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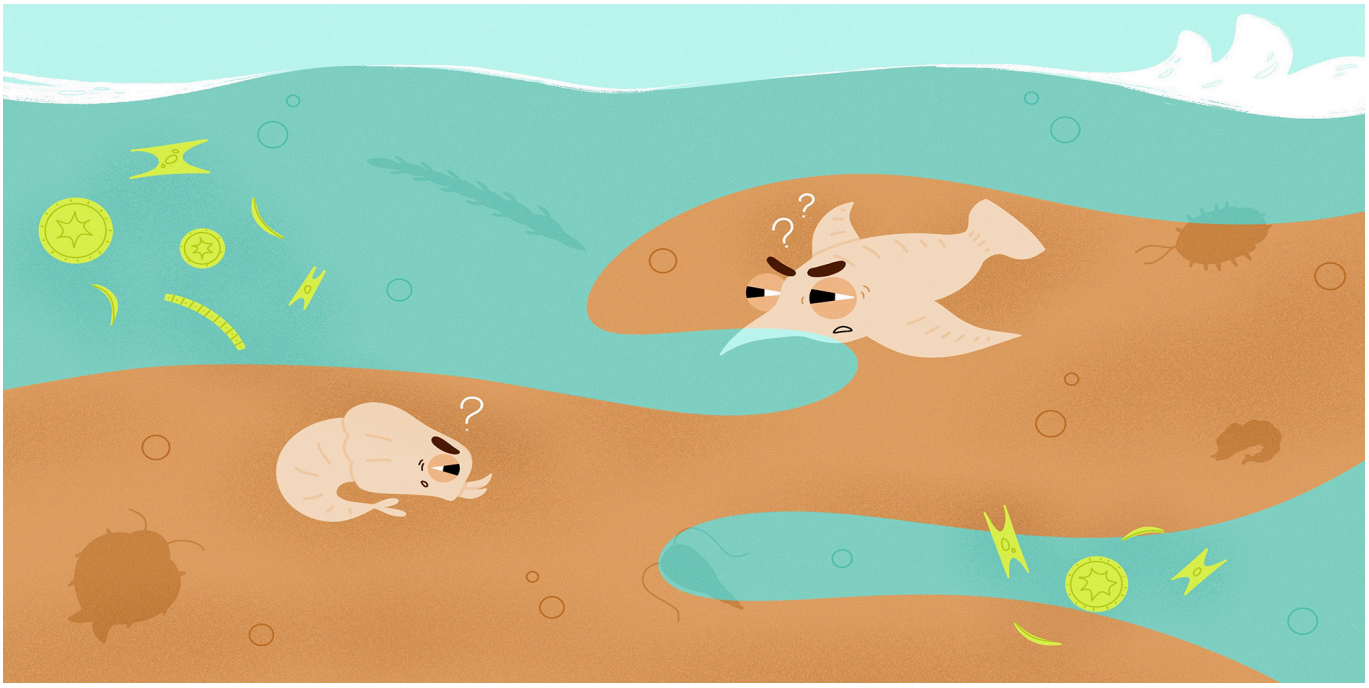

HOW MIGHT BROWNER SEAWATER AFFECT MARINE ORGANISMS?

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YOUNG REVIEWERS:

AARON
AGE: 13

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AGE: 11

Climate change is having many negative impacts worldwide. Increased rainfall caused by climate change has become a serious issue in the northern parts of the world. With more rainfall, a larger amount of brown-colored decaying plant material is transported from the land to oceans, making the seawater browner. The brown color reduces the amount of sunlight that penetrates into the seawater, which can decrease the growth of microscopic plant-like organisms called phytoplankton that rely on sunlight to grow. Phytoplankton are an important food source for ocean animals, such as tiny creatures called zooplankton. This study explored the effects of seawater browning on phytoplankton and zooplankton in the northern Baltic Sea.

RUNOFF

Flow of water over the ground with carrying things like soil and plant leaves.

HUMIC SUBSTANCES

Colored compounds that are found in plant materials. They are released into the surrounding environment when plant material decays.

BROWNING

When the water color turns browner due to the high level of humic substances from decaying plant material.

Figure 1

From left to right, the water gets browner in color due to increasing amounts of humic substances in the water [2] (Photographed by Stefan Löfgren).

PHYTOPLANKTON

Microscopic plant-like organisms that live in water. Like plants, they can produce their food by using carbon dioxide (CO_2), sunlight, nutrients, and water.

ESSENTIAL FATTY ACIDS

Biochemical compounds that are needed for growth and various body functions in human and animals. They are the basic structural components of cell membranes in many organisms.

FOOD WEB

A diagram of how various animals in the environment connect to each other based on who eats whom.

WHAT IS BROWNING?

