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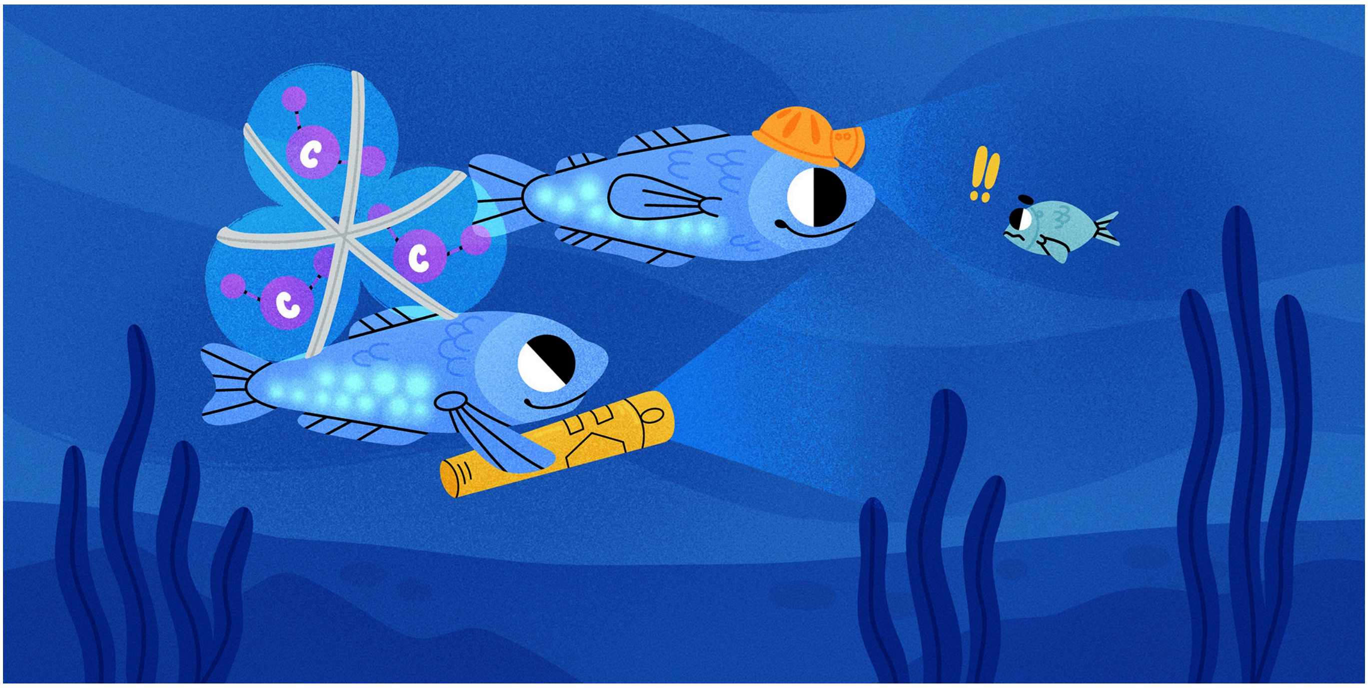

ILLUMINATING THE LIVING LANTERNS OF ANTARCTICA

Anna Belcher, Jennifer J. Freer*, Tracey Dornan and Ryan A. Saunders

Ecosystems Team, British Antarctic Survey, Cambridge, United Kingdom

YOUNG REVIEWERS:

IGOR
AGE: 12

OWEN
AGE: 10

Lanternfish are a relatively small but very abundant fish. They live deep in the ocean's "twilight" zone where there is not much light. A unique community of lanternfish live in the Southern Ocean, where they are a key part of the Antarctic food web. Lanternfish also play an important role in moving carbon from the atmosphere into the deep ocean, where it is stored. In this article, we explain current knowledge on Southern Ocean lanternfish, including how they produce their own light! We will also tell you about some mysteries surrounding lanternfish that scientists are yet to solve.

THE LIFE OF A LANTERNFISH

At <20 cm long, lanternfish (scientific name Myctophidae) are relatively small fish. However, what they lack in size they make up for in abundance and diversity! There are around 254 species of lanternfish and lanternfish species can be found living in all the world's oceans. As a family, lanternfish are some of the most abundant fish on Earth, providing food and energy to marine predators across the world. In general, tropical regions contain the highest numbers and greatest species diversity of lanternfish, but lanternfish are also found in polar regions. They have been seen in Arctic waters close to the North Pole but are much more abundant in the ocean surrounding Antarctica, which is called the Southern Ocean.

