Plankton are central to life on Earth: How is climate change affecting them?

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Green algae blooms in the Baltic Sea. Credit: Photo: European Space Agency

Recently, scientists reported that more than half of our oceans are

turning greener, an indication that they might contain more phytoplankton. Along the California coast, hundreds of sea lions and dolphins turned up sick or dying after being exposed to toxic algae blooms caused by harmful plankton. And in Thailand, thousands of dead fish washed ashore, suffocated by a plankton bloom.

Plankton are the building blocks of marine and freshwater ecosystems, and key to cycling of gases in the Earth's atmosphere. But the planet's waters and air are changing rapidly due to shifting climate, and this affects plankton. Some of these effects are not good. Here is a look at what plankton are, and their interactions with climate.

What are plankton?

"Plankton" comes from the Greek word for "drifter." Plankton are organisms that float around in the ocean. "Many can swim, but they can't swim strongly enough to oppose the currents. Basically, they're at the mercy of the currents," said Andrew Juhl, a research professor at Columbia University's Lamont-Doherty Earth Observatory specializing in aquatic ecology.

"Plankton is not a particular group of organisms; it's many different kinds of organisms that share a lifestyle," he said. They can be found in salt or fresh water, and can range in size from microscopic (most are) to easily visible crustaceans or jellyfish.

Plankton are divided into two groups: phytoplankton, which are plants, and zooplankton, which are animals. However, in the plankton world, the distinction between plant and animal is complicated.

Some organisms get their nutrition from photosynthesis; others get it by eating other organisms; some organisms are photosynthetic, but also eat other organisms; some bacteria are also classified as plankton and are

decomposers; and many more organisms are in between or do multiple things.

In terms of photosynthetic organisms, there is far more diversity in ocean plankton than on land, said Juhl. There are probably 100,000 different species of phytoplankton, each of which may have different characteristics, different ecological functions, and different distributions. Zooplankton, too, include many, many, different groups.

Phytoplankton, which, like land plants, contain chlorophyll, are found near the surface because they need the sun's rays. They use sunlight and nutrients such as phosphate, nitrate and calcium to create energy and grow, taking in carbon dioxide and releasing oxygen. Phytoplankton perform about 50% of all the photosynthesis on the planet. It is estimated that they have produced about half of all the Earth's oxygen.

Some examples of phytoplankton are cyanobacteria (also known as blue-green algae); diatoms, which have cell walls of silica, and are the most abundant and diverse group; and dinoflagellates, which have appendages that help them move. All algae are phytoplankton, but not all phytoplankton are algae.

