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RIVERS OF BRINE IN ANTARCTIC SEA ICE PROVIDE HOMES FOR TINY ORGANISMS

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Antarctic sea ice is more than just frozen seawater at the ocean surface. It is an important home for many tiny-sized marine organisms! When seawater freezes, tiny salty rivers and streams form inside the sea ice. These are called brine channels. To live in these channels, organisms must be smaller than a pinhead. Some organisms can live their whole lives in the sea ice. Many spend their lives crawling around, finding food, and laying eggs. Organisms that are too large to fit in the brine channels can live just below the ice. Fish, krill, and sea butterflies live under the ice for protection from larger predators. They do this by hiding in ice crevices and caves. Warming temperatures mean there is less sea ice in some parts of Antarctica. Animals will have to adapt if marine life is to continue to thrive in this salty environment.

HOW IS SEA ICE FORMED?

Many marine organisms live in and around the **sea ice** along Antarctica. For such a cold environment, what kinds of strategies do these organisms use to survive? To answer this, let us take a closer look at the Antarctic sea ice itself. Have you ever wondered how there can be so much ice around Antarctica? Up to 19 million square kilometers of sea ice form around Antarctica each year. This is enough to cover Australia about three times over!

SEA ICE

Ice formed from seawater on the ocean surface, offering a unique habitat for various small marine organisms.

Sea ice is different from icebergs and glaciers, which form from freshwater or snow. This is because sea ice only consists of seawater. Seawater is salty, so it freezes at lower temperatures than freshwater. In autumn, freezing air causes the ocean surface to cool. Gradual mixing of the top 20 m of ocean water occurs, and the surface layer drops to about −2°C. Here, the water becomes so cold that tiny ice crystals begin to form. These tiny ice crystals are known as frazil ice (Figure 1A). They are only 3–4 mm long and float to the surface, where they combine to form thicker ice sheets. Wind and waves can have a big effect on this process. In calm weather, smooth, thin ice sheets called grease ice (Figure 1B) form from the frazil ice. These ice sheets thicken over time to form nilas ice (Figure 1C), which has a smooth bottom surface. In rougher waters, the frazil ice gets bumped around and forms disks called pancake ice (Figure 1D). The waves then force the pancakes to pile on top of one another, forming a rough-bottomed ice sheet.