Roughly 20 species of lanternfish live in the Southern Ocean, playing a crucial role in the ecosystem. Read the story of one such species in Box 1. The waters of the Southern Ocean are very cold and there is a unique community of animals for lanternfish to feed on (for example, Antarctic krill) and a unique community of predators that lanternfish can be eaten by. For example, the king penguin is a specialized hunter of lanternfish—around 80% of a king penguin's diet is lanternfish and these penguins can dive up to 300 m deep to catch their prey! Lanternfish are also an important source of food for fur seals, birds, and larger fish including the Patagonian toothfish.

Box 1 | The life and times of Luna the lanternfish.

"Hi! My name is Luna and I am a lanternfish of the species *Electrona antarctica* (see Figure 1). I am a real polar specialist, as I only live in the cold water of the Southern Ocean. I can be found from the ocean surface down to depths of more than 1 km. I grow up to 11.5 cm long, which may seem small but lots of lanternfish species that live in warmer water are even smaller. Scientists tell me that I might live to be about 4 years old. Would you believe they figured this out by counting the rings in small calcium deposits in our ear bones, called otoliths—a bit like counting rings in a tree trunk. To study us, scientists try to catch us using nets, but we are excellent at detecting when a net is coming and quickly get out of the way. So, scientists also use sound-emitting devices called echosounders to work out where we are and how many of us there might be (For more information on ecosounders, see this Frontiers for Young Minds article). There are lots of things about lanternfish that scientists are still trying to find out like: Do I migrate to the surface to feed every night, or just now and then? Where do I breed? Where do I go in the winter? How do changes in the environment affect my yearly routine? There are still lots of mysteries that we are hiding and that scientists are keen to solve!"

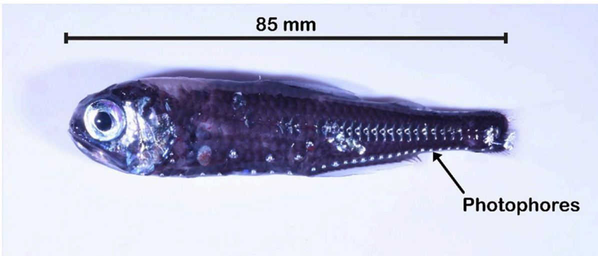

Figure 1

Figure 1

An image of the lanternfish species *Electrona antarctica* (the same species as Luna in Box 1). Lanternfish have light-producing organs called photophores along their bellies and the sides of their bodies. credit: T. Dornan, BAS.

MESOPELAGIC

The middle layer of the open ocean between 200 and 1,000 m deep. Light rapidly declines in this layer, so it is often called the "twilight zone."

PHYTOPLANKTON

Microscopic marine plants that are the base of the food chain in the sea. Just like plants on land, phytoplankton need sunlight to live and grow.

Most lanternfish live deep in the ocean's **mesopelagic** zone, which is the name for the layer of the ocean that is 200–1,000 m deep. *Meso* means "middle" and *pelagic* refers to the open ocean, away from the coast. The mesopelagic zone is also known as the twilight zone, because there is not enough sunlight at this depth for **phytoplankton** (tiny marine algae) to make energy from photosynthesis, or for animals to see well—but it is not completely dark. The twilight zone is a great place for small lanternfish to hide and avoid being eaten, but it is not great for finding food! Lanternfish eat tiny animals called **zooplankton**, so they must swim up toward the surface to feed. Being near the surface puts them at greater risk of being eaten by top predators like penguins and seals, which hunt by sight.

To reduce the risk of being eaten, many species of lanternfish swim up toward the surface at night, returning to the safe depths of the mesopelagic zone during the day. This process is known as **diel vertical migration** (To learn more about this daily migration, see this Frontiers for Young Minds article). The lanternfish must balance finding the best light level to hunt for zooplankton with their chances of being hunted themselves!

LANTERNFISH BIOLUMINESCENCE

Lanternfish have some awesome tricks that help them survive in the dark and treacherous mesopelagic zone. As they do with their daily migrations, they use light to their best advantage as lanternfish can generate their own light! This is called **bioluminescence**, and it is quite common for deep sea animals. Lanternfish make the bioluminescent light from a chemical reaction inside special cells that live within light organs called **photophores**. Lanternfish photophores are very complex—just like a human eye, photophores contain lenses, filters, and reflectors.

Almost all lanternfish have many photophores on their bellies and on the sides of their bodies (Figure 1). Some lanternfish have extra light organs on their tails and heads. These headlamps and taillights are larger than photophores, and scientists think they emit a bright light that can flash on and off, like fireflies.

