Fleeting phytoplankton

"Changing the arrival and departure of sea ice changes the timing of phytoplankton growth."

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by Laura Naranjo

Over the long, dark winters, sea ice forms across the Southern Ocean surrounding Antarctica. During the short summer much of the sea ice melts, and the ocean bursts into a brief flurry of life, feeding everything from fish to penguins to massive humpback whales. This annual summer boom is based on phytoplankton, microscopic plant-like creatures that live near the ocean surface. Dormant during the winter, in the summer sunlight they reproduce and bloom prolifically. Or they used to.

Scientists working on the Antarctic Peninsula noticed that over the past several decades, phytoplankton blooms have been on the wane. At the same time, the length of the ice season has shortened by nearly three months. On average, ice along the Peninsula now forms fifty-four days later and melts thirty-one days earlier. The shorter ice season means more sunlight reaches the ocean surface. More sunlight should mean more phytoplankton, and consequently, a booming ecosystem further up the food chain. But the researchers discovered that was not happening. They

Krill are small, shrimp-like sea creatures that form the basis of an entire marine food chain. Along the northern Antarctic Peninsula, penguins and whales feed on krill. Southern Ocean krill are similar to the northern krill shown in this photograph. (Courtesy Ø. Paulsen) began to wonder, was disappearing sea ice to blame for the disappearing plankton? And what happens to the animals that depend on the microscopic creatures?

Receding ice

As it turns out, sea ice creates just the environment that phytoplankton need to thrive. Although the ocean is constantly swirling and mixing, it settles into layers that stratify the water. Phytoplankton prefer the topmost layer, nearest the sun, which is why their brilliant red or green blooms are often visible. They also like the fresher water contained in this surface layer, as it allows them to float above the saltier and denser layers below.

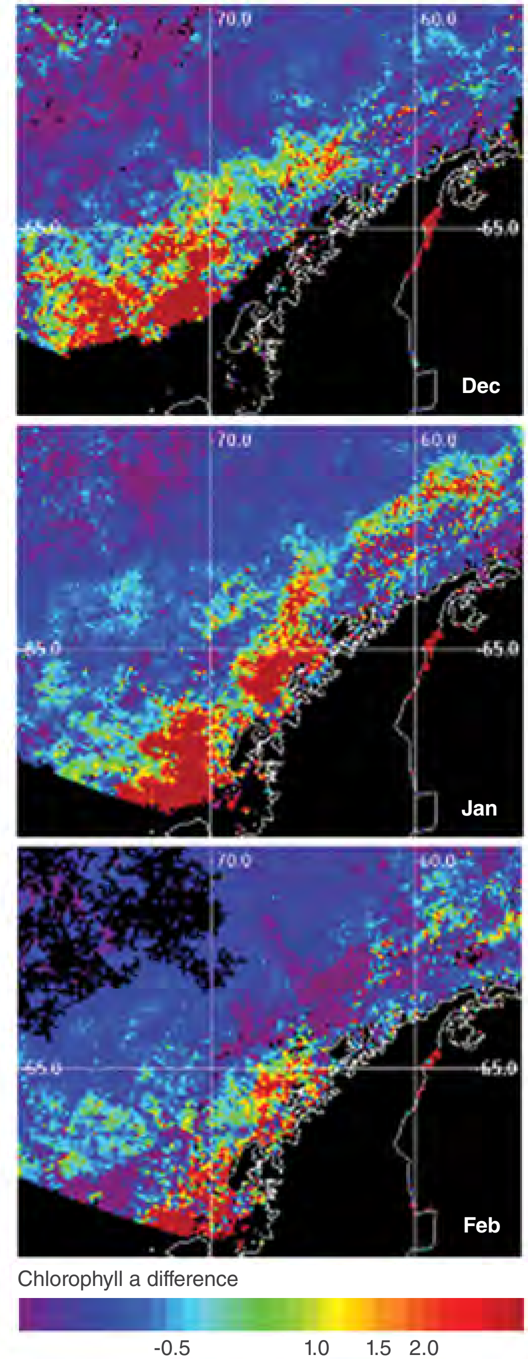
In the Southern Ocean, the annual spring sea ice melt helps create this top layer. Because salt does not freeze, it is slowly expelled as ocean water freezes, meaning sea ice contains almost no salt. "Melting sea ice means fresh water, which is going to help stratify salty water. It creates a cap of fresh water near the surface that helps phytoplankton to grow," said Martin Montes-Hugo, a researcher at the University of Quebec. Montes-Hugo collaborated with colleagues conducting research at Palmer Station, situated on the western coast of the Peninsula, to see how sea ice might be affecting phytoplankton.