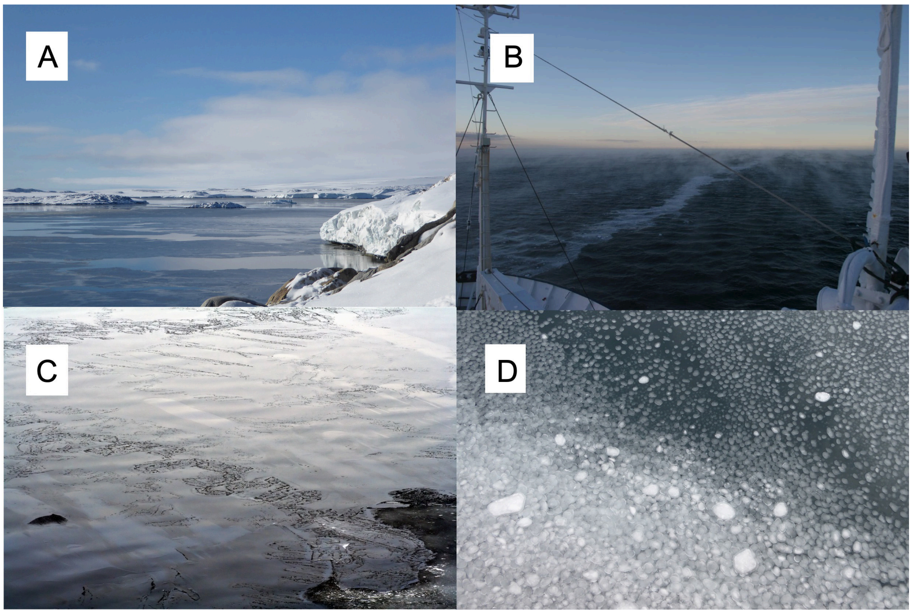

Figure 1

Figure 1

Several types of sea ice can form in ocean waters. **(A)** Frazil ice, made of tiny crystals, seen close to Casey Station, Antarctica. **(B)** Thin sheets of grease ice formed near the Ross Ice Shelf. **(C)** Nilas ice, which has a smooth bottom surface, seen in Baffin Bay in the Arctic. **(D)** Pancake ice, formed from collections of frazil ice, near Antarctica [Photo credits: **(A, D)** Christine Weldrick; **(B)** Bruce McKinlay, Flickr; **(C)** Brocken Inaglory, Wikimedia Commons].

When seawater freezes, a process called **brine rejection** occurs. This is when the salts and particles in water are forced out of the ice crystals. This creates a highly salty, nutrient-rich liquid called brine.

BRINE REJECTION

When seawater freezes, it pushes out salts and particles, creating brine—a very salty, nutrient-rich liquid.

BRINE CHANNELS

Narrow and microscopic rivers in sea ice, filled with brine, providing habitats for tiny organisms.

Brine becomes trapped in pockets between ice crystals as the ice sheets form. This can create complex systems of **brine channels** within the ice itself (Figure 2). These channels are quite narrow and measure only a few hundred micrometers in diameter. This is about the same thickness as two pieces of paper. Brine channels become an important habitat for microscopic organisms [1]. Many tiny animals and algae live in these salty brine channels (Figure 2). Nutrients and food found in brine channels allow these tiny organisms to survive the cold winters.

