Science News

EDUCATOR GUIDE

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The Case of the Arctic's Missing Ice

SOCIETY FOR SCIENCE & THE PUBLIC

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About this Guide

In the winter of 2017–2018, sea ice was absent from the Bering Sea and a large mass of cold, salty water that usually pools near the seafloor was AWOL too. Scientists are investigating what caused this break from the typical seasonal pattern and what it means for life in the Arctic. If last year's events represent a new normal, then a cascade of changes could be in store for the complicated ecosystem that has long thrived in the Bering Sea. "The case of the Arctic's missing ice" explores the decades-long warming trend in the Arctic and the effects that warming is already having on sea life, including phytoplankton blooms.

This Guide includes:

Article-based observation, Q&A — Students will answer questions based on the *Science News* article "The case of the Arctic's missing ice," Readability: 10.6. Questions ask students to think about patterns in sea ice formation and cause and effect for Arctic ecosystems. Students are also asked to analyze a graph of summer temperatures and make predictions, including citing evidence. Another version of the article, "Disappearing sea ice could disrupt Arctic's food web," Readability: 6.9, appears on *Science News for Students.*

> **Article-based observations, questions only** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular connections, teacher guide — Students will use the prompts provided to design a strategy for minimizing or mitigating the effects of Arctic phytoplankton blooms for one group of people. The prompts ask students to design and refine the strategy based on feedback, and to think about how they would define and measure success.

> **Cross-curricular connections, student questions** — These prompts are formatted so it's easy to print them out as a worksheet.

Activity: Web of Changes

> **Purpose**: Students will think through and diagram an Arctic and local food web and will explore how ecosystem disruptions can impact the food webs. Students will then apply what they have learned to a local food web.
>
> **Approximate class time:** 1 to 2 class periods.

SN EDUCATOR GUIDE

March 16, 2019

The Case of the Arctic's Missing Ice

Standards

Next Generation Science	Common Core ELA
Earth and Human Activity: HS-ESS3-1, HS-ESS3-4, HS-ESS3-5	Reading Informational Text (RI): 1, 2, 4, 5, 7
Ecosystems: Interactions, Energy, and Dynamics: HS-LS2-1, HS-LS2-2, HS-LS2-3, HS-LS2-4	Writing (W): 1, 2, 3, 4, 6, 7, 8, 9
Biological Evolution: Unity and Diversity: HS-LS4-4, HS-LS4-5, HS-LS4-6	Speaking and Listening (SL): 1, 2, 4, 5, 6
Engineering Design: HS-ETS1-1, HS-ETS1-2, HS-ETS1-3	Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
	Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 8, 9

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Article-Based Observation, Q&A

Directions: After your students read the article "The case of the Arctic's missing ice," have them answer the questions below. Questions are organized by story section with summary questions at the end.

Introduction

1. What was unusual about the Bering Sea in the winter of 2017–2018? Why are scientists concerned?

Sea ice never appeared in the Bering Sea, and a large mass of cold, salty water that's associated with the ice never formed near the seafloor. This development concerns scientists because sea ice is important to the Arctic ecosystem. Its absence could disrupt every part of the Arctic food web.

Open waters

2. Describe the typical pattern of winter sea ice formation in the Bering Sea. What factors contributed to a different scenario in the winter of 2017–2018?

Most years, ice forms in the Bering Sea or migrates south from the Chukchi Sea through the Bering Strait. In the winter of 2017–2018, strong winds from the south not only kept the sea ice in the Chukchi Sea but also brought warmer waters into the sea, limiting sea ice formation. Higher-than-normal air temperatures in the Chukchi meant less ice was available to drift through the Bering Strait. Both of these factors contributed to record-low winter sea ice cover in the Bering Sea.

3. What does Peggy, or mooring M2, do? What unexpected data did Peggy collect in the summer of 2018?

Peggy, or mooring M2, tracks the temperature, salinity and other properties of water at one spot in the southern Bering Sea. In the summer of 2018, Peggy detected that the temperatures near the seafloor never dropped below zero.

4. According to the graph titled "Deep warming" on Page 23 of the article, how did Peggy's data from the summer of 2018 compare with previous years? Based on the caption and the text of the "Open waters" section, what explains the summer 2018 data?

Though there is yearly variation, water temperatures near the seafloor typically average below zero degrees Celsius in the summer. But in 2018, the average temperature was much higher — about 1.5 degrees Celsius. The data suggest that no cold pool formed in 2018. Cold pools are by-products of sea ice formation, so the fact that the Bering Sea didn't "freeze up" in the winter of 2017–2018 is likely responsible for the cold pool's absence.

<u>Arctic in transition</u>

5. What effects has sustained warming already had on the Arctic ecosystem? Be sure to frame your answer in terms of a "cascade of changes," the terminology used in the opening of the article.

Warming has triggered changes in the lower levels of the Arctic food web, which has impacted species higher up in the web. Bivalves — which are food for walruses, seals and a kind of sea duck called a spectacled eider — have moved north. Less nutritious marine worms have taken the bivalves place to the detriment of other species. Populations of small copepods have increased while larger copepods, which juvenile fish depend on to survive the winters, have declined. Changes at the lower level of the food web have affected the distribution and types of fish populations, which in turn impacts seabirds. The summer of 2018 was the third year in a row with a massive seabird die-off.

<u>The heat is on</u>

6. What factors affect the timing, location and size of phytoplankton blooms in the Arctic? Provide an example from the article.

Sea ice and sunlight both play a major role in where and when phytoplankton bloom. Other factors such as nutrient availability and water temperatures can affect the size of blooms. In 2018, more light penetrating early in the year meant more phytoplankton blooms, and the blooms came earlier in the northern waters.

7. Phytoplankton make up the base of the Arctic food web and animals depend on the food, but sometimes the blooms are problematic. Why?

Blooms can turn toxic, akin to the deadly red tides that have blossomed along Florida's coast. Toxic blooms can kill wildlife and make people ill.

<u>Summary questions</u>

8. Do you think the relatively iceless Arctic winter was a one-time fluke or is it likely to happen again? Cite evidence from the article to explain your answer.

Students' answers will vary. An argument for a one-time fluke includes the fact that the combination of southerly winds and warm temperatures that led to the record-low sea ice was unusual and scientists don't yet have enough data to say whether the Bering Sea is increasingly likely to be ice-free in winter. Students might also cite natural variability from year to year. An argument for the iceless winter happening again includes the fact that the Arctic is warming twice as fast as the rest of the planet — the five years since 2014 are the five warmest scientists have ever measured in the Arctic. That temperature increase has led to a sharp decline in summer sea ice cover. It wouldn't be that surprising if warming conditions affected winter sea ice cover, too.

9. What questions do researchers still hope to answer about the interplay of ice, temperature and life in the Arctic?

Questions could include: How warm will it be in the future Arctic? How typical will southerly winds be? How are toxic phytoplankton responding to changing Arctic conditions?

March 16, 2019

The Case of the Arctic's Missing Ice

Article-Based Observation, Q

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Open waters

2. Describe the typical pattern of winter sea ice formation in the Bering Sea. What factors contributed to a different scenario in the winter of 2017–2018?

3. What does Peggy, or mooring M2, do? What unexpected data did Peggy collect in the summer of 2018?

4. According to the graph titled "Deep warming" on Page 23 of the article, how did Peggy's data from the summer of 2018 compare with previous years? Based on the caption and the text of the "Open waters" section, what explains the summer 2018 data?

Arctic in transition

5. What effects has sustained warming already had on the Arctic ecosystem? Be sure to frame your answer in terms of a "cascade of changes," the terminology used in the opening of the article.

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SN EDUCATOR GUIDE
March 16, 2019

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Cross-Curricular Connections, teacher guide

Directions for teachers: The *Science News* article "The case of the Arctic's missing ice" describes the prolific phytoplankton blooms observed in the Arctic in 2018. Less and thinning sea ice, as well as the presence of melt ponds, means more light can reach through to the sea below, encouraging the growth of such blooms. In some cases, the blooms can become toxic, killing fish and leading to neurological damage in humans. After students read the article, divide them into groups to consider how the phytoplankton blooms might affect people's lives. The discussion prompts below ask students to design a strategy to minimize or mitigate the effects of the blooms.

Suggestions for structuring the discussion: After each group develops a proposed strategy, have the groups pair up and present their strategies to one another. Each group can get feedback from members of another group and think about ways to refine the approach.

Discussion questions:

1. Identify one group of people — living locally or across the globe — whose lives might be adversely affected by an increase in Arctic phytoplankton blooms. How might these people be affected?

2. Over what time frame might the consequences of the phytoplankton blooms play out for this group?

3. Propose one strategy (whether an engineering solution, policy approach, lifestyle change or something else entirely — get creative) that might minimize or mitigate the adverse effects of the phytoplankton blooms on the group you've selected.

4. What would be the goal of the strategy? How would you measure success?

5. Outline at least eight steps you would take to implement your strategy? What step would be first? What would come last?

6. To implement your strategy successfully, what background scientific knowledge would you need? What types of experts could you hire to provide or help you acquire that knowledge?

7. How might you determine the cost of your strategy? How might you fund your project?

8. How would you communicate the strategy to the group you've identified in Question 1?

9. Can you foresee any unintended consequences of your strategy? Consider safety, ethical, cultural or environmental consequences for the group you identified and others.

10. Pair up with another group and present your impact and strategy in three minutes or less. Once you have presented, ask the members of the other group for feedback. Has the other group brought up any concerns or issues that you hadn't considered?

11. After getting additional feedback on your strategy, do you still think it will be successful?

12. How would you refine your strategy based on the feedback?

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Cross-Curricular Connections, student questions

Directions for students: The *Science News* article "The case of the Arctic's missing ice" describes the prolific phytoplankton blooms observed in the Arctic in 2018. Less and thinning sea ice, as well as the presence of melt ponds, means more light can reach through to the sea below, encouraging the growth of such blooms. In some cases, the blooms can become toxic, killing fish and leading to neurological damage in humans. After reading the article, follow the prompts below to design a strategy to minimize or mitigate the effects of the blooms on one group of people.

1. Identify one group of people — living locally or across the globe — whose lives might be adversely affected by an increase in Arctic phytoplankton blooms. How might these people be affected?

2. Over what time frame might the consequences of the phytoplankton blooms play out for this group?

3. Propose one strategy (whether an engineering solution, policy approach, lifestyle change or something else entirely — get creative) that might minimize or mitigate the adverse effects of the phytoplankton blooms on the group you've selected.

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SN EDUCATOR GUIDE

March 16, 2019

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Activity Guide for Teachers: Web of Changes

Purpose: Students will think through and diagram an Arctic and local food web and will explore how ecosystem disruptions can impact the food webs.

Procedural overview: After reading the *Science News* article "The case of the Arctic's missing ice," students will describe the Arctic food web and the factors that are impacting it, including proposing a mathematical model and experiment to explore how one population changes over time. Students will then apply similar methods to a food web in their local ecosystem.

Approximate class time: 1 to 2 class periods (depending on the depth of investigation into a local ecosystem).

Supplies:
Activity Guide for Students: Web of Changes
Online access or resource books to look up information on organisms and food webs

Directions for teachers:

Review the basics of ecosystems, trophic levels, food chains, food webs and the factors that influence population size with the class as necessary. Have your students read the article "The case of the Arctic's missing ice," in the March 16 issue of *Science News*, and ask them to work through the activity below. The activity asks students to create a simple food web, define factors that affect its stability and predict and graph how a change in one factor will disrupt the web's stability.

After students complete the questions for the Arctic food web, have them apply the learned concepts to a local ecosystem by designing a more comprehensive food web and thinking about the factors that are disrupting it, or might in the future. If time permits, consider having students answer Questions 4 and 5 for their local ecosystem.

Depending on time, you can also encourage students to get creative with the presentation of their food webs. They can draw or print images of the organisms to make their diagrams more engaging.

Directions for students:

Food chains and food webs help us visualize how energy and matter move among trophic levels in an ecosystem. Use the Arctic ecosystem described in the article "The case of the Arctic's missing ice" to answer the following questions.

1. Create a simple food web for the Arctic ecosystem described using examples from the article. Include at least 10 organisms, and use arrows to show the direction of energy flow between organisms. Identify the roles of different organisms (as outlined below). Some organisms may have more than one role.

Producer
Primary consumer
Secondary consumer
Tertiary consumer
Omnivore
Scavenger
Detritivore
Decomposer

Students answers will vary but should include organisms mentioned in the article. A sample diagram offers an example of what a student diagram might look like — it not comprehensive.

2. What factors affect the stability and carrying capacity of this Arctic ecosystem?

Boundaries with land, amounts and locations of sea ice, sunlight, temperatures throughout the year, ocean currents, nutrient input, and amounts of fishing and hunting by humans.