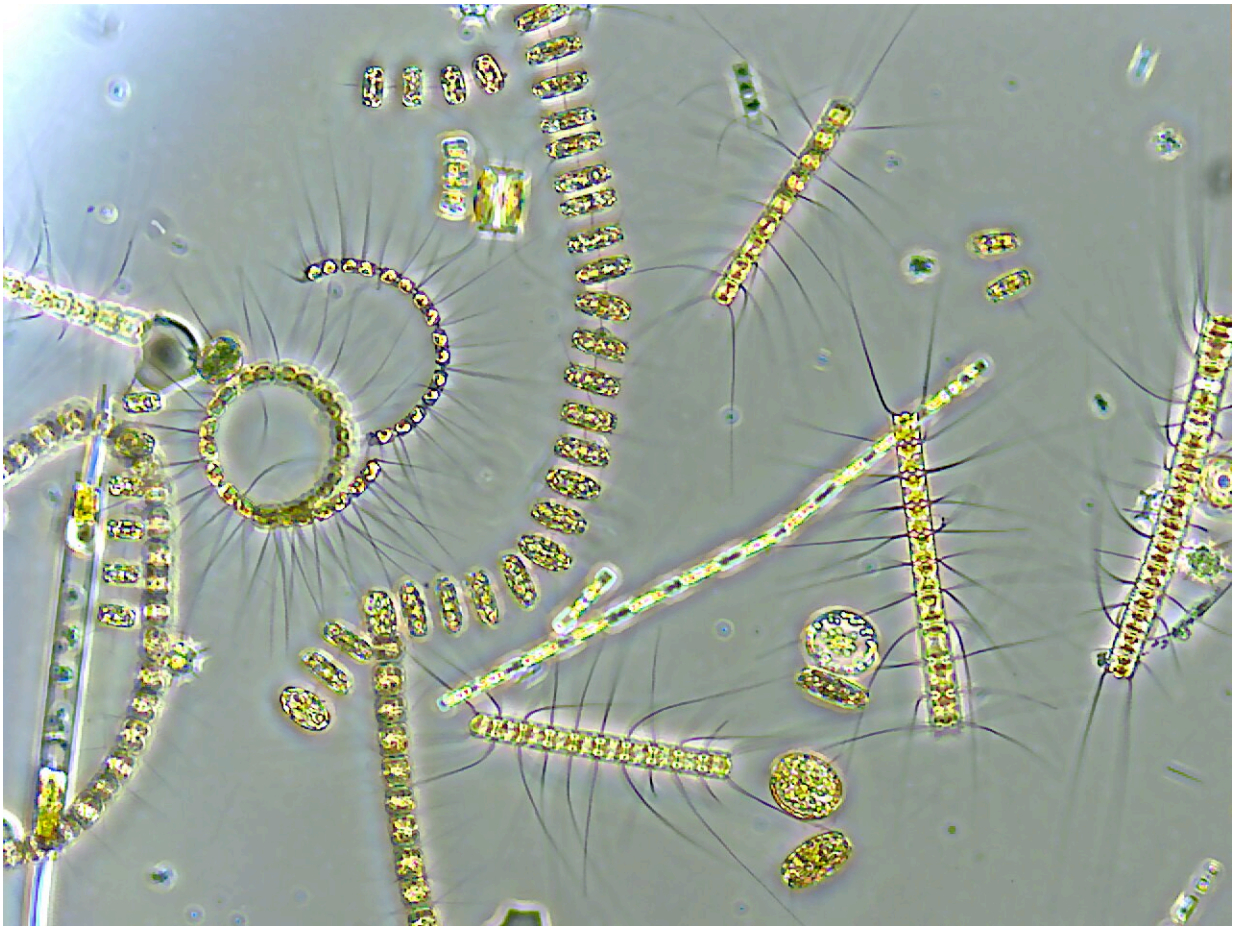
Zooplankton include animals such as krill, copepods, small shrimp-like crustaceans and jellyfish. They generally feed on phytoplankton and are in turn eaten by fish and other larger organisms.

Why are plankton important?

Plankton are the foundation of the entire marine food chain. The health and productivity of all marine life ultimately depend on them.

Plankton also play important roles in the Earth's carbon cycle. When phytoplankton die, some of the carbon they take in through

photosynthesis sinks to the ocean depths, where it is sequestered from the atmosphere. This process, called the biological pump, makes the ocean the Earth's largest carbon sink.



Phytoplankton community. Credit: NASA

Oceans have absorbed an estimated 40% of all the carbon dioxide humans have put into the atmosphere since the Industrial Revolution. Globally, the biological pump transfers 10 billion metric tons of carbon from the atmosphere to the ocean depths each year.

Phytoplankton are useful to humans in other ways as well. More efficient than land plants at photosynthesis and carbon storage, phytoplankton can be a renewable resource. Protein-rich phytoplankton can provide an alternative to fish meal used in aquaculture, and supplements for meat- and soy-based animal feeds. While growing soy and other crops uses up land, fertilizer and other resources, algae production requires little space and is less harmful for the environment.

Enzymes from plankton are used in pharmaceutical products and food products. Fats from plankton are put into cosmetics and food supplements. They can also be used as fertilizers in place of chemical-based products. Organic compounds produced by plankton have potential to be used to treat Alzheimer's, cancer, diabetes, AIDS, osteoporosis and other diseases.

There has been much interest in cultivating phytoplankton for biodiesel fuel, but that promise has yet to be met.