North and south

Although phytoplankton blooms are sometimes visible to the naked eye, seeing their full extent often requires an aerial view. Satellite sensors can be ideal for this, because they capture the large swaths of ocean colored by blooms. For the scientists, the trick was to find satellite data that extended back in time far enough to reveal a trend they could compare to decades of sea ice records. They could get data collected by the NASA Coastal Zone Color Scanner from 1978 to 1986, and by the NASA Sea-Viewing Wide Field-of-View Sensor from 1998 through 2006, from the NASA Ocean Biology Processing Group. To fill the time gap between the two data sets, the scientists used meteorological and oceanographic data gathered on annual cruises, along with records from their colleagues at Palmer Station.

They found that the northern and southern parts of the Peninsula told very different stories. The northern tip of the Peninsula was experiencing the most change, including the most drastic sea ice loss, and the plankton populations there were decreasing dramatically. But on the southern end, where the Peninsula broadens into the continent, sea ice was not diminishing as fast, and plankton were still thriving.

These differences between north and south carried consequences for the food chain along the Peninsula. The vast blooms of microscopic phytoplankton feed krill, which are larger, shrimp-like plankton. In turn, fish, penguins, nd whales live on the krill. "Changing the arrival and departure of sea ice changes the timing of phytoplankton growth," said Montes-Hugo.



These satellite images show how chlorophyll a populations decreased during the Southern Hemisphere summer months along the Antarctic Peninsula. Chlorophyll a indicates the presence of phytoplankton, which are at the base of the marine food chain. Blue and purple indicate decreasing phytoplankton; orange and red indicate stable or increasing populations. Land is shown in black. Data are monthly average satellite-derived chlorophyll difference between 2001 and 2006 from the Coastal Zone Color Scanner and the Sea-Viewing Wide Field-of-View Sensor. (Courtesy M. Montes-Hugo)

This Adelie penguin (top) is regurgitating krill to feed its chick. Adelie populations have crashed along the northern Antarctic Peninsula, as their food source of krill diminishes. Adelies have been replaced by other species, like Chinstrap penguins (bottom), that do not rely as heavily on krill. (Top: Courtesy L. Quinn; bottom photograph by Lieutenant P. Hall courtesy NOAA Corps)

"The krill are disappearing in the north and are actually increasing in the south. The food web is moving south and is being replaced by a different food web to the north."

Plankton blooms in the north now favor smaller organisms instead of the large diatoms that krill prefer. As the krill move south, a form of plankton called salps are taking over the northern part of the food chain. Salps are large, translucent, barrel-shaped plankton that resemble jellyfish. They are mostly composed of water and are not as nutritious as krill, so some penguin and whale species cannot survive on them.

Receding sea ice in the north was pushing certain species to the more stable ice conditions remaining along the southern Peninsula. But when the researchers looked at the entire region, they discovered that disappearing sea ice was only part of what was causing such a dramatic shift in phytoplankton populations.

Wind, clouds, and currents

At first glance, it seemed that a shorter sea ice season would prime the ocean for more frequent or more extensive blooms. "Typically, you'd think that as the ice retreats, it opens the water up to let more light in and stratify the water. That's very good for the phytoplankton," said Scott Doney, a senior scientist at the Woods Hole Oceanographic Institution, and one of Montes-Hugo's colleagues. But as they pored through the data, the team discovered that over the same time period, changes in weather were exacerbating the changes in sea ice and plankton.

