarctic Peninsula and every contest group was able to gather some type of data even if they ran into a few hiccups along the way.

There was one group that was hoping to find sea ice in a place where there turned out not to be very much left. They had to change their plans a little, but science is all about asking questions and not being afraid to be wrong about the answers.

Before we knew it, ten days had come and gone, and it was time to start the journey back home. I was sad to go, even more so once I remembered I'd have to endure the Drake Passage again on the way home.

Chapter 6

In the months following our return from Antarctica, Aman and I were still busy with all the samples we had collected there. Dr. Fleming had stayed behind at a field station and kept in regular contact with us, updating us on any progress with our project.

Like Aman thought, our counts showed that krill populations were decreasing as we moved toward the hotter parts of the temperature gradient. The warmer the water, the less krill we found.

I was still curious about how it might impact whales, so Dr. Fleming offered to reach out to some whale scientists so that I could ask them my questions directly. I couldn't wait to see what connections I could make between our data and those collected by other real scientists.

On top of that, we found out that the data we collected about our krill might be useful in a study on penguins that had been conducted for decades.

Populations of Adélie penguins, a species found in Antarctica that thrive on the sea ice, had declined 90% since the 1970s. These penguins relied on sea ice as an important habitat and krill as a major food source, and scientists were investigating how climate change might affect these two things and how, in turn, that could be affecting the penguins.

There were lots of other data included in the study, but what we had seen and collected during our short time in Antarctica might still prove useful to other scientists!

One thing is for sure though, and it's that more investigations are if anyone wants to find the answers. It was a little crazy to think that the work two middle schoolers had helped with could possibly hold the answer to such important questions!

Mrs. Sanchez had asked if we could do a presentation for our class on what we got up to on the coldest continent on Earth. We got the idea to invite Dr. Fleming to do a video chat with the whole class too.

Aman and I felt so cool standing up there showing pictures from our expedition, the whole class kept oo-ing and ahh-ing with each new snap.

I could tell some of our classmates were a little jealous, even though they had thought the contest would be too much work or not enough fun. I hoped that if something like this ever came around again, that they'd consider submitting their own ideas! I wasn't sure about the thought of having more competition for another one of these contests, though!

It was kind of funny, how this entire expedition changed the way I saw science.

Sure, science had always been an alright subject in school, and I thought it was cool from time to time. But seeing how quickly the world is changing and how important science and scientists are to investigating these changes really made me want to learn all I could.

Lots of kids say they want to be marine scientists when they're little, and maybe I might change my mind about what I wanted to be when I grew up as time went on, but in that moment I really meant it.

That trip to Antarctica taught me that I could be a real scientist and that I was capable of making real change in the world.

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.

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

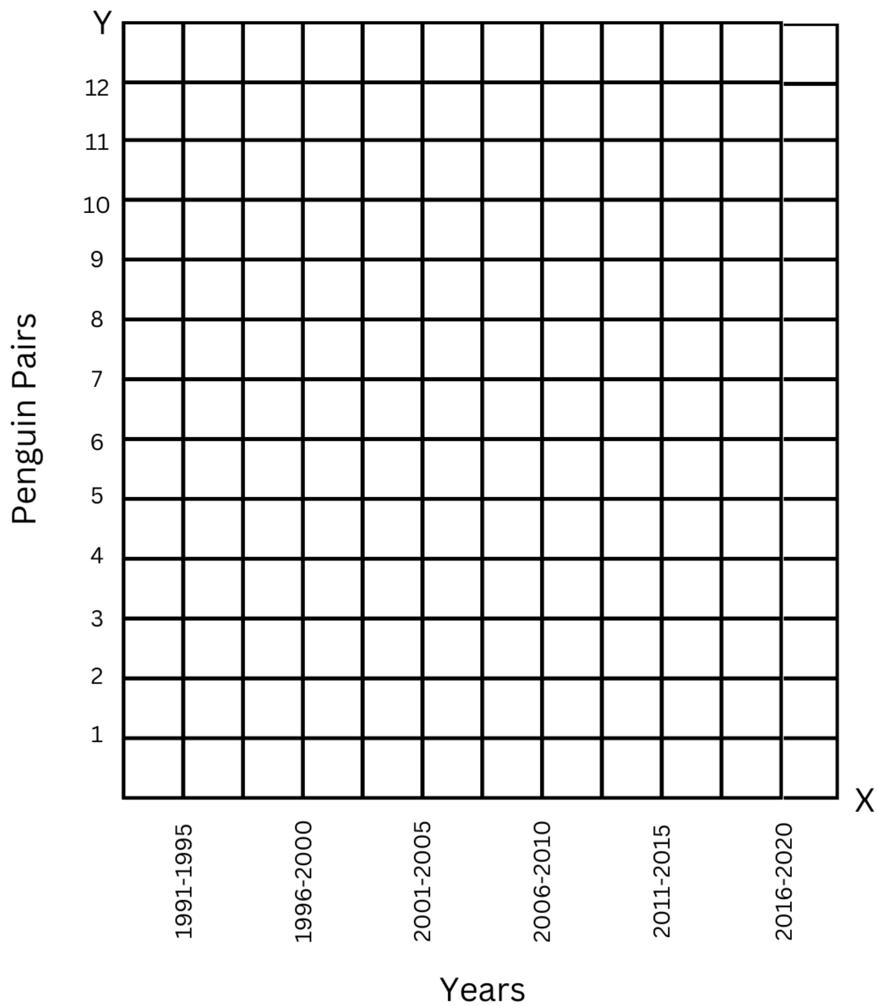
   Is there a big difference between these numbers?

