frontiers FOR YOUNG MINDS

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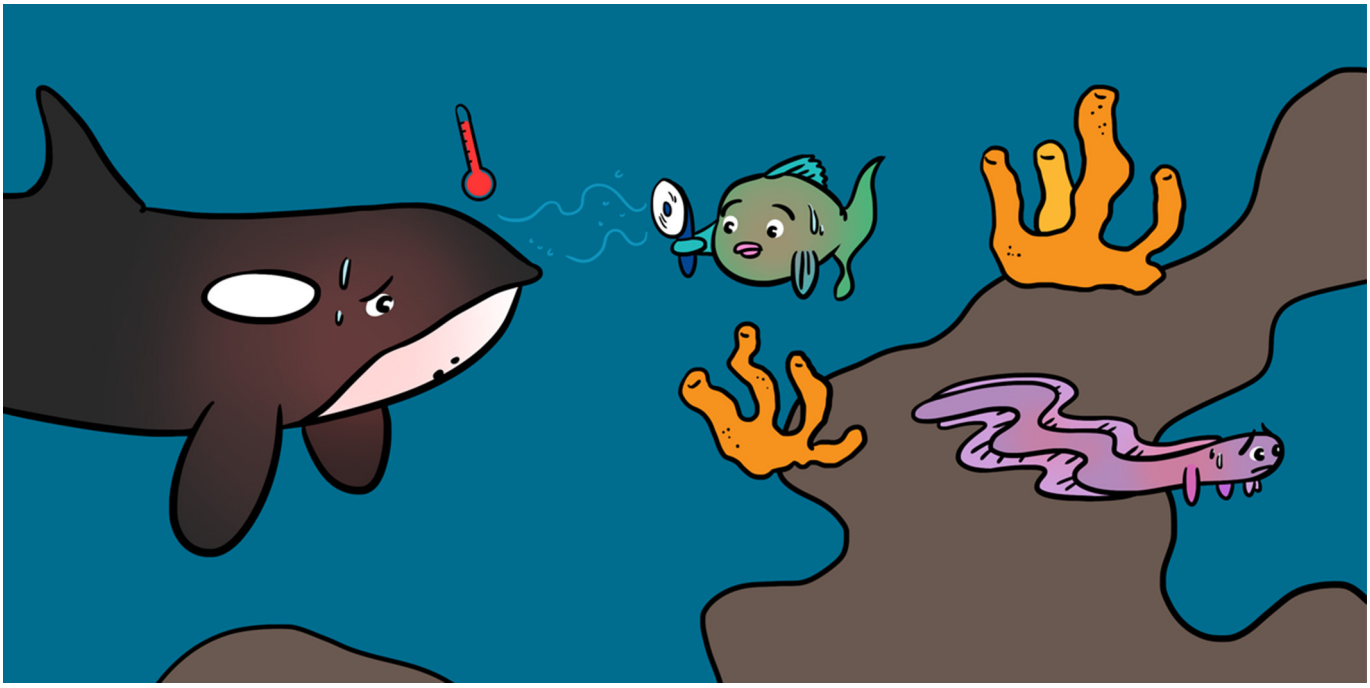

HOW MARINE HEATWAVES IMPACT LIFE IN THE OCEAN

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YOUNG REVIEWERS:


ALREEM
AGE: 15


NOURA
AGE: 14


SAIF
AGE: 14


YOUNIS
AGE: 15

Heatwaves are long periods of hotter-than-usual weather. They happen both on land and in the ocean. In the ocean, these hot periods are called marine heatwaves. Marine heatwaves can be deadly for marine life such as fish, seabirds, and corals. In the past decade, marine heatwaves have become more frequent, and more intense. Every marine heatwave is harmful to marine ecosystems. Marine heatwaves happen all around the world, from the Pacific Ocean to the Atlantic Ocean to the Mediterranean Sea. Climate scientists predict that, in the future, marine heatwaves will last longer and be more frequent, which will inevitably create more problems for marine life and humans. Therefore, we need to better understand why marine heatwaves occur and how they impact life in the ocean.

INTRODUCTION

HEATWAVES

Long periods of abnormally hot weather that can last days, weeks, or even months.

GLOBAL WARMING

Gradual increase of the Earth's air temperature caused by excess carbon dioxide in the atmosphere from human activities, such as burning fossil fuels and deforestation.

Heatwaves, which are long periods of hot weather, are becoming more common and intense due to **global warming**. When the air gets too hot, water evaporates and causes very dry weather conditions, which can trigger bushfires, droughts, and damage to crops. Heatwaves are responsible for thousands of deaths around the world each year [1], and they threaten many animals that cannot survive long periods of heat. Heatwaves can occur in the ocean as well, and we call these events marine heatwaves.