They grow rapidly, have high fat content and produce up to 30 times more energy than other biofuels. However, recent research found that manufacturing and using biodiesel from phytoplankton actually consumes more energy than the biofuel can produce, and may have a bigger carbon footprint than fossil-fuel diesel. In order for a viable low-carbon fuel to be made from microalgae, enhanced microalgae strains and improved infrastructure design would be necessary.

How is climate change affecting plankton?

Because of the enormous diversity in the plankton world, it's unlikely that the many different kinds of organisms would have a universal response to any given stress from climate change.

Some climate models project that warming temperatures will alter ocean

currents, reducing the amount of nutrients that well up from the deep ocean, resulting in fewer phytoplankton. With fewer phytoplankton, the ability of the oceans to sequester carbon dioxide would likely be hampered, leaving more in the atmosphere to exacerbate climate change.

A recent study found that warming temperatures cause certain phytoplankton to change from carbon absorbers to carbon emitters, a potential and unanticipated climate tipping point. Some phytoplankton are mixotrophs, meaning they can get energy either through photosynthesis or by eating other organisms. When they perform photosynthesis, they take carbon out of the atmosphere; but when they eat other organisms, they end up emitting more CO_2 than they absorb.

Climate change may also be increasing the frequency of large phytoplankton blooms in both fresh water and the ocean. Numerous factors contribute to such blooms: more nutrients in the water from fertilizer runoff or sewage; the upwelling of deep ocean water toward the surface, which brings up more nutrients; warmer water temperatures; slow water flow or still water; and low turbidity, which enables the sun to shine through the water, helping phytoplankton growth.

As ocean temperatures rise and circulation patterns change, blooms are growing bigger and more frequent around the world. A recent study that mapped marine coastal algal blooms between 2003 and 2020 found that globally they increased in size by 13% (1.5 million more square miles), and frequency by 59% during that period.

Large blooms can be beneficial for marine life and fisheries, but harmful algal blooms can be toxic to living creatures or harm the environment in other ways.

An octopus zooplankton. Credit: NOAA

"Blooms happen all the time," said Juhl. "At least at higher latitudes, it is part of the typical seasonal cycle—you get a bloom in the spring. And in many other places, you get a bloom as a result of a storm passing through or something that mixes nutrients up. Or if you have a lot of rain, you might get nutrients flushed out of a river that can cause a bloom."

While Juhl said that there are relatively few harmful phytoplankton types, their blooms seem to be on the increase. He believes that it is at least partly due to better observations and increases in nutrient concentrations. Some research has documented an increase in harmful algal blooms over time that coincides with changes in the climate, but it's

unclear whether climate change is driving this.

That said, climate change can create conditions that make blooms more likely. Drought followed by extreme precipitation increases the amount of runoff from agricultural lands and lawns, delivering more nutrients into water bodies. Droughts can reduce flow in water bodies, making remaining water warmer and more stagnant, which favors algal blooms. And because algae need CO_2 to grow, higher levels of CO_2 in the atmosphere and water can promote algae growth, especially toxic blue-green algae. Rising sea levels also mean that coastal water is stabler and shallower, which can enhance algae growth.

Harmful algae blooms cost the U.S. millions of dollars in damages each year due to fishery and tourism losses, damage to drinking water, cleanup costs, and hospital visits.

Freshwater harmful algal blooms, found in all 50 U.S. states, are often caused by cyanobacteria, which release toxins. They can also occur in salt water.

In warmer water, they grow faster than nontoxic algae. Cyanobacteria can turn water green, blue, red or brown, and often produce a smelly scum on the water's surface. Some cyanobacteria produce toxins that can cause neurological damage. Others release toxins that cause liver damage, skin irritations or respiratory problems.

People and pets can be exposed to the toxins by swimming in or swallowing contaminated water, inhaling droplets of airborne toxins, or eating contaminated fish or shellfish, even after it is cooked. The health impacts can be mild, severe or even fatal, depending on the type of toxin and level of exposure.

Joaquim Goes, a biological oceanographer at Lamont-Doherty, is leading

a study of a harmful algae bloom in an artificial pond in Manhattan's Morningside Park. His team's goal is to figure out ways to lessen such blooms and devise an early warning system. The study may extend to other city parks.