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: ____________

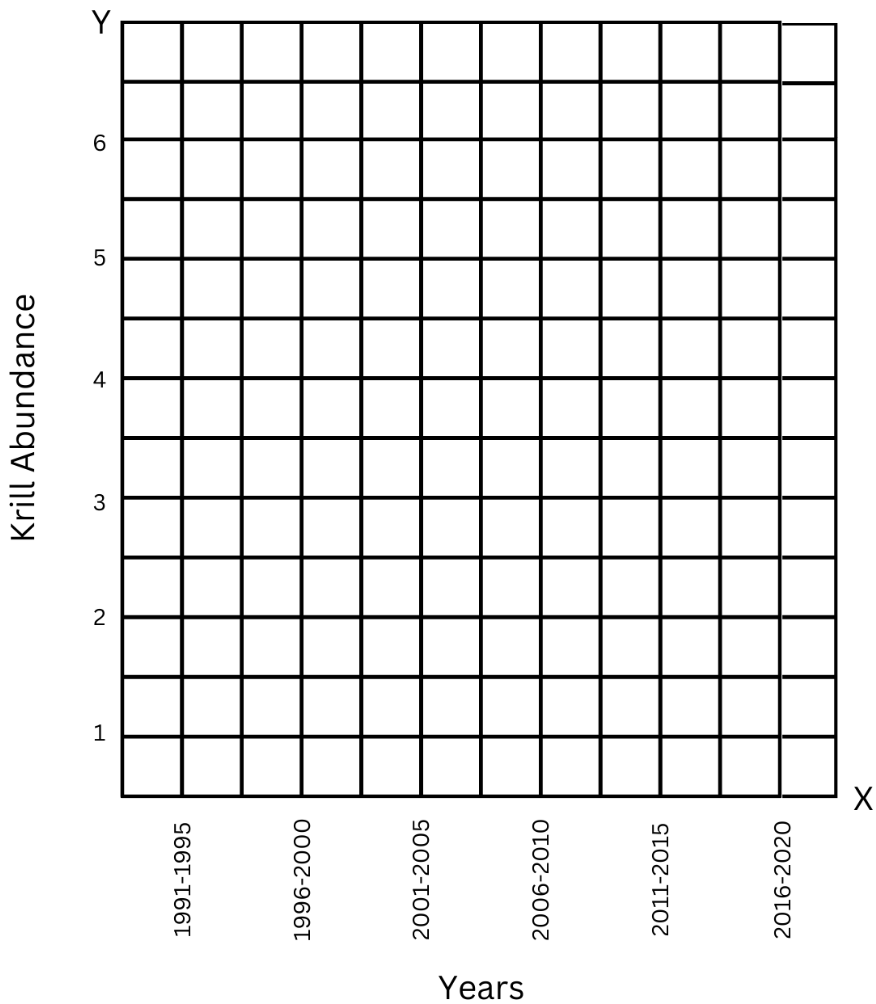
2. Analyze the data you have collected. What years had the highest krill abundance? The lowest?

   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.