Receding ice was leaving the ocean surface vulnerable to intense wind. Some wind mixing is beneficial because it helps dredge up nutrients from deeper ocean layers without disturbing the stratified layers that keep fresh water, and phytoplankton, near the surface. But the winds around Antarctica are notoriously strong, and were becoming even more intense. Doney said, "A lot of wind mixing destroys that stratification, and the phytoplankton mix down deeper in the water column where there's less light." The lack of sea ice left phytoplankton to the mercies of an increasingly wind-whipped surface, particularly along the northern Peninsula. And even if phytoplankton managed to stay near the turbulent surface, the stronger winds were blowing more clouds over the northern Peninsula, obscuring sunlight and further restricting blooms.

In addition, the Peninsula may be receiving a double dose of warming: changes in atmospheric circulation are sweeping warmer, sub-polar air across the region while at the same time the temperature of the Antarctic Circumpolar Current that surrounds the continent may be rising. This current normally helps chill Antarctica and acts as a barrier against more temperate currents. But the circumpolar current is now bathing the coasts in slightly warmer water. Doney said, "The whole climate change story is connected. In the north, you're getting changes in wind, and that's also linked to cloudiness. So you have less sea ice, more northerly winds, more cloudy conditions, and warmer conditions. Those are all linked together."

Fluctuating food webs

Sea ice may have been the most obvious indicator of phytoplankton health, but the entire climate of the Peninsula has been shifting for decades, and these changes are starting to propagate up the region's food chain. Doney said, "We've seen almost a complete collapse of the local Adelie penguin population." Adelie colonies along the Peninsula have been replaced by Chinstrap penguins, which do not depend on krill. Montes-Hugo added, "Now these food chains are going to be replaced by a different food chain, based on a different kind of penguin." Likewise, baleen, fin, and humpback whales also feed on krill, and will be affected by changes in phytoplankton blooms and locations.

Disappearing sea ice is causing a cascade of change throughout the ecosystem. Although sea ice is more stable along the southern coasts, environmental change may be creeping to that portion of the Peninsula. With more ecological shifts in store, scientists wonder whether these changes will soon manifest in other parts of Antarctica. Montes-Hugo asked, "How will the future be, in terms of wind, in terms of cloudiness, in terms of sea ice? How are all of them going to impact the timing and magnitude of the blooms?"

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Reference

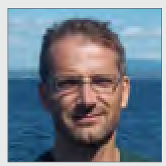
Montes-Hugo, M., S. C. Doney, H. W. Ducklow, W. Fraser, D. Martinson, S. E. Stammerjohn, and O. Schofield. 2009. Recent changes in phytoplankton communities associated with rapid regional climate change along the western Antarctic Peninsula. *Science* 323(5920): 1470−1,473, doi:10.1126/science.1164533.

About the remote sensing data used

Satellites	Nimbus 7	SeaStar
Sensors	Coastal Zone Color Scanner	Sea-Viewing Wide Field-of-View Sensor
Data sets	CZCS Monthly Climatologies	SeaWiFS Monthly Climatologies
Resolution	4.5 kilometer	4.5 kilometer
Parameters	Chlorophyll a	Chlorophyll a
DAACs	NASA Ocean Biology Processing Group (OBPG)	NASA OBPG

About the scientists

Scott C. Doney is a senior scientist in marine chemistry and geochemistry at the Woods Hole Oceanographic Institution. He studies marine biogeochemistry and ecosystem dynamics. The National Science Foundation supported his research. (Photograph courtesy S. Doney)



Martin Montes-Hugo is a professor and researcher at the Institut des Sciences de la Mer de Rimouski at the University of Quebec. He specializes in polar marine ecosystems and remote sensing of marine environments. The National Science Foundation supported his research. (Photograph courtesy M. Montes-Hugo)

For more information

NASA Ocean Biology Processing Group (OBPG)
http://oceancolor.gsfc.nasa.gov
Coastal Zone Color Scanner (CZCS)
http://oceancolor.gsfc.nasa.gov/CZCS
Sea-Viewing Wide Field-of-View Sensor (SeaWiFS)
http://oceancolor.gsfc.nasa.gov/SeaWiFS
Palmer Station Antarctica
Long Term Ecological Research
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