Marine heatwaves are long periods of warmer-than-usual temperatures, measured at the surface of the ocean [2, 3]. They can persist for days, weeks, or even months, and they can occur at any time of year. Marine heatwaves have disastrous consequences for marine animals and plants, such as the destruction of coral reefs and kelp forests. Many species of fish, marine mammals, and seabirds do not survive major marine heatwaves. Death of marine species is also a major problem for humans, as many people living along the coast rely on fish and other ocean organisms for food.

Marine heatwaves happen all around the world and are becoming more frequent (Figure 1). Notable marine heatwaves occurred along the western Australian coast in 2011, in the Tasman Sea in 2015–2016, in the Pacific Ocean in 2013–2015 (called "The Blob"), and in 2019 [4]. In 2015–2016, an important marine heatwave happened over the northwest Pacific Ocean. The water temperature was over 6°C warmer than usual. This event forced entire fish communities such as Chinook salmon, cod, and sockeye salmon to move far away where the water temperature was more bearable [5]. Many sea lions, whales and seabirds were found beached because of the lack of food caused by the migration of fish [4].

Figure 1

Marine heatwaves happen all around the world. Those shown here have happened since 2000.

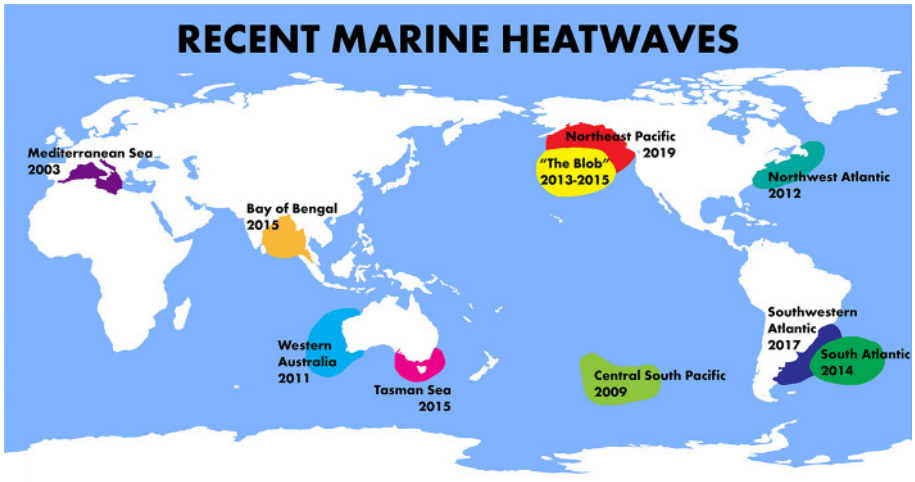

Figure 1

Figure 2

Marine heatwaves are ocean-driven or atmosphere-driven. Ocean-driven marine heatwaves are caused by ocean currents bringing warm waters. Atmosphere-driven marine heatwaves are caused by weak winds preventing heat to escape from the ocean. In both cases, the heat accumulates at the surface of the ocean and creates a marine heat wave.

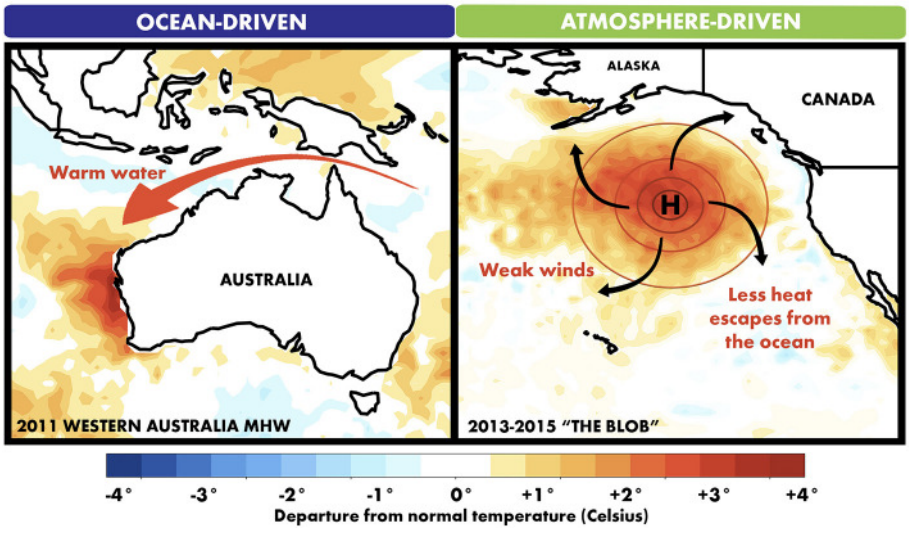

Figure 2

Climate scientists predict that, due to global warming, future marine heatwaves will become more frequent and last longer. Why do marine heatwaves happen? Understanding what causes these dangerous heatwaves is important if we want to protect life in the ocean.