Appendix A: Instructor Key

Part 1

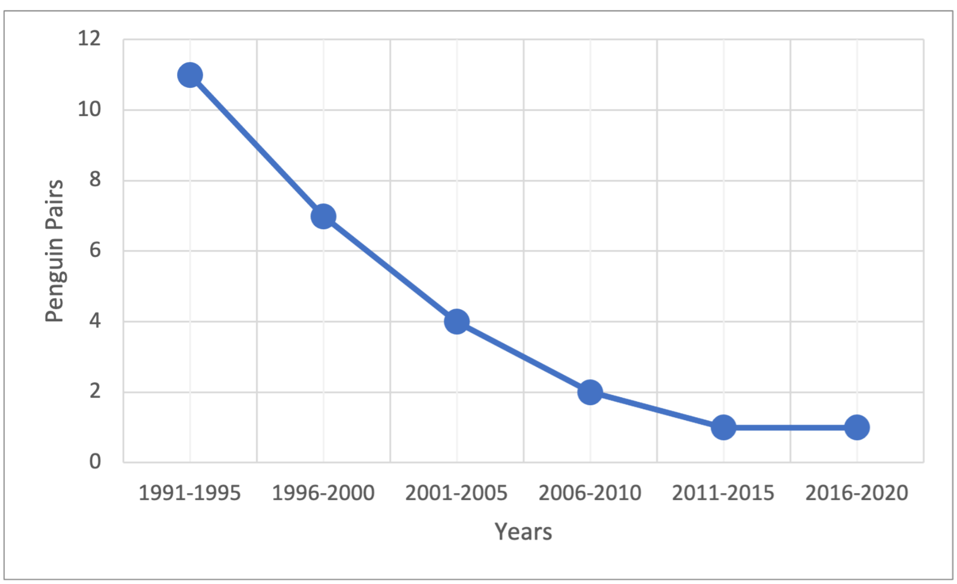
Table of Adélie penguin pairs over time.

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

Total number of penguin pairs: 260 Total number of individual penguins: 520

1. Years with highest penguin pairs: 1991-1995
   Years with lowest penguin pairs: 2011-2015 and 2016-2020

2. Independent variable: Time or years
   Depended variable: Penguin pairs



Graph of Adélie penguin pairs over time.

3. Based on the data collected, the number of penguin pairs has decreased over time. This indicates a negative trend.

Part 2

1. If there are less krill available, Adélie penguins may not be getting enough to eat. If the penguins are not eating enough, their populations will likely start to decline.

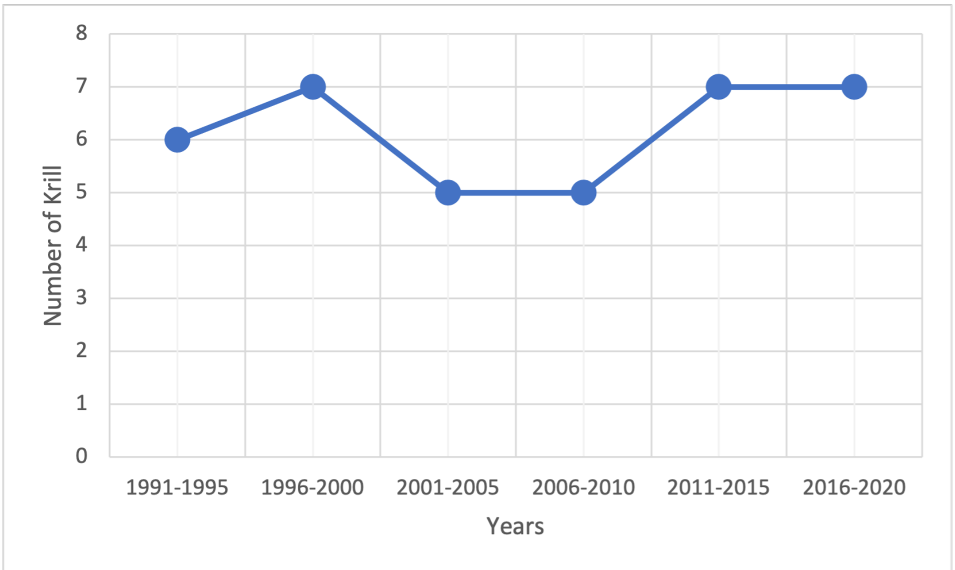
Table of average krill abundance inside Adélie penguin stomachs over time.

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

Total krill abundance: 370

2. Years with highest krill abundance: 1996-2000, 2011-2015, and 2016-2020
   Years with lowest krill abundance: 2001-2005 and 2006-2010

3. Independent variable: Time or years
   Dependent variable: Krill abundance



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

4. There does not seem to be a trend in the krill data. Krill abundance remains fairly stable with a slight decrease in the middle years.

5. Since Adélie penguins need sea ice to survive, changes in sea ice could affect their populations. Less sea ice could lead to decreased Adélie penguin populations, more sea ice could lead to increased Adélie penguin populations.

6. Based on the graph and the trendline, there seems to be a negative trend in the sea ice data. Over time, sea ice coverage seems to be decreasing.

