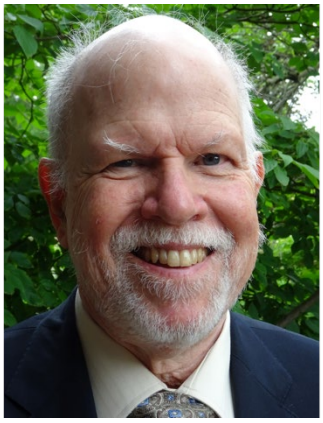
Food and Freshwater Supplies at Risk: Interview with Professor Stephen Carpenter on "What We Need to Do to Protect the Future of the Earth"

On June 15, 2022, the Asahi Glass Foundation announced the 2022 Blue Planet Prize winners. One of the two winners, Professor Stephen Carpenter, Emeritus Director of the Center for Limnology at the University of Wisconsin-Madison, highlights the critical state of nitrogen and phosphorus problems on Earth. The current situation has already exceeded the planetary boundary (limits of the Earth), and the situation is becoming irreversible. We interviewed the professor, who sounded the alarm about the current status of the phosphorus problem, the expected risks, and the actions we should take to protect the future of the planet.

Accelerating Pollution, Severe Damage

"Earth's Phosphorus Cycle is Broken"



Professor Carpenter puts it this way.

Industrial fixation of nitrogen to build munitions during World War II was available to make nitrogen fertilizers after the war. Expanded mining of phosphorus created a good nutrient mix for agriculture. Use of fertilizers rose steeply after about 1950. Since then the massive use of these chemical fertilizers, soil contamination by nitrogen and phosphorus compounds, has continually worsened. Since agriculture is carried out over a wide area, runoff from the soil flows into rivers, lakes and eventually the sea. As a result, the water pollution in lakes has increased dramatically. Professor Carpenter explains the impact of phosphorus pollution as follows.

"Lake Mendota in Wisconsin, which is the subject of my research, has a total area of about 40 square kilometers. In contrast, the surrounding agricultural land is roughly 15 times the size of the lake or 600 square kilometers. Chemical substances, including the phosphorus compounds in fertilizers, are added to agricultural land, and then eventually flows into the lake from all directions, causing eutrophication. The result is a bloom of toxic algae that could exterminate other organisms in the lake."

<Caption>Lake Mendota, Wisconsin

The phenomenon in which eutrophication causes harmful blooms of toxic algae is known as “algae bloom.” The algae blooms are now occurring not only in the U.S. but also in lakes around the world where chemical fertilizers are used in surrounding farmland.

On the other hand, the phosphorus reserves on Earth are finite. It is a rare resource that could be depleted as early as within the next 100 years. If the phosphorus resources are depleted, agricultural production will be affected, and the current level of the world food supply will become impossible. The temporary global shortage of phosphorus resources was, in fact, associated with the political unrest in the Middle East around 2007. Due to market shocks, the export of phosphorite was suspended in major phosphorite-producing countries, which caused the market price of phosphorite to skyrocket and prevented agricultural countries from procuring sufficient fertilizers. Wheat production decreased, causing famine in the Middle East and North Africa.
Not only is preventing phosphorus pollution necessary, but also the recycling of limited phosphorus resources to ensure a sustainable supply for life on Earth.

“The ecosystem will not be able to recover from the polluted state.”

Professor Carpenter warns about the risk of regime shifts caused by water pollution from phosphorus. A regime shift is a phenomenon in which an ecosystem undergoes a discontinuous change from one state to another so abruptly that it is difficult to go back to the previous state. Excessive inflow of phosphorus into lakes causes eutrophication of the lake water. It could result in a massive amount of toxic algae blooms that could prevent the ecosystem from returning to its original state. Professor Carpenter explains as follows:

“There can be two types of regime shifts in the lakes: Phenomena occurring over a few hundred years and those over a short period.”

Long-term regime shifts occur after phosphorus-containing chemicals are deposited to the bottom of the lake over time. It is also triggered by massive algae blooms associated with eutrophication. When the zooplankton can no longer consume the excessive algae blooms on the surface water, most of the algae sink to the lake bottom. As the algae decompose in the deep water, the water becomes anoxic, and the phosphorus bound to iron dissociates and rises to the surface water. When the phosphorus deposited to the lake floor reaches the surface water, eutrophication progresses even further, causing enormous algae blooms and the death of other organisms. Once this phenomenon occurs, it is impossible to reverse the trend with current technology.
On the other hand, short-term regime shifts occur several times every summer. When phosphorus from nearby agricultural lands enters the lake water, algae that use this as a source of nutrients bloom in large quantities. The zooplanktons are then unable to control the algae, so the algae explode and take over the lake.
Professor Carpenter and his colleagues, who had researched ways to respond to short-term regime shifts, have been working to change the food web in Lake Mendota since 1988.

“As a concrete measure, we increased large fish and decreased small fish, and at the same time increased small grazers like your fingernails. These grazers prey on the algae and eventually become food for the large fish. As a result, by 2010, Lake Mendota was as clean as it used to be.”

The global cycle of phosphorus and nitrogen is a matter of planetary boundary. Planetary Boundary is a concept that literally means “the limits of the Earth.” Based on this, the nine most important processes for maintaining the stability of the Earth were identified, and for each process, a “safe operating space for humanity on a stable Earth system” was defined. Of the nine parameters, along with climate change, biodiversity, and land use, the global cycles of nitrogen and phosphorus are also considered to have exceeded their limit values and entered the dangerous zone.

“The WHO has set an upper limit for algae for lakes. Based on this, the maximum amount of phosphorus that can be put into the soil as fertilizer has also been calculated. If phosphorus input exceeds that limit, problems can occur. The nine boundaries are strongly interconnected and need to be resolved from a holistic perspective.”

Can the Earth still be saved?

Practical applications of Professor Carpenter's major findings can be summarized in the following two points: First, the effects of trophic cascades, or chains of predators linked through the food web, are applied effectively. As the results in Lake Mendota have shown, when large fish are placed in the surface water, and grazers are placed in the middle after small fish have been removed, a trophic cascade is then formed in which grazers eat the algae, and the large fish eat these grazers. This mechanism can be used to purify lakes. The key is to remove small fish that eat grazers.

Another outcome is the analysis of regime shifts using a mathematical model. The mathematical model incorporating lake shape, littoral zone plant dominance (the degree to which an organism is dominant or recessive within the biotic community), water temperature, and other factors made it possible to determine the critical amount of phosphorus entering the lake.

Second, Carpenter's research uses whole-lake experiments on small lakes, management studies of Lake Mendota, and mathematