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THE IMPORTANT BUT MYSTERIOUS ANTARCTIC KRILL

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Antarctic krill are very important animals. They are well-known as the food of ocean giants such as blue whales, but they also feed many other animals and help to slow climate change by keeping millions of tons of carbon out of the air. Antarctic krill grow no longer than a human thumb, but together they weigh more than any other wild animal species. Although Antarctic krill live only in the cold waters of the Southern Ocean, they can live anywhere from sunlit surface waters to the darkest depths, from near the coast and under sea ice to ice-free waters far from land. In this article, we explore how their huge population and ability to live in diverse conditions make Antarctic krill important for other animals, people, and the world. We also introduce some key mysteries, such as what will happen to these animals as the climate continues to change.

INTRODUCING ANTARCTIC KRILL

Antarctic krill (Figure 1) are small sea creatures that grow no bigger than a human thumb but can do amazing things. For example, they

glow in the dark and they can shrink or grow by replacing their skeletons, which are on the outside of their bodies. Those abilities are impressive, but their most amazing achievement is that they have developed a huge population. There are about 800 trillion Antarctic krill [1], or 100,000 for every human being! These enormous numbers make Antarctic krill very important for other animals, for human beings, and for the planet (Figure 2), as you will see if you keep reading!

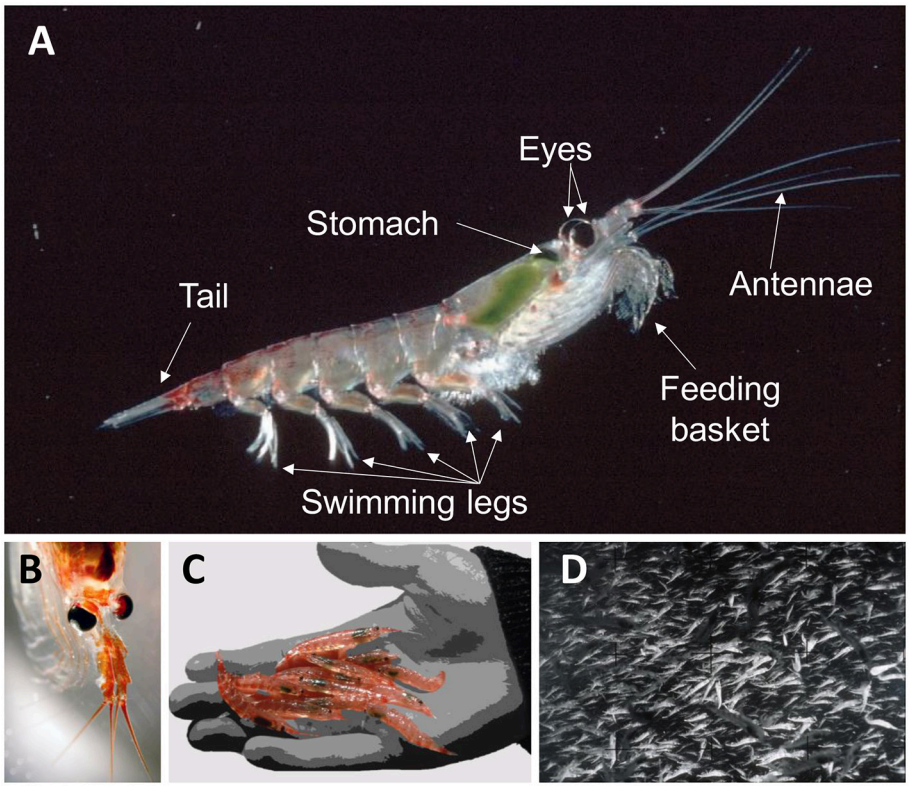

Figure 1

(A) Antarctic krill from the side, with some body parts labeled. The green color behind the stomach comes from recently eaten phytoplankton. **(B)** A close-up of a krill's head. **(C)** Several krill in a human hand, to show their size—no larger than a thumb. **(D)** A swarm of krill (Image credits: British Antarctic Survey).

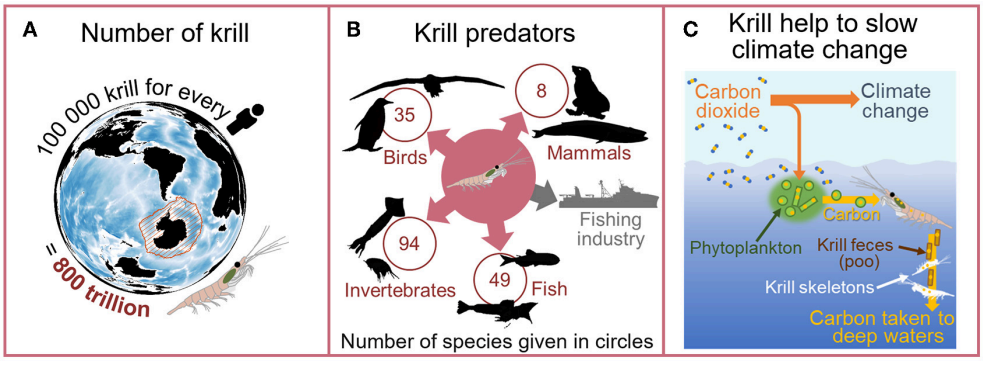

Figure 2

(A) Antarctic krill are an important species, with huge numbers in the Southern Ocean. **(B)** Krill populations feed many other animals and supply the fishing industry. **(C)** Krill help to slow down climate change by sending carbon atoms down to deep water. The yellow dots represent carbon atoms, which are tiny in real life.

CRUSTACEANS

A group of animals with jointed limbs and skeletons on the outside of their bodies that mainly live in water. Examples include crabs, shrimps, lobsters and krill.

Antarctic krill belong to a group of animals called **crustaceans**, which includes crabs, shrimps, lobsters, and 86 species of krill. The other krill species are important in their own ways, but Antarctic krill is such an important species that many people simply call it "krill", as we do in

the rest of this article. This species of krill lives in the cold Southern Ocean that surrounds the frozen continent of Antarctica. They mainly feed on tiny plants called **phytoplankton**, which they filter out of the water using their feeding basket (Figure 1A), but they can also eat other small animals.

LOTS OF KRILL MEANS LOTS OF PREDATORS AND LOTS OF POO

We know of almost two hundred species of predators that feed on krill (Figure 2B) [2], but there are probably many more. These species include blue whales, which are the biggest animals that have ever lived, and most of the other **baleen whales** that live south of the equator. Other krill predators include most penguin species, several types of seals, flying birds such as albatrosses, fish, jellyfish, and squid. Many people think of krill as penguin or whale food, but in fact, the billions of fish in the Southern Ocean eat more krill than all the other predators eat. Most of these predators feed on other species as well as krill, but they still manage to eat up to 390 billion kg of krill per year. That is more than all the meat eaten by humans. Without krill, the animals that depend on them would be scarce or extinct.

The world would also be hotter without krill. Carbon, in the form of carbon dioxide gas (CO_2), drives **climate change** when it builds up in the air (Figure 2C). Krill help to reduce the build-up of CO_2 by sending carbon down to deep waters, far away from the air. This process starts when phytoplankton use CO_2 to build their cells. Krill eat the phytoplankton, and some of the carbon comes back out of them, packed into pellets of **feces** (also known as poo). Huge numbers of krill produce huge numbers of pellets, which sink rapidly down to deep waters, taking the carbon with them (for more information about krill's importance for Earth's climate, see this Frontiers for Young Minds article). The skeletons that krill shed when they change size, which also contain carbon, sink to deep waters too [3]. Each atom of carbon that krill send to deep waters is one less atom causing climate change.

Krill are important for people, too. It is easy to see how we benefit from krill's effect on CO_2, and we see the importance of the Southern Ocean **ecosystem** every time we notice a picture of a penguin. There is also a krill fishing industry that provides hundreds of jobs. Krill is the main species caught in the Southern Ocean, and this catch is mainly used to feed farmed fish and other animals. However, some people think that krill could become a valuable food for humans in the future.

KRILL ARE EXPLORERS

Krill are often described as **plankton**, but two things set them apart from other animals that drift on ocean currents. The first is their size:

PHYTOPLANKTON

Small plant-like living things that drift in water and are the main source of food in ocean ecosystems.

BALEEN WHALES

Whales that feed by filtering small animals out of seawater. Examples include blue and humpback whales.