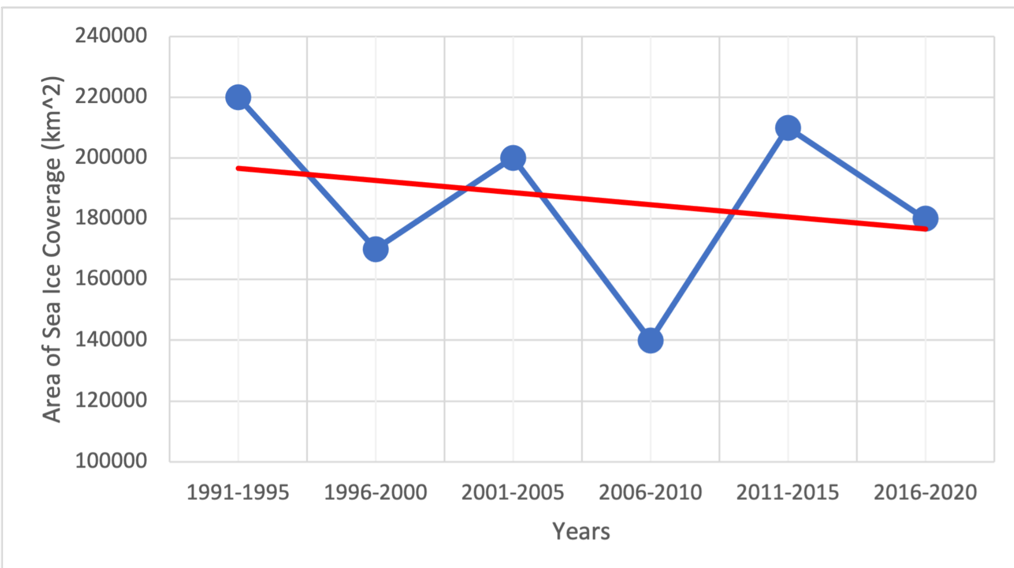
7. Because there is a negative trend in the sea ice coverage data and no trend in the krill data, decreases in sea ice coverage may be the reason for decreasing Adélie penguin populations.

Part 3

Questions 1 and 2 are subjective and there can be many answers. As long as students are able to defend and explain their hypotheses and demonstrate understanding of the lesson in their suggestions for question 2, they should receive credit.

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.

Title: Fishing for… Plankton?

Focus: Design and engineer tools for plankton collection; graph and analyze data pertaining to plankton in the Western Antarctic Peninsula.

Grade Level: 7th Grade Life Science

VA Science Standards

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

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

- Ask questions and form hypotheses.
- Practice the engineering design process.
- Analyze and make predictions about potential drivers for the trends seen in representative datasets of Antarctic plankton.

Total Length of Time Required

Initial preparation of materials: 30-45 minutes. Each subsequent setup should go much faster with pre-prepared materials.

Total time for lesson: 45-60 minutes, or one full class period. Class discussion or additional design time may lengthen this estimate. Bonus activity: 30-45 minutes outside, 30 minutes classroom time.

Vocabulary

- Climate Change: Long-term change in the Earth's average temperature and weather patterns, either natural or caused by humans
- Cod end: The bottom of a plankton net where a jar or bottle is attached to collect the sample
- 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
- Holoplankton: An organism that spends its entire life in the planktonic stage
- Meroplankton: An organism that only spends a portion of its life, generally larval or early stages, in the planktonic stage
- Phytoplankton: Microscopic, aquatic plants that drift with (cannot easily swim against) the currents
- Plankton: Aquatic microorganisms that drift with (cannot easily swim against) the currents
- Plankton net: Mesh net of various sizes that is towed through the water to collect plankton
- Primary production: Energy produced through photosynthesis
- Population: A group of individuals of the same species living in one location
- Spatial gradient: Changes or differences observed through space
- Zooplankton: Microscopic, aquatic animals that drift with (cannot easily swim against) the currents

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

Background Information

This engineering activity takes place in the Western Antarctic Peninsula, a region in Antarctica that is known for having abundant life—from tiny plankton to gigantic whales, and everything in between. Despite this, the region is still very vulnerable to the warming effects of climate change, which can alter physical aspects by melting ice and altering currents, and biological aspects as well.

The Palmer Long Term Ecological Research Station (PAL-LTER) is a research site in the Western Antarctic Peninsula where scientists have been investigating the ecology of the region for 30 years to better understand how the ecosystem and its processes are changing over time. 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. Scientists can use this gradient to study how Antarctica might look as climate warms by using the warmer areas to represent the region under future warming conditions and comparing that to the current, cooler conditions in other areas. This is called a space for time substitute, and it allows scientists to study present and future conditions at the same time.

One thing that is studied in-depth by Palmer scientists are plankton. Plankton are small, typically microscopic organisms that drift in the ocean and are unable to swim against the current. Actually, that is where they get their name: planktos is the Greek word for drifter or wanderer. There are two types of plankton: phytoplankton are microscopic plants and zooplankton are tiny animals. Phytoplankton are responsible for much of the primary production in the Western Antarctic Peninsula, which means that when they conduct photosynthesis to turn carbon dioxide into energy and oxygen, they are creating energy that helps to sustain the entire ecosystem in the area. Zooplankton are a very important food source in Antarctica as well, feeding organisms like fish, penguins, and whales.