Dinoflagellates and diatoms cause the most harmful algal blooms in salt water; these are called red tides because they turn the water red. Red-tide toxins can make both humans and animals sick. The dinoflagellate species Karenia brevis produces a neurotoxin that can cause paralysis and respiratory failure, and disrupt reproduction in marine life.

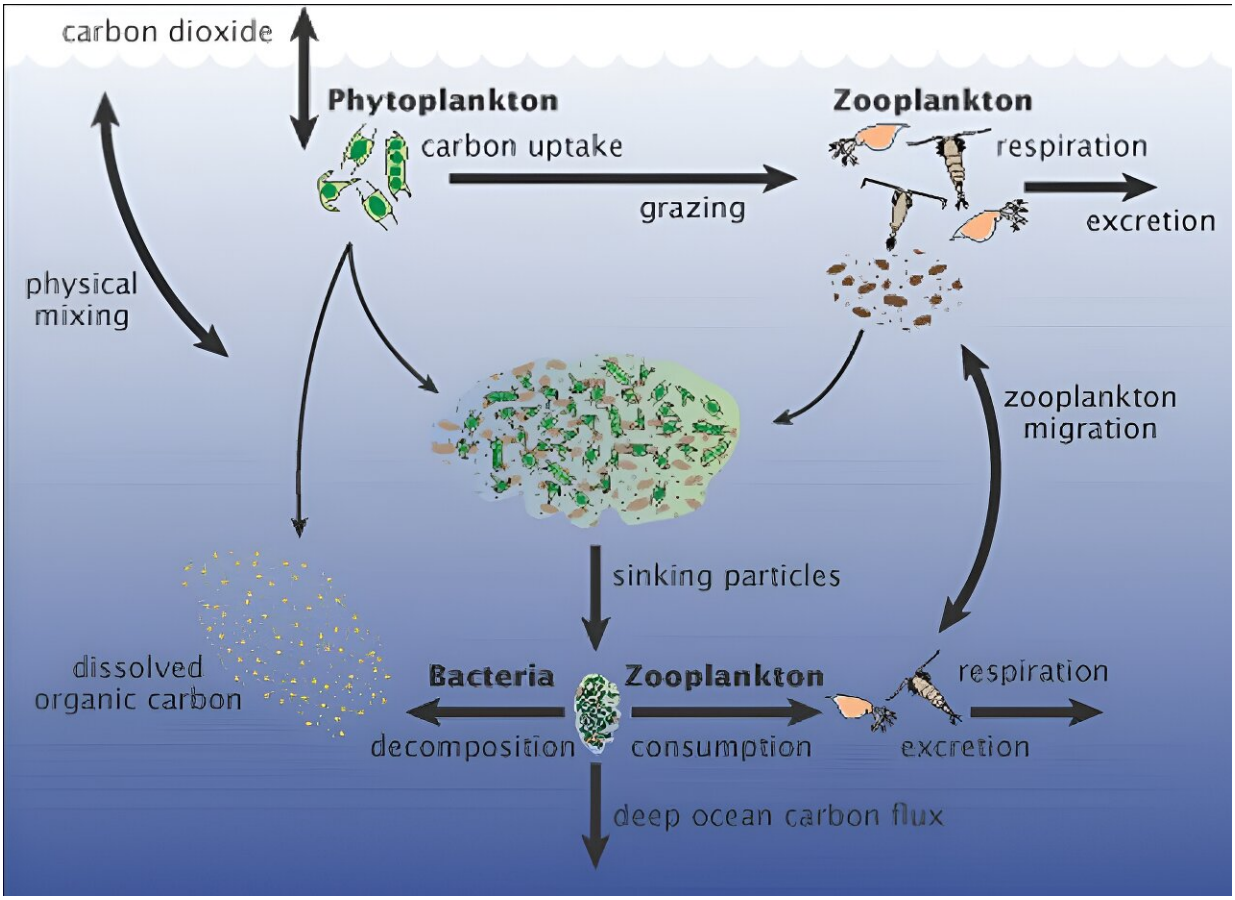
In humans, it causes eye and respiratory irritation and, if consumed in tainted seafood, numbness, nausea, vomiting and diarrhea. This spring, red tides in Florida killed thousands of fish and other marine animals including increasingly threatened manatees. Red tides have increased fifteen-fold in Florida over the last 50 years.