The light from lanternfish photophores points downwards (underneath them), and they can adjust the shade of blue-green light that they emit. This has given scientists some clues as to what they use all this light for. Scientists believe that lanternfish use the glow from their belly photophores to blend into their blue background. They do this by matching their light to the light coming down from the surface of the ocean [1]. This camouflages them to any pesky predators who might be spying from below! From what we know, light-emitting fish generally emit blueish light. This has likely evolved because blue light can penetrate deepest into the water. Colors at the opposite ends of the light spectrum (the reds and violets visible in a rainbow) are quickly lost. Many deep-sea animals are colored red for camouflage because there is no red light available in the deep ocean, making red animals pretty invisible! One group of deep sea fishes called dragonfishes have a light organ beneath their eye which emits red light. This may act to illuminate red colored prey or enable dragonfish to communicate with each other without other animals seeing them.

ZOOPLANKTON

A diverse group of marine animals, mostly microscopic in size, that can swim a little to find food and mates, but can only travel long distances by drifting with ocean currents.

DIEL VERTICAL MIGRATION (DVM)

The diel (meaning daily) synchronized movement of marine animals between the surface and deep layers of the ocean.

BIOLUMINESCENCE

The emission of light by an animal, most often created by a chemical reaction inside a photophore. Bioluminescence can help animals survive in the deep, dark ocean.

PHOTOPHORE

A light-producing organ that appears as a glowing spot on some marine fish and squid. Photophores can vary in complexity and size and produce light by a chemical reaction.

Some scientists think lanternfish might also use their lights as signals, although we still do not have clear evidence of this. We do know that the light organs on the tails of different species can flash at different speeds, and that lanternfish can control the strength of the light they produce. Signals would be very handy in this vast darkness. Light could attract or illuminate food or it could startle or confuse predators, helping lanternfish to escape. Light signals could even help find lanternfish find each other or find potential mates [2]. In fact, lanternfish eyes are highly specialized to detect bioluminescent light, and they can even spot a bioluminescent source up to 30 m away [3]!

Whatever lanternfish use their dazzling lights for, their bioluminescence is a powerful adaptation that has certainly helped them thrive in the mesopelagic ocean.

LANTERNFISH AND FISHING

Lanternfish are a good source of protein, but humans often find them too waxy and oily to eat. Lanternfish also live in deep waters far offshore, which makes them difficult and expensive for fishermen to catch. Because of this, lanternfish have rarely been fished commercially. However, it is possible that lanternfish could become an important resource in the future, as we seek new ways to feed the increasing human population and as fishing technology improves. Lanternfish could be used to make fish meal products to feed other, more edible types of fish that can be produced on fish farms. As is done for other fish like mackerel, herring, and cod, scientists would need to gather detailed information on lanternfish to monitor their numbers and set catch limits to stop them from being overfished. Overfishing can also have harmful effects on other marine creatures and the health of our oceans. Currently, we do not have enough information on the biology of lanternfish to ensure that they would be fished in a way that is safe for the ecosystem. This is another reason why scientists are studying lanternfish with great interest.

LANTERNFISH AND ENVIRONMENTAL CHANGE

One of the neat things about lanternfish is that every day, when they move up and down through the water, they do a little bit to help fight climate change (Figure 2). The phytoplankton that live near the ocean surface remove carbon dioxide from the atmosphere, using it to grow. These organisms store the carbon from the atmosphere in their cells. Although lanternfish like Luna are not fans of eating phytoplankton, they *do* like eating the krill and copepods that feed on phytoplankton. This means that, by eating food at the ocean surface, lanternfish are taking up carbon that was once in the atmosphere. Even better, because lanternfish like to hang out deep in the mesopelagic ocean during the day, to hide from predators, they take that carbon with them. So, when they breathe out carbon dioxide, or when they poo, they release that carbon into the deep ocean where it can be trapped away from the atmosphere for centuries or more. Lots of other critters in the ocean help with this process, too. All these organisms are part of the biological "carbon pump" that takes carbon out of the atmosphere and transports it into the deep ocean. It is tricky to figure out just how much carbon these processes transport, especially because lanternfish like Luna and her mesopelagic friends are so good at avoiding detection. Scientists estimate that all the fish in the ocean might transfer 1.5 billion tons of carbon out of the surface layer—that is 16% of the total biological carbon pump [4]. That is a lot of poo!