WHAT CAUSES MARINE HEATWAVES?

Temperatures at the surface of the ocean vary all year long. The surface water gets colder in winter and warmer in summer, due to the energy of the sun. This natural cycle benefits marine life, which migrates according to the water temperature. Certain weather conditions can increase the surface water temperature significantly. If these conditions last for a long time, we call it a marine heatwave. Marine heatwaves are often unbearable for marine life.

The main factors that influence the ocean surface temperature are **ocean currents** and the exchange of heat between the ocean surface and the atmosphere [2] as shown in Figure 2. Ocean currents can bring warm waters to a colder area. Additionally, the atmosphere controls heat transfer into and from the ocean, via the winds. When winds are strong, heat can escape easily from the ocean, just like wind blowing on your skin draws heat away from your body. The opposite is also true: if the winds are weak, the heat remains trapped at the ocean surface for longer. We can broadly classify marine heatwaves into two categories: those driven by the ocean, and those driven by the atmosphere.

OCEAN CURRENTS

Continuous movement of large quantity of water in the ocean, driven by winds and temperature differences.

An ocean-driven marine heatwave occurred in 2011 offshore of western Australia. During that time, a climate phenomenon called **La Niña** modified the ocean currents and brought warm water to the western Australian coast. The ocean temperatures were more than 3°C

LA NIÑA

A weather pattern in the equatorial Pacific Ocean, causing water to become much colder than usual off the coast of Peru, and much warmer off the coast of Australia.

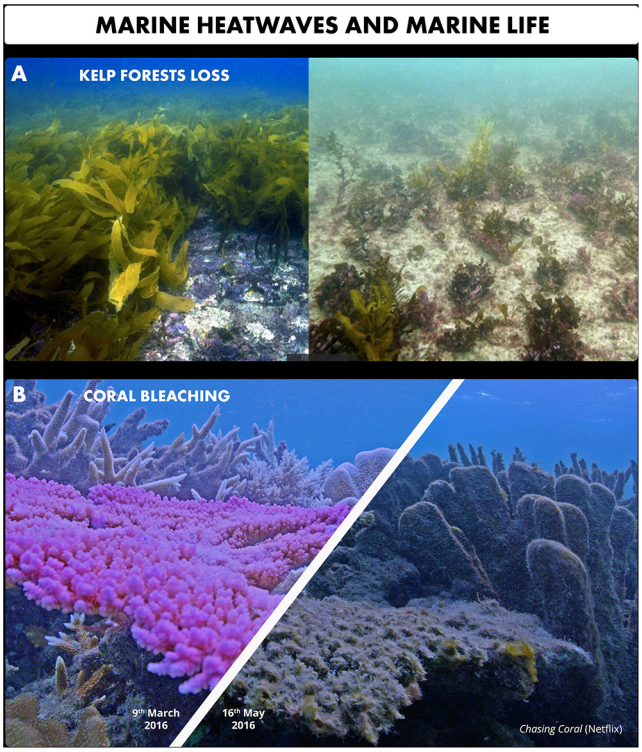

Figure 3

Marine heatwaves have disastrous impacts on marine life. **(A)** A recent marine heatwave caused kelp forest loss in Australia (Photograph credit: Thomas Wernberg). **(B)** Marine heatwaves can cause coral bleaching, which happens when the algae that live on corals and give them their color leave to escape the heat, leaving the corals white (Photograph credit: Chasing Corals, Netflix).

above normal. Weak winds allowed this heatwave to persist for several months [6].

"The Blob" in the northwest Pacific, on the other hand, was caused by the atmosphere. The **atmospheric pressure** (the weight of air) over the region was higher than usual, which led to very weak winds. Those weak winds prevented the heat from escaping to the atmosphere, resulting in the strongest marine heatwave ever recorded at that time [7].

ATMOSPHERIC PRESSURE

Force exerted by the weight of the air above the Earth's surface.