Another type of harmful bloom is caused by so-called golden algae, found mostly in the ocean, but increasingly now in freshwater too. These blooms can kill large numbers of fish, but are not harmful to humans. Between 2001 and 2010, golden algae blooms in Texas wiped out more than 34 million fish, costing the state more than $14 million.

Blooms don't have to release toxins to do damage. When blooms die and decay, they create "dead zones." This is because the decomposition process uses up most of the oxygen in the water, so that other organisms suffocate and die.

The U.S. Environmental Protection Agency says there are scores of dead zones in U.S. waters at any one time, the largest being one at the mouth of the Mississippi River that can extend in summer to 6,500 square miles, due to excessive nutrients washing out. A 2020 report estimated that this dead zone results in $2.4 billion each year in damages to

fisheries and marine habitat. The decomposition process can also produce harmful gases such as methane and hydrogen sulfide. Dense blooms can block the sun for other plants and animals, clog the gills of fish, and smother corals.



Credit: NASA

Changing environmental conditions

Climate change is altering environmental conditions all over the world. "When you change environmental conditions, you're definitely going to

have change [in plankton]," said Juhl. "That change at the base of the food web is going to reverberate through the entire food web."

Different plankton species are used to different water temperatures and environmental conditions. As oceans warm and conditions change, species must adapt, migrate or go extinct. How plankton respond to warming waters and ocean acidification—another product of climate change—will affect ecosystem functioning and biomass production, and ultimately the productivity of the food web.

For example, the Gulf of Maine, off New England and southern Canada, has become warmer and saltier over the last 20 years; concurrently, phytoplankton have become 65% less productive.

Tropical oceans host the most diverse populations of plankton. Eight million years ago, when the earth was as warm as it is today, tropical plankton lived 2,000 miles from the equator. According to a recent study , they moved back toward the equator as the planet cooled. The research suggests that today, warm-water plankton could once again move away from the equator. This could alter ecosystems in higher latitudes and potentially harm the fish and coastal communities that depend on them.

In the Arctic, researchers have found that changing conditions offer opportunities for new plankton species to prevail. Here, melting glaciers increase the amount of fresh water in the Arctic Ocean; it lies on top of the salty ocean waters and stops nutrients from upwelling to where plankton can access them. One study found that mixotrophs, which do not rely only on photosynthesis, do well in relatively fresh water with less nutrients. The scientists studied a toxic mixtroph algal bloom and speculated that if these blooms start to appear more frequently in the Arctic, they could have ecological and socio-economic impacts.

Will plankton survive climate change?

"Most of the organisms that we see in the plankton have been around for a very long time and have lived through lots of cycles of climate change that are not anthropogenic," said Juhl. "They dealt with it, so they're probably not going to go away." But because our societies are built around assumptions that things will stay the way they've always been, these changes will bring disruptions.

"It's not existential from the perspective of the plankton," said Juhl. "But it is existential, perhaps for human beings. Plankton don't care about us, but we should care about them. One of the things I often tell people is to take a breath. Every time you breathe in, one of our lungs is filling up with oxygen that came from the tropical rain forest, which are often described as the lungs of the planet. But the other lung is filling up with oxygen that was produced in the ocean by phytoplankton."

How to protect yourself from harmful algal blooms

- Check with local health advisories to see if there are harmful blooms in nearby water bodies.
- Know the warning signs: bright green, blue-green or red water; slimy plants or scum on the surface; smelly water.
- Avoid contact with the water if warning signs are posted.
- Keep pets from going into the water.
- Don't go boating, fishing, or do other water sports when harmful algae are around.
- If exposed, rinse skin immediately with clear water.
- Wearing gloves, rinse off animals that have come in contact with contaminated water.
- Don't wash dishes or camping equipment in water bodies.

If you'd like to help monitor harmful algal blooms, volunteer for the Phytoplankton Monitoring Network, established by National Oceanic

and Atmospheric Administration.

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