In order to study such small organisms, scientists at PAL-LTER need special tools to collect their samples from the ocean and so they can conduct their experiments onboard the research vessel. The main tool that scientists use to collect plankton samples is called a plankton net, which is a large, mesh net that is towed (pulled) off the back or the side of the ship. The mesh material can be different sizes to allow for the collection of different-sized organisms—a larger mesh size will allow more things to escape, while smaller mesh size will trap smaller organisms. As the net is towed, water flows through the holes in the mesh and the plankton are caught on the inside, and concentrated in the cod end, which is a collection tube attached to the end of the net. One special plankton net is the Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS), which can have anywhere between 6-20 nets and can be used to collect plankton samples at different depths in the water column. The MOCNESS is the type of plankton net you'd see onboard a vessel like the ones that conduct work at PAL-LTER, but smaller ones are still used often by scientists.

For this activity, your class will work together in groups or pairs to come up with a research question and design and test a tool to collect zooplankton. Your class will also compare different samples based on real data collected at PAL-LTER to discuss how climate change can affect planktonic communities and how, in turn, this can affect the entire ecosystem in the Western Antarctic Peninsula.

Materials & Supplies

- Plankton tow box
  - Plastic bin or tank
  - Assorted beans to represent different plankton*
- Plankton net materials*
  - Different sized mesh
    - Recommended: Pantyhose, fishnet stocking, mesh grocery/vegetable bags
  - Plastic bottles
    - Recommended: 2-liter size. Smaller bottles can also be used, but it may be more difficult to attach mesh
  - String
  - Scissors
  - Masking tape or duct tape
- PAL-LTER Zooplankton Samples
  - Baggie or cup of beans*
- Student worksheets or notebook paper

Bonus

- Microscopes
- Dichotomous keys of local plankton species

*See Appendix A for Instructor Key and example plankton nets.

Teacher Preparation

- Students should be divided into pairs or groups of 3-4.
- Plankton tow boxes should be prepped in advance. These need only be made once, as they can be stored in zip-top bags for future use.
- Each group will receive net materials based on the type of plankton they wish to sample for, therefore enough materials for all groups to have each mesh is recommended.
  - Alternatively: Assign plankton sizes to each group to reduce the amount of material prep needed.

Procedure

- On slide 3, ask students what they think of when they hear the word “plankton.” Answers may vary, click to reveal, “Maybe a certain cartoon character?” and they may think of the Spongebob Squarepants character Plankton.
  - Click until “Phytoplankton & Zooplankton” pops up and ask students what they think these words mean. The color coding is a hint, you can provide as many hints as they may need to arrive at the answer.

    - Click to reveal the answer and to introduce the idea that they are ubiquitous in our ocean.
- On slide 4, ask students the True or False question. Click to reveal that the answer is true.
    - Explain photosynthesis and primary production to students and click to reveal pictures of different phytoplankton.
- On slide 5, ask students if they think zooplankton are part of animals' life cycles or their own creature.
    - Click to reveal the answer is both and discuss holoplankton and meroplankton.
- Use slides 6-9 as a holoplankton vs. meroplankton game
    - For each slide, have students guess if the picture represents a holoplankton or a meroplankton before clicking to reveal the answer
- On slides 10-11, introduce today's study site and the PAL-LTER.
    - Plankton are one of the many things Palmer scientists are studying in Antarctica.
- On slide 12, introduce the Antarctic food web.
    - This food web is very short and efficient, both phytoplankton and zooplankton play a very important role.
        - Phytoplankton are the very base of the Antarctic food web and are eaten by krill, which are a type of zooplankton. Krill are then important food sources for animals like whales, fish, and penguins.
- On slide 13, ask students how they think scientists collect plankton samples to study.
    - Click to reveal the answer, plankton nets. Discuss how they work and click to slide 14 to show the anatomy of a plankton net.
- On slides 15-16, discuss the larger nets used on large research cruises.
    - The MOCNESS is one example. This tool has 8 different nets and sensors to record environmental data.
- On 17-19, introduce the design activity.
    - Students will be choosing a species of plankton to sample for, forming and defending hypotheses, designing and testing their own plankton nets, recording their data, and sharing findings with the class. Students can also share among groups.
    - Show students the beans they will be sampling from and the different sizes of mesh.
    - Allow 2 minutes for students to write their hypotheses.
    - Allow 15-20 minutes for students to design their tools and test them. Students can/should have up to three attempts to test and revise their tool.
        - Display slide 20 for instructions on how to make a plankton net. Hide it for a greater challenge.
    - Allow approximately 5-10 minutes for graphing and sharing.
- Once time is up, lead class in discussion about what worked about their designs and what didn't.
    - Discuss how many attempts it may have taken to achieve their goal, if they achieved it at all.
    - Discuss how different goals and hypotheses could have led to different designs.