3. Choose one factor listed above and predict how a change in that factor over time could lead to a disruption in the stability of organisms mentioned in your food web.

Less sea ice formation can lead to fewer or smaller cold pools of salty water near the ocean floor. Without those cold, salty pools, Arctic cod will have fewer refuges to grow, which could lead to a decline in Arctic cod. A decline in Arctic cod could lead to a decline in polar bears, seals, whales, thick billed murres and other seabirds.

4. Pick one organism and graph the predicted population change over time due to the disruption you've chosen. Determine a possible mathematical model for this change.

Responses will vary, but students should consider the food sources available to the organism, predator population sizes and the abundance of the organisms' preferred habitat. A stable population will remain constant over time. A population with abundant resources and few predators may grow exponentially until it reaches its carrying capacity, at which time it may remain constant or crash. A population with diminishing resources and a greater number of predators will face exponential decay, or could crash linearly in the absence of vital resources.

5. Propose a simple observational study to test your model. (Assume you have enough resources, funding and time. You do not actually have to do any experiments.)

Students' experiments will likely rely on observation methods to monitor the population of a particular organism over time. Observational techniques might include direct human observation, monitoring of animal tracks, analyses of animal wastes, thermal and other imaging, image recognition software, DNA sampling, chemical analysis and so on. Students may consider where to put the sensors (on land, on or under the sea, in the air, on satellites), how many sensors to deploy, what area to cover and how to estimate the population that is not directly detected by the sensors. Students may consider how many years to continue the monitoring program before reaching conclusions about population changes.

Directions for students continued:

Now relate the information, examples and answers given about the Arctic ecosystem to a local ecosystem using the prompts and questions that follow.

6. Research and choose a local ecosystem. Create a more comprehensive food web for your local ecosystem. It should include:

At least 25 organisms (be sure to include some examples of plants, fungi and bacteria)
Arrows to show the direction of energy flow between organisms
All the trophic levels at which organisms feed:

- Producer
- Primary consumer
- Secondary consumer
- Tertiary consumer
- Omnivore
- Scavenger
- Detritivore
- Decomposer

Student responses will vary, but should be comparable to the model presented for the Arctic food web.

7. What factors affect the stability and carrying capacity of this ecosystem?

Student responses will vary, but responses may include geographic or human-made features that define the boundaries of that ecosystem, the resources available within that ecosystem (soil, water, sun and so on), climate and weather (including cycles throughout the day and throughout the year), and competition from neighboring ecosystems and/or from humans.

8. What factors are currently disrupting your chosen ecosystem, or may disrupt it in the future?

Student responses will vary, but responses may include climate change, encroachment by humans (more roads, more houses, noise, artificial lighting), pollution, infectious diseases, introduction of domestic animals such as cats and dogs, invasive species, farming and farm runoff, fishing and hunting, as well as natural disasters.

9. Choose one of these potential disruptors and predict the cascade of effects over time for one organism in the food chain.

Student responses will vary.

March 16, 2019

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Secondary consumer
Tertiary consumer
Omnivore
Scavenger
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2. What factors affect the stability and carrying capacity of this Arctic ecosystem?

3. Choose one factor listed above and predict how a change in that factor over time could lead to a disruption in the stability of organisms mentioned in your food web.

4. Pick one organism and graph the predicted population change over time due to the disruption you've chosen. Determine a possible mathematical model for this change.

5. Propose a simple observational study to test your model. (Assume you have enough resources, funding and time. You do not actually have to do any experiments.)

Directions for students continued: Now relate the information, examples and answers given about the Arctic ecosystem to a local ecosystem using the prompts and questions that follow.

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7. What factors affect the stability and carrying capacity of this ecosystem?

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9. Choose one of these potential disruptors and predict the cascade of effects over time for one organism in the food chain.

March 16, 2019

The Case of the Arctic's Missing Ice

Related Articles

Science News:
"A peek into polar bears' lives reveals revved-up metabolisms," Readability: 11.4

"Radical idea could restore ice in the Arctic Ocean," Readability: 9.4

Science News for Students:
"Climate change cripples planet's glaciers and ice caps," Readability: 7.4

"Why Antarctica and the Arctic are polar opposites," Readability: 7.3

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