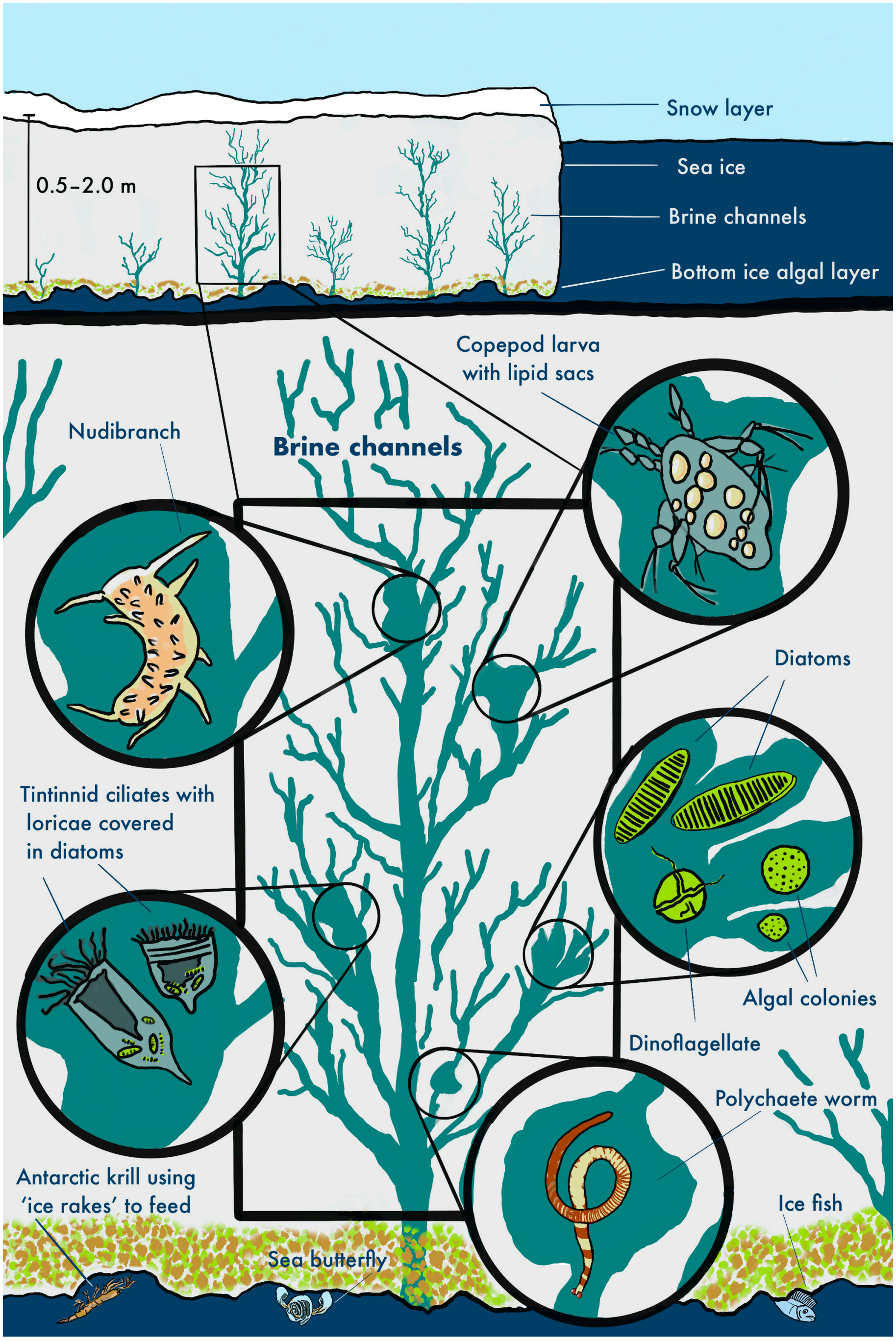

Figure 2

Figure 2

Many tiny animals and algae live inside and under the brine channels of sea ice.

These tiny organisms are food for other organisms and generally play an important role in food webs in and around the sea ice.

WHAT IS THAT GOLDEN-BROWN COLOR UNDER THE SEA ICE?

PHYTOPLANKTON

Microscopic algae that move with water currents and use sunlight to make food, a crucial element of ocean life.

The smallest marine algae in the sea ice community are **phytoplankton**. They are commonly found on the bottom of the sea ice. They may use the brine channels to move away from the open water below. Most of the sea ice phytoplankton are diatoms (Figures 3A–C). Diatoms are

Figure 3

Figure 3

Algae and animals of the sea ice. **(A–C)** Diatoms. **(D)** Dinoflagellate. **(E)** Tintinnid. **(F)** Sea butterfly. **(G)** Antarctic krill. **(H)** Icefish. **(I, J)** Copepods. **(K)** Copepod with eggs. **(L)** Fish eggs. **(M)** Flatworm (turbellarian). **(N)** Nudibranch. **(O)** Copepod [Photo credits: **(A–E)** Ruth Eriksen; **(F)**: R. Giesecke, Wikimedia Commons; **(G–O)**: Bluhm et al. [3]].

a diverse group of organisms that make beautiful silica shells called frustules. We identify and examine sea ice diatoms using powerful light and electron microscopes. Single-celled algae, including diatoms, use **photosynthesis** to convert sunlight into energy. Diatoms have special pigments that help them with photosynthesis. This is why you can see a distinctive golden-brown color at the bottom of the sea ice [2]. Diatoms use the brine channels to migrate closer to the light, to maximize photosynthesis.

PHOTOSYNTHESIS

Process by which plants and algae, including sea ice algae, use sunlight, carbon dioxide, and water to create oxygen and obtain sugar, which is used as energy to survive.

Flagellates are another type of sea ice phytoplankton (Figure 3D). Flagellates are even smaller than diatoms and they can feed in many ways. While they also use photosynthesis to capture energy from the sun, they can also eat small particles that accumulate in the brine channels, like bacteria and the remains of dead phytoplankton, called **detritus**.

DETRITUS

Organic matter created by the decomposition of plants, algae, or animals.