- See slides 21-25 to introduce part 2.
    - Discuss spatial gradients and how scientists are using them to ask questions about how climate change will affect plankton populations and, in turn, the Western Antarctic Peninsula as a whole.
    - Allow 10 minutes for counting and graphing of the sample.
- Lead class share-out to wrap up.
- See slide 26 for a bonus class activity if you have access to a body of water (river, lake, ocean) and a microscope.
    - Make your (or have your students make) a plankton net using the finest mesh stocking you have.
    - Bring students to the water and have them take turns sampling.
        - Alternatively, collect samples before or after school without the whole class.
    - Pour a small amount of your sample into a petri dish or use a pipette.
    - Observe your samples under a microscope and see if/what plankton you have collected.
        - If local species are known, have students try to identify any plankton in the sample.

Name: ______________________ Date: _______________

Part 1: Design your own plankton net

Antarctic scientists use plankton tow nets to collect plankton samples to use in their experiments. Depending on what type and size of plankton they want to study, they may use different tools.

1. Which size of plankton do you want to sample for? Circle your answer.

   SMALL MEDIUM LARGE

2. Based on the materials given, write a hypothesis on which mesh size you think will be most effective in sampling for your chosen plankton.

3. After each test of your design, fill out the table below with the total number of each plankton you caught. Try to do this at least twice.

Test 1	**Test 2**	**Test 3**
Small:	Small:	Small:
Medium:	Medium:	Medium:
Large:	Large:	Large:

4. Which mesh size did you choose?

   What size plankton were you able to catch with your net? Use evidence from your data to support your answer.

   Were you able to catch your target size?

Name: ______________________ Date: _______________

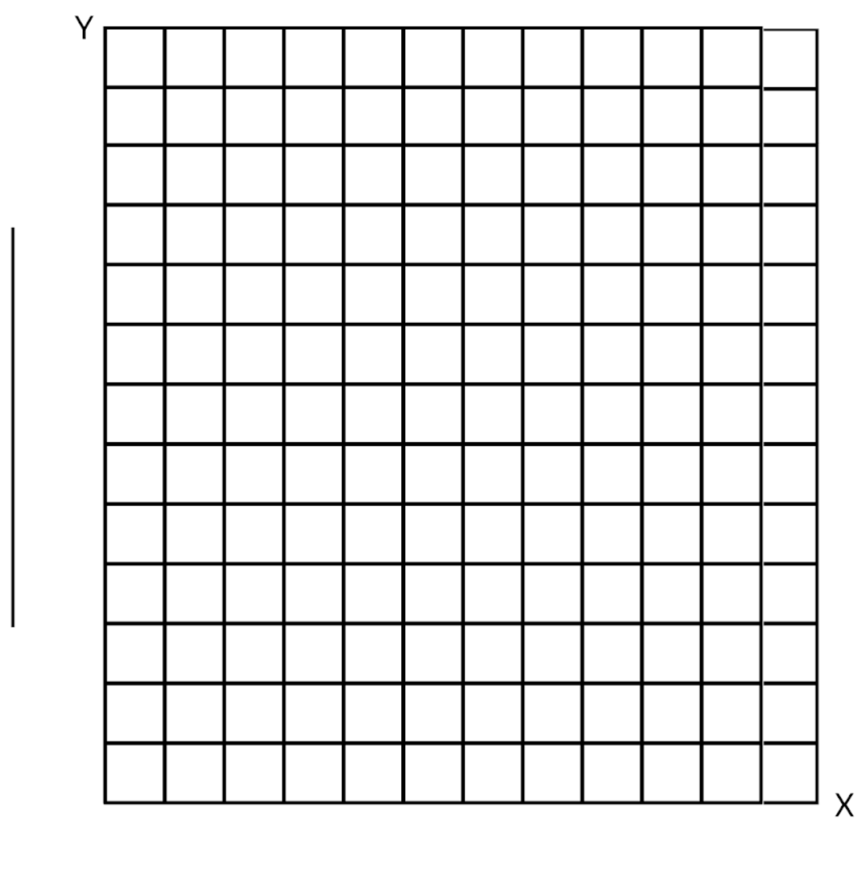
Part 2: Antarctic Case Study

1. Your group has been given a sample of krill (lentils) and salps (lima beans) based on a real plankton tow from the Western Antarctic Peninsula. Count both samples and fill in the table below with your data.