You have most likely heard about climate change, which is causing changes in the world's weather. Climate change has different effects in different areas of the world (You can read more about climate change in this Frontiers for Young Minds article). For example, due to climate change, some places in the world receive more rainfall, while other places experience severe lack of rain, which is called drought.

In the northern parts of the world, climate change generally results in more rainfall [1]. The increased amount of rainfall causes more water **runoff** from the land to the sea. This runoff usually contains a lot of plant material. When plant material decays, it releases compounds called **humic substances**. The more humic substances that enter the water, the browner the color of the water becomes. We call this effect **browning** (Figure 1). In many places, browning has become a major environmental problem in both freshwater and seawater. This is true in the northern Baltic Sea, for example [3, 4].

Figure 1

WHAT HAPPENS WHEN WATER BECOMES BROWNER?

When water becomes browner, the amount of sunlight that can penetrate into the water is reduced. Lack of sunlight can affect tiny organisms in the water, such as **phytoplankton**, which rely on sunlight, CO_2, nutrients, and water to grow. Browning is expected to reduce the growth of phytoplankton. Phytoplankton are an important source of nutrients, including **essential fatty acids**, which are needed by sea animals to grow and stay healthy. So, reduced growth of phytoplankton means a lower supply of nutrients for ocean **food webs**.

WHAT ARE ESSENTIAL FATTY ACIDS AND HOW DO ANIMALS GET THEM?

Have you ever seen products in supermarkets or pharmacies that are labeled as containing omega-3 fatty acids (Figure 2)? These are also called essential fatty acids, because they are essential (needed) for the health of animals including humans. In humans, essential fatty

acids help prevent heart disease and several types of cancer, and they can improve growth and brain development [5–7]. Phytoplankton can produce essential fatty acids, but animals usually cannot. So, how do animals get essential fatty acids? Well, animals receive these important substances through food webs (You can read more about food webs in this Frontiers for Young Minds article). For example, essential fatty acids produced by phytoplankton can be transferred to tiny animals called **zooplankton** when zooplankton feed on phytoplankton. When zooplankton are then eaten by larger animals, such as fish, the essential fatty acids obtained by zooplankton are then transferred to the fish. Therefore, humans can obtain essential fatty acids by eating fish. The omega-3 fatty acids found in many products sold in supermarkets or pharmacies are actually extracted from fish oil.

ZOOPLANKTON

Small animals that live in water. Some of them look like very small crabs and shrimps. Most of them eat phytoplankton.

Figure 2

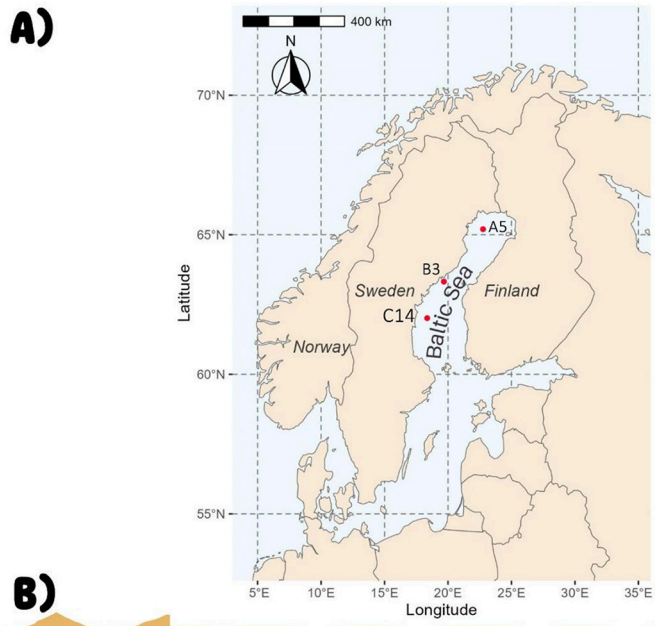
Capsules of omega-3 fatty acids (also called essential fatty acids), obtained from fish oil, are sold in pharmacies and supermarkets.

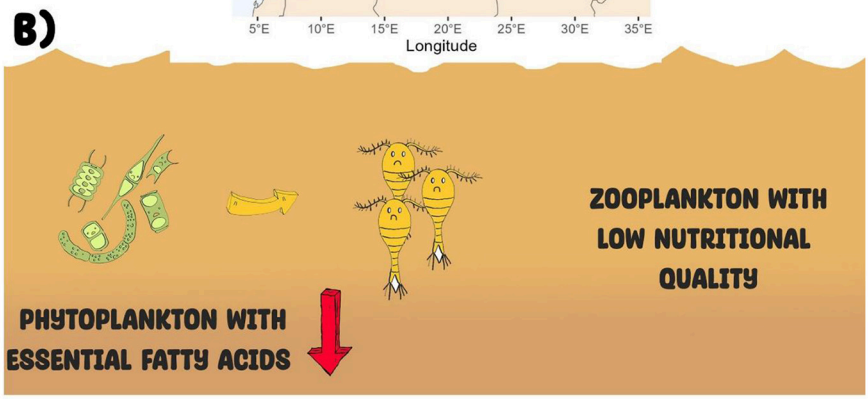
Figure 2

HOW DOES BROWNING AFFECT PHYTOPLANKTON AND ZOOPLANKTON?