Dinoflagellates are another microplankton that live in the brine channels. At some point in their lifecycle, they all have two flagella that help them move (Figure 3D). Dinoflagellates can be photosynthetic like diatoms, but they also obtain energy by grazing on flagellates or diatoms.

Ciliates are among the most fascinating organisms in brine channels. They are single-celled organisms that have fine hair-like structures called cilia. Ciliates use their cilia to swim and feed. They do this by selecting and moving food particles toward them. Unlike the other single-celled organisms, ciliates do not photosynthesize. Some ciliates, called tintinnids (Figure 3D), live inside delicate houses called lorica. Some Antarctic researchers have seen these loricae covered in diatoms. Many think this benefits both tintinnids and diatoms, enabling them to survive the challenging conditions inside the brine channels. Or it may provide a way for diatoms to access the open ocean—they simply hitch a ride on a tintinnid as it swims free during the ice melt [4].

In the spring, water and air temperatures begin to rise and the sea ice begins to melt. Diatoms then become the "seed population" for **phytoplankton blooms** around the edges of the sea ice [2]. Phytoplankton blooms are when these tiny marine algae grow and spread quickly, and they provide food for many organisms that graze on the plankton. Spring is a critical time of year for the Antarctic food web. For more information about life under the sea ice, see this Frontiers for Young Minds article.

PHYTOPLANKTON BLOOMS

When countless tiny phytoplankton rapidly grown and spread throughout the ocean, creating a lively underwater gathering.

THE MANY TINY ANIMALS SWIMMING UP AND DOWN BRINE CHANNELS

Like phytoplankton, most animals living in brine channels are so small you need a microscope to see them. They are not very diverse, but their numbers can be quite high. Thousands of them can exist in an area no bigger than a laptop. The most common animals are called copepods. They are a type of crustacean that is like a tiny shrimp but can exist in many kinds of shapes (Figures 3I–K). There are also many small worms in the channels, including turbellarians (Figure 3M), which are flat and have two "eyes" at the front that help them sense light.

Some of the animals that live in the ice stay there their whole lives. They carry their eggs (Figure 3L) and crawl around on the sea ice walls, where they eat ice algae and detritus. In the winter, food is not easy to find. Sea ice animals build up fat stores called lipid sacs (you can see them clearly in the bodies of the tintinnid and the copepod in Figures 3E, O, respectively) in their bodies, as a strategy to survive in times of no or little food.

One unusual sea ice animal is a small, white snail called a nudibranch (Figure 3N). They can be found in a large ice-covered bay in Antarctica called the Weddell Sea. Nudibranchs have no shells and carry their gills on their backs. It is unusual to find them in Antarctica—most nudibranchs are brightly colored and live on tropical reefs. The Weddell Sea nudibranchs are up to 4 mm long. The adults cannot swim, and their eggs do not float, so they must stay in brine channels to survive. These animals do not freeze solid because they have a type of antifreeze in their blood that helps them live comfortably in low temperatures.

There are animals that rely on sea ice but are too big to live in brine channels. They use the sea ice as a place to find food or hide from predators. These bigger animals include sea butterflies, krill, and small fish (Figures 3F–H). Sea butterflies are a type of snail that swims using their feet as wings. Researchers have seen them feeding on ice algae released into the ocean during the spring ice melt. Krill are a type of crustacean that also feed on ice algae. They swim upside-down and use special ice rakes on their feeding limbs to scrape algae into their mouths. Krill are an important food source for whales, seals, penguins, and fish. Small fish live in little caves in the ice and feed on copepods and krill.

THE FUTURE OF SEA ICE ORGANISMS: WHAT WE CAN DO TO HELP

Scientists have made a few predictions about the future of Antarctic sea ice. They predict that there might be times when the ice becomes thinner, and they predict that ice may disappear earlier in the year. One thing we know for certain is that these changes are due to climate change. We know that some sea ice animals and algae may survive with less ice, but other organisms may not fare so well. Remember how that small nudibranch seems to need to live in ice year-round? The ice might disappear at times when they need to lay their eggs.