Now that we know why marine heatwaves happen, we can make projections for the future. Marine heatwaves have already become 34% more frequent and 17% longer between 1925 and 2016 [8]. At current rates of global warming, climate scientists predict that global ocean and atmospheric temperatures will keep increasing. As the ocean surface warms up, marine heatwaves will probably become more frequent, more intense, and last longer [3, 8].

MARINE HEATWAVES ARE DISASTROUS FOR MARINE LIFE

Heatwaves have disastrous impacts on marine life. Just like heatwaves on land worsen human health issues and can kill people (for example, through heat stress or bushfires), marine heatwaves affect the health of marine species [1]. In some cases, heat stress destroys marine habitats

(Figure 3). Fish, whales, and sea turtles are forced to migrate to cooler areas of the ocean. Although these animals naturally migrate to hunt for food and reproduce, marine heatwaves force them to change their migration behavior more drastically.

For example, during "The Blob," fishermen unexpectedly saw blue sharks and thresher sharks in the Gulf of Alaska in summer, when these animals are usually found around the coast of California [9]. Many other species of fish, such as coho salmon and Alaskan pollock, experienced impacts on their migration patterns as well. This shift in where fish are found can have an important effect on the food chain [9].

Other marine species, like corals, cannot change location. The 2011 western Australia marine heatwave caused extreme damage to immovable plants and animals. It wiped out kelp forests and caused **coral bleaching**, which happens when the algae living on corals, which give them their color, escape from the heat, leaving the corals white [8].

CORAL BLEACHING

Whitening of corals caused when the algae normally living on them, which give corals their color, leave or die. This happens when the ocean gets too warm.

WHAT DOES THE FUTURE HOLD FOR MARINE LIFE?

Each time marine heatwaves occur, they alter and often destroy marine ecosystems [4]. Some species can adapt to the extreme temperatures, such as fish that can swim away to cooler areas. Many species, like corals or kelp forests, cannot escape the heat—although some are better at resisting it. In general, marine heatwaves are destructive and their impacts on the marine ecosystem could be greater than we currently know. For example, coral reefs provide a habitat for fish, sea stars, crabs, sponges, and clams. Thus, coral bleaching due to marine heatwaves could lead to disastrous consequences for a lot of marine life.

The ocean is valuable; it provides vast economic benefits, from food (such as fish and shellfish) to tourism to all the jobs related to those industries, along with energy for our homes, and even medicines. We need to protect ocean inhabitants and resources. Actions to halt global warming can prevent marine life from dying, including reducing our emissions of carbon dioxide. Marine heatwaves are becoming increasingly more common, so we need to find ways to protect and maintain marine ecosystem systems and all the animals that live there. One solution is to create **marine protected areas**, which are regions of the ocean where human activities, from fishing to mining, are limited or completely banned. These areas do not prevent damage caused by marine heatwaves, but they serve as sanctuaries where marine life can develop peacefully, away from human pressure, and they allow marine life to recover from periods of intense stress such as those caused by marine heatwaves [10]. Understanding the impacts of marine heatwaves on life in the ocean, and developing strategies to

MARINE PROTECTED AREAS (MPAS)

Protected areas of the ocean providing marine ecosystems with an environment with limited to no stress caused by human activities such as fishing, boating and leisure activities.

counteract their impacts, is important as healthy marine ecosystems are necessary to our livelihood and wellbeing.

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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

ALREEM, AGE: 15
Alreem is an animal lover who loves science and adventures, a night owl, I am not a good cook however when it comes to instructions, I can follow and make a decent dish. I have two love birds one is named hades the other is daisy, love them and treat them like my own kids.

NOURA, AGE: 14
I am Noura, I have many interests such as building robots and playing the piano, but science has a special place in my heart and I have always been looking for the latest scientific researchs and projects.

SAIF, AGE: 14
Hi! My name is Saif. I am 14 years old from the United Arab Emirates. I have always been passionate about science, particularly biology and chemistry. I love to read science books and biographies about fascinating people such as Steve Jobs. I also participate in programs and competitions that enhance and improve my passion for science, such as wining the best group project at the National Science Fair in 2020. I also enjoy doing experiments with my science teacher.

YOUNIS, AGE: 15
Hi! My name is younis, and I am 15 years old, I have always felt attracted to science subjects as they are very fascinating, especially environmental management geography geology and space. And through frontiers for young minds I hope to learn more about the world we live in.

AUTHORS

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I am a Ph.D. student in Ocean Sciences at Georgia Institute of Technology in Atlanta, USA. I do research on marine heatwaves and their impacts on land and in the ocean. I use numerical models to simulate the ocean currents and the atmosphere. I am also involved in science communication focused on understanding the science

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