To find out how browning affects phytoplankton and zooplankton, we conducted a study in the northern Baltic Sea (Figure 3A). We found that northern locations in the Baltic Sea had higher amounts of humic substances in seawater than southern locations did. This shows that browning is more severe in northern locations. We also measured the amounts of phytoplankton in the seawater samples. Interestingly, we found that the northern locations had lower amounts of phytoplankton than the southern locations had. This means there were fewer phytoplankton available to produce essential fatty acids in the northern locations.

We then measured the amount of essential fatty acids in zooplankton. A higher amount of essential fatty acids indicates that the zooplankton are more nutritious for other organisms that eat them. As we expected, the nutritional quality of zooplankton at the northern locations with more browning was much lower than the nutritional quality of zooplankton at the southern locations. The lower nutritional quality of





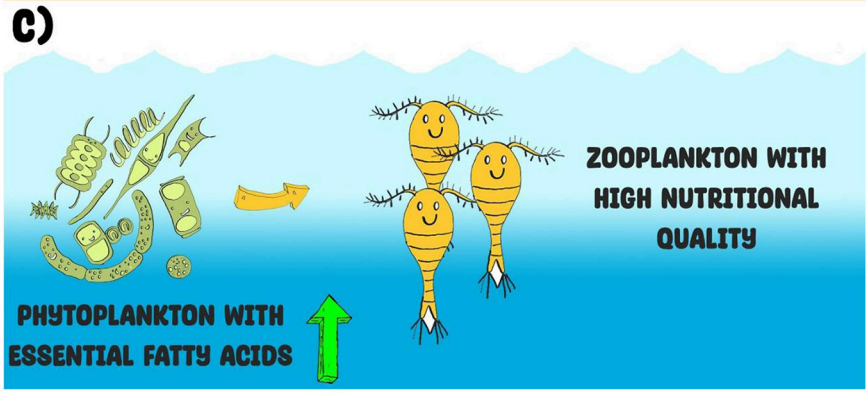


Figure 3

(A) Map of the Baltic Sea. The red dots show the northern (A5 and B3) and the southern (C14) locations of sample collection for the study. **(B)** Northern locations in the northern Baltic Sea had brown water and few phytoplankton producing essential fatty acids. Zooplankton feeding on these phytoplankton had a low amount of essential fatty acids in their bodies, meaning that the zooplankton had low nutritional quality. **(C)** Southern locations in the northern Baltic Sea had clear water and more phytoplankton producing essential fatty acids. Zooplankton feeding on these phytoplankton had a high amount of essential fatty acids in their bodies, so they had a high nutritional quality.

zooplankton was probably due to the lower amounts of essential fatty acids produced by phytoplankton at the northern locations (Figures 3B, C).

WHAT WILL HAPPEN TO MARINE FOOD WEBS?

Zooplankton are a common food for many fish in the Baltic Sea. So, feeding on zooplankton of a lower nutritional quality in browner

waters may negatively affect the nutritional quality and health of fish. The negative effects may pass on through the food web when these fish are eaten by other animals such as birds. However, we are not sure exactly what will happen, and we need to carry out more studies to understand how increased browning may affect the nutritional quality and health of other animals in the food web.

WHAT CAN WE DO?

How can we reduce the effect of browning on marine food webs? The first thing we can think of is promoting actions that will help to reduce climate change. Actions such as reducing the use of fossil fuels, educating yourself and others about climate change, and saving as much energy as possible are several ways to slow climate change. In addition, protecting and restoring streams and rivers that have been destroyed by human activities can also help to fight against browning [2]. Restoration of streams by various activities (e.g., addition of large stones and adding wood to streams) can hold decaying plant material for a longer time, which allows humic substances to decompose completely [2, 8]. This may greatly reduce the amount of humic substances entering the sea and reduce seawater browning. Efforts to reduce browning of seawater will help restore healthy marine organisms and food webs.

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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.

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AARON, AGE: 13
I am a 13-year-old with a passion for karate and basketball. When I am not kicking and shooting hoops, you can find me tinkering with robots or wandering through the forest with my dad, soaking in nature's wonders. I have got two adorable

rabbits who keep me company, and I love nothing more than goofing around with my sister.

ERIC, AGE: 11

My name is Eric, and I am Brazilian. I am 11 years old and in the sixth grade at school. I like to run and participate in sports such as swimming, capoeira, football, and biking. I also enjoy playing games, playing the violin, going to the beach, and playing with my cat, Crystal. Additionally, I have a keen interest in space and robots.

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