   For the actual value of salps in Tow 1, multiply the number of beans by 10.
   Do this *only* for Tow 1!

Tow 1		Tow 2	
Krill	Salps	Krill	Salps

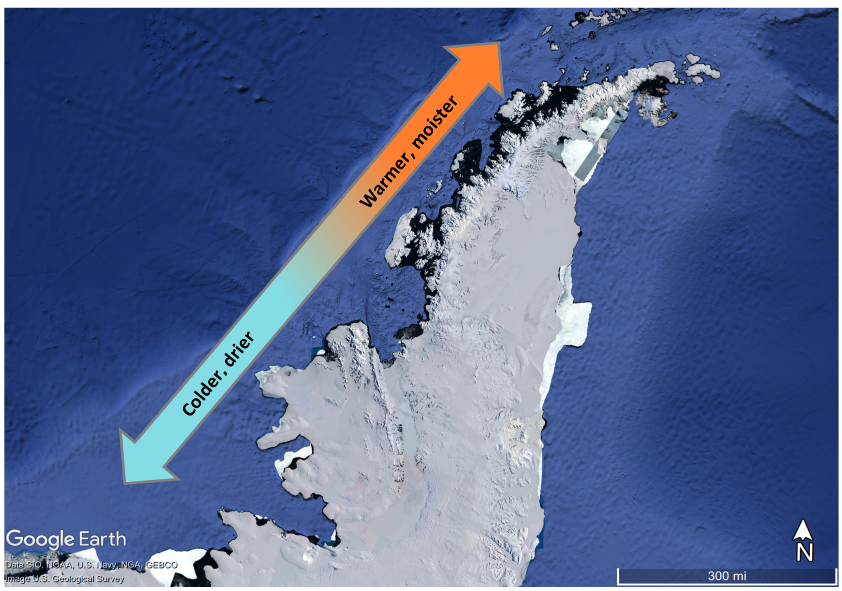
2. After counting the plankton, make a bar graph to display your data. Be sure to create a key to tell which tow is which.



3. Compare your data. What plankton was most abundant in Tow 1?

   What plankton was most abundant in Tow 2?

4. Krill prefer colder, icier water while salps thrive in warmer conditions. Using what you know about these plankton and the map below, describe where you think each sample was taken.



5. How might continued warming affect these two populations of zooplankton? What effects might these changes have on the rest of the ecosystem? Support your claims with evidence from the lesson.

Appendix A: Instructor Key & Blank Graph Worksheets

Suggestions for plankton tow bean sizes

- Small: rice, lentils, pastina
- Medium: Navy beans, pinto beans
- Large: Lima beans

Based on mesh size, ideal beans may vary!