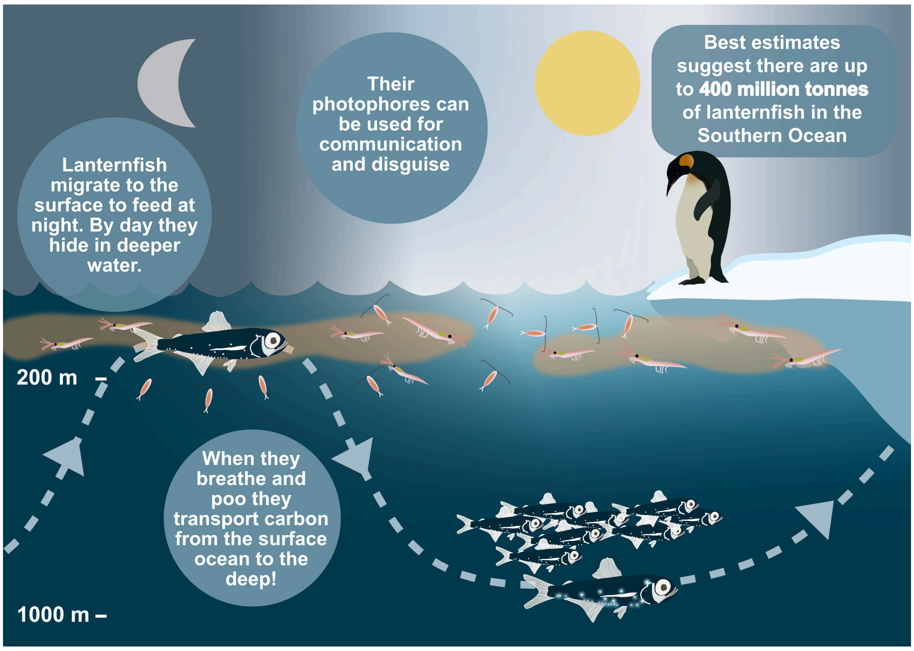

Figure 2

Figure 2

A diagram showing the diel vertical migration of Antarctic lanternfish, important facts about these species, and their role in transporting carbon to the deep sea. During darkness, they come up to the surface to feed on small zooplankton such as krill and copepods. They move back down to the safety of the mesopelagic ocean during the day, to avoid predators like penguins. Credit: A Belcher, BAS.

Lanternfish are a key part of Southern Ocean food webs. Yet the Southern Ocean ecosystem is changing as ocean surface temperatures are warming, which may affect the life cycles, behavior, and distribution patterns of Southern Ocean lanternfish. Also, as Antarctic krill become scarcer in a warming Southern Ocean, many predators are likely to eat lanternfish more readily as a replacement. Overall, this may reduce lanternfish populations in the region and thus reduce the amount of carbon that reaches the deep ocean through these fish.

In summary, it is important for scientists to continue to study lanternfish, to understand how these fish might cope as their ocean home changes, and how changes in lanternfish numbers might impact the Antarctic animals that rely on them as a food source. Lanternfish research will also help scientists to understand the role that our oceans play in storing carbon, and how much the oceans help to shield the Earth from climate change.

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YOUNG REVIEWERS

IGOR, AGE: 12

I live in Brazil, on the beach. I like Lego, travel, surf, and love to read. In the future, I will become an architect and I love science. In my house I have a huge yard with a tree house.

OWEN, AGE: 10

I am 10 years old, and I am interested in science, chemistry, and physics. One of my favorite things to do is to read. I also love gardening, and I am interested in growing carnivorous plants and mushrooms.

AUTHORS

ANNA BELCHER

I am a marine scientist at the British Antarctic Survey in Cambridge, UK. I am really interested in how the organisms living in the ocean help remove carbon dioxide from the atmosphere. I study Antarctic krill, fish living in the dark ocean, as well as sinking animal poo! When I am not in the office or out at sea collecting data, I spend my time rock climbing, bike-packing and enjoying the wild outdoors.

JENNIFER FREER

I am a marine scientist at the British Antarctic Survey and have always been fascinated by life in the oceans. My work aims to help understand how marine animals are distributed, what controls their distributions, and how climate change might affect them. I study zooplankton and pelagic fishes found in the polar oceans and use model-based tools to predict their future ranges. Whether it is spending time on a ship, beach walks, or surfing, I am happiest on or by the sea. *jenfree@bas.ac.uk

TRACEY DORNAN

I am a marine scientist with the British Antarctic Survey and I am fascinated by the communities that marine animals live in. My research is focused on the use of active acoustics to study fish and zooplankton. I want to know who lives where, how many fish and zooplankton there are, and how this changes with time. In my free time I enjoy gardening, woodworking, cycling, camping, and best of all rock-pooling.

RYAN SAUNDERS

I am a marine scientist with the British Antarctic Survey, and I am fascinated about our world's oceans and marine life. I study pelagic fish, zooplankton, and sharks to help understand how these marine creatures live in our oceans and how they might be affected by environmental change and fisheries interactions. I am passionate about protecting our world's polar oceans for future generations. Outside of work, I enjoy cycling, sea swimming, the great outdoors, and playing guitar.