CLIMATE CHANGE

Changes to weather and oceans, including warming, that happen over many years. Human activities that burn oil, coal, and natural gas cause dangerous changes.

FECES

Material that comes out of an animal and contains the waste that is left over from feeding. Also known as poo.

ECOSYSTEM

The plants, animals, and other living things, together with their habitat, that are found in a particular place and are connected by activities like eating each other.

PLANKTON

Small living things (bacteria, phytoplankton, and animals) that float in water. They are mainly unable to swim against currents but may change depth to control their movement.

krill can grow much bigger than most other plankton species. The second is their ability to swim against currents, which gives them more control over where they go. Swimming allows krill to form large, tightly packed groups called swarms. The biggest swarms can cover areas up to 100 km^2 and contain over 10 billion krill. Krill swarm together to defend themselves against predators. Although whales can scoop up great mouthfuls of krill from a swarm, more krill escape than get eaten. Most predators have much smaller mouths and eat only one krill at a time, meaning that any individual krill in a swarm has a very high chance of escape.

Individual krill can travel thousands of kilometers during their lifetimes. As a result, adult krill are found throughout an area of 19 million km^2 (5% of the world's ocean). Their **habitats** stretch from the ice-covered waters that surround the Antarctic continent to the ice-free edge of the Southern Ocean, up to 2,000 km further north, and from coastal areas to remote waters in the middle of the ocean (Figure 3).

HABITAT

The places where a particular type of living thing is found.

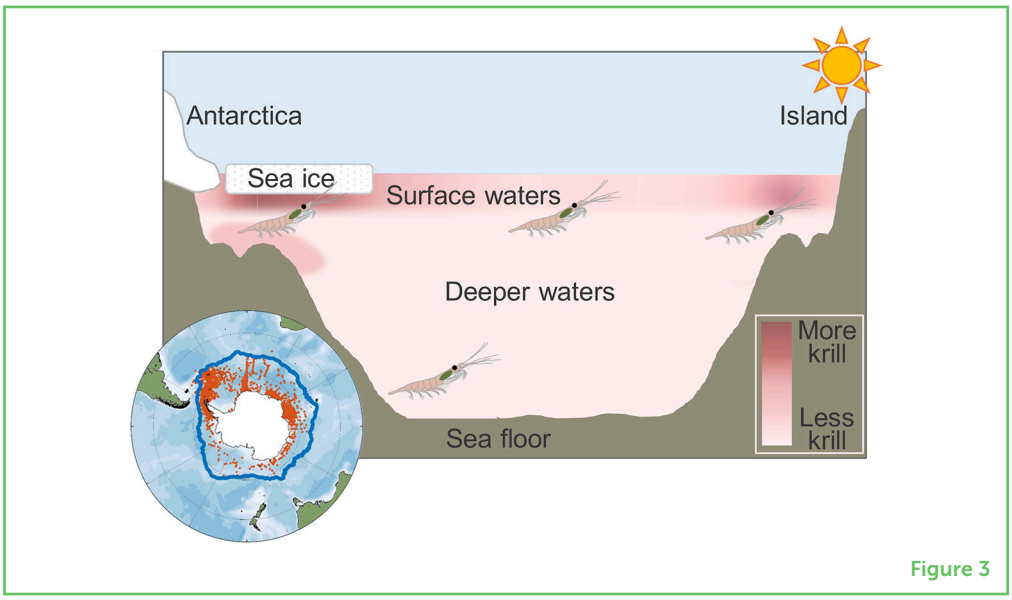

Figure 3

Antarctic krill live throughout the Southern Ocean. The orange dots on the map show places where scientists have found krill. The blue line is the Polar Front, where cold Antarctic waters meet warmer waters from further north. The main image shows a slice through the ocean, with more krill indicated by darker shades of pink. You can see that krill can live in a wide range of cold-water habitats, but they are most common in surface waters, especially near shallow, coastal seas. They can also live under sea ice, in the open ocean, and on the sea floor.

Krill also travel up and down. They mainly live near the ocean surface where they can find the most food, but adults can also swim down to depths of 3,000 m, way beyond the reach of whales, seals, and penguins. Krill eggs sink to a depth of about 500 m before they hatch, so young krill start their lives by traveling back to the surface to feed.