How to make a plankton net

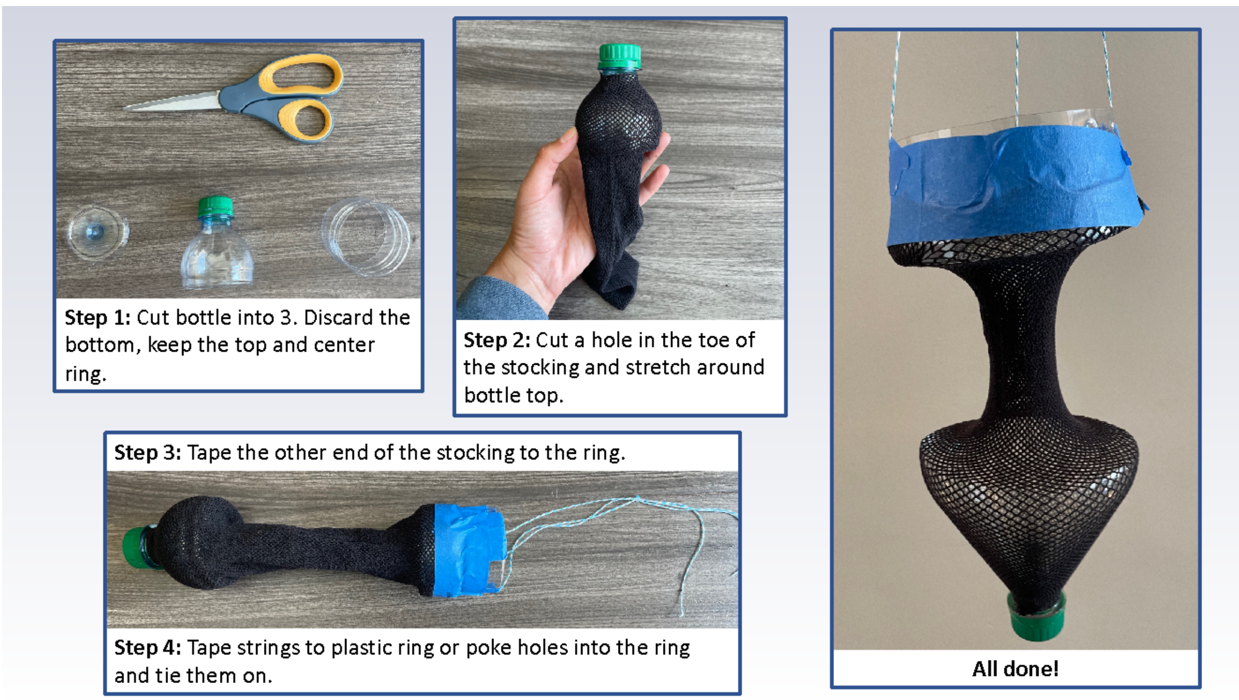
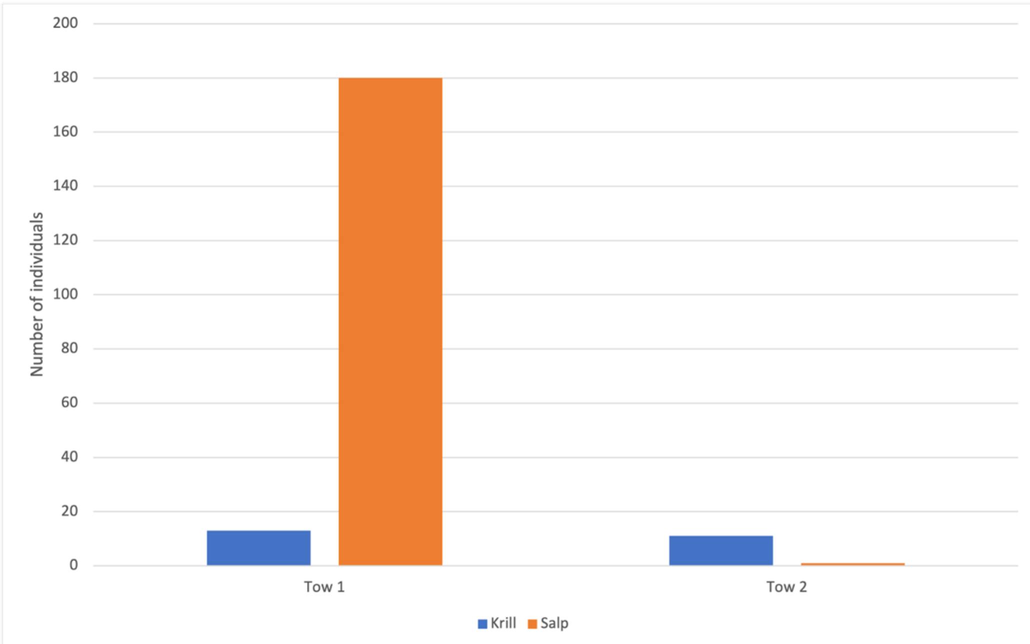


Table of krill and salp data. Krill are represented in the samples by lentils and salps by lima beans.

Tow 1		Tow 2	
Krill	Salps	Krill	Salps
13	180	11	1

Because the number of salps is so large for Tow 1, include 18 beans and instruct students to multiply by 10 for the actual value.



Graph showing krill and salp data for Tow 1 and Tow 2.

Appendix B: Bilingual Resources

Glosario en español

- Community : Comunidad
  Todos los organismos que viven e interactúan en un lugar particular
- 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
- Cod end : fondo de la red
  El fondo de una red de plancton donde se une un frasco o botella para recolectar la muestra
- 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
- Holoplankton : Holoplancton
  Un organismo que pasa toda su vida en la etapa planctónica
- Meroplankton : Meroplancton
  Un organismo que solo pasa una parte de su vida, generalmente larval o etapas tempranas, en la etapa planctónica
- Phytoplankton : Fitoplancton
  Plantas acuáticas microscópicas que se desplazan con (no pueden nadar fácilmente contra) las
  corrientes
- Plankton : Plancton
  Microorganismos acuáticos que se desplazan con (no pueden nadar fácilmente contra) las corrientes
- Plankton tow net : Red de plancton
  Red de malla de varios tamaños que se remolca a través del agua para recolectar plancton
- Primary production : Producción primaria
  Energía producida a través de la fotosíntesis
- Population : Población
  Un grupo de individuos de la misma especie que viven en un lugar
- Spatial gradient : Gradiente espacial
  Cambios o diferencias observados a través del espacio
- Zooplankton : Zooplancton
  Animales acuáticos microscópicos que se desplazan con (no pueden nadar fácilmente contra) las corrientes

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-LS2-4. 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.