Other species can live quite well in the water under the ice, and they may be able to survive for longer in open water when no ice cover is present. If the sea ice becomes unpredictable, the lives of animals that depend on it may suffer from lack of food and may not be able to reproduce to create future generations.

We can help in a few ways. First, if we understand how human activities affect the environment, we can make changes to behaviors that may impact faraway places like Antarctica. For example, reducing our carbon footprint and supporting sustainable practices can help slow the effects of climate change and preserve the delicate balance of ecosystems in Antarctica. Second, we can pay attention to how our actions impact organisms so small we need a microscope to see them. These miniscule creatures play a vital role in the broader web of life in Antarctica. For example, we can support research and conservation efforts that focus on these microscopic organisms. By taking these steps and working together we can protect the remarkable life within the sea ice to make sure it continues to thrive as the world changes.

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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

CHESED, AGE: 11

I am Chesed, and I am a 6th grader. I love science and technology. I like listening to music, reading Harry Potter books and Mandarin comics, and coding.

RUMAISA, AGE: 10

Rumaisa is a Grade 4 student interested in Biology, Biodiversity, Environmental pollution, and Animals. Her curiosity and desire to learn more about the natural world are evident. She respects the environment and is dedicated to exploring ways to preserve biodiversity and reduce pollution. Rumaisa is eager to share her knowledge and insights with others. With her inquisitive mind and commitment to the environment, she is sure to make a positive impact in the years to come.

AUTHORS

CHRISTINE K. WELDRICK

Dr. Christine Weldrick is a marine zooplankton ecologist working with the Australian Antarctic Program Partnership at the University of Tasmania's Institute for Marine & Antarctic Studies. She is currently focused on investigating tiny animals in the Southern Ocean, including krill, copepods, and sea butterflies, and how their ecology may be affected under changing ice conditions around the marginal ice zone of Antarctica. Her favorite zooplankton is the sea butterfly, and she has spent many years observing them under the microscope in laboratories and on research vessels at sea. *christine.weldrick@utas.edu.au

RUTH K. ERIKSEN

Dr. Ruth Eriksen is a phytoplankton biologist working with the Commonwealth Scientific and Industrial Research Organization and is an affiliate of the Institute for Marine & Antarctic Studies and the Australian Antarctic Program Partnership. Ruth loves using microscopes to determine what phytoplankton species are living in different parts of the world's oceans, especially in Antarctica. We do not know how many species of phytoplankton there are, and the use of electron microscopes reveals some of the incredible diversity, complexity, and beauty within seawater and sea ice samples. Over time, phytoplankton communities change in response to ocean warming and acidification, and Ruth's work explores this using past and present observations to predict what our future oceans may look like.

SYLVIA KING

Sylvia King is a marine ecologist with a love for zooplankton in the Southern Ocean. She is currently completing her Master of Marine and Antarctic Science at the Institute for Marine & Antarctic Studies in Hobart. She is particularly interested in studying how changing sea ice conditions affect zooplankton community structure, and how this may influence the wider Antarctic coastal ecosystem.

KERRIE M. SWADLING

Dr. Kerrie Swadling is a zooplankton and sea ice ecologist with the Australian Antarctic Program Partnership and the Institute for Marine & Antarctic Studies, and an Associate Professor at the University of Tasmania. Her research field is the ecology of ocean invertebrates, with over 30 years' experience working in Southern Ocean and temperate marine ecosystems. Kerrie has contributed to significant advances in understanding the roles that these invertebrates play in sea ice ecosystems, and to evaluating future climate-related impacts. Her favorite zooplankton is the sea ice calanoid copepod *Paralabidocera antarctica*, as it can live in both the sea ice cover and in some Antarctic lakes that contain saltwater.