MYSTERIOUS KRILL

Studying krill is not easy. It usually requires a ship that can withstand storms and sea ice, and special equipment to observe or catch krill. Even then, it is only possible to study a small part of the vast area where krill live. Scientists are exploring new technologies to provide

more information, but in the meantime, there are a lot of unsolved mysteries about krill. We worked with other krill experts to identify the main mysteries for scientists to solve [4].

One important mystery is that the number of young krill changes from year to year, but we do not know what causes this change. There is no clear relationship between the number of adults and the number of offspring. Certain factors might affect whether young krill live long enough to become adults. For example, hiding from predators under sea ice and feeding on the phytoplankton that grow there allows some young krill to survive their first winter, but others survive in places without sea ice. Solving the mystery of young krill numbers will help us to understand whether the krill population can continue to replace the immense numbers eaten by predators every year, along with the smaller numbers caught by the fishing industry.

Another krill mystery is where young krill come from. Krill lay their eggs in surface waters. The eggs sink and hatch far below the surface. This can only happen in places with warm, deep water that allows the young krill to develop quickly and return to the surface to feed before they starve. Adults must be able to reach these egg-laying places in high numbers, and young krill must be able to reach safe habitats to survive their first winter. There are very few places with all these qualities. Detective work has identified some suitable places, and confirming whether krill really *do* produce offspring in these places is the next step toward protecting them.

The biggest mystery concerns the future. The Southern Ocean is getting warmer, and winters have become less icy. How will these changes affect krill populations and populations of predators that depend on them? Will warmer temperatures and less ice reduce the size of the krill population and make parts of the Southern Ocean uninhabitable for krill? There are signs that changes have already begun, and that krill have become less common in the northern part of their habitat where waters are warmest [5].

Antarctic krill is an important species, but climate change threatens the things that make it important: its population size and ability to live in most of the Southern Ocean. Krill fishing could make the situation worse. We need to solve some of the mysteries about krill so that the people responsible for protecting the ecosystem where krill live have the information necessary to do their job. People from all over the world can help, including scientists, people in the fishing industry, and people responsible for protecting the ecosystem. Krill scientists have recently formed an organization called the Krill Expert Group, to help everyone work together. We hope that through teamwork we will solve the mysteries and help to protect this important species.

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ORIGINAL SOURCE ARTICLE

Meyer, B., Atkinson, A., Bernard, K. S., Brierley, A. S., Driscoll, R., Hill, S. L., et al. 2020. Successful ecosystem-based management of Antarctic krill should address uncertainties in krill recruitment, behavior and ecological adaptation. *Commun. Earth Environ.* 1:28. doi: 10.1038/s43247-020-00026-1

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

DENISSE, AGE: 14
I am Denisse, a young mind that reads a lot and always want to learn about history, biology, and literature. I want to travel around the world and know about other cultures and languages.

KINABALU INTERNATIONAL SCHOOL, AGES: 10–11
Science is everywhere in the world so we want everyone to recognize the power of science. Every single person needs to understand science. One day, these articles might be able to help someone, therefore we want people to know them. We strive to teach, educate, and encourage the future generations! We are an ordinary bunch of kids in Malaysia but we are trying to make a difference in the world.

LAURUS INTERNATIONAL SCHOOL OF SCIENCE, AGES: 10–11
Hello! We are the Y6 class from Laurus, in Tokyo. Our everyday is chaos, but we have a lot of fun here! We all love to challenge new things. Our class has good friendships and we are very glad to review science articles.

AUTHORS

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Simeon Hill works for the British Antarctic Survey and investigates how climate change and fishing affect the Southern Ocean ecosystem. He likes fish, food webs, and fieldwork; and he was recently made a "half wombat" by the organization responsible for managing krill fishing. This might be a compliment, meaning that he has dedicated a lot of his life to studying, and protecting krill. He also enjoys being on his bike, by the sea, in his garden, and up mountains—but not all at the same time. *sih@bas.ac.uk

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Sally Thorpe is an ecosystem modeler at the British Antarctic Survey. She likes finding out why animals in the Southern Ocean live where they do, and how their distributions might change as the environment changes. To do this, she writes and uses computer code to investigate a wide range of data—from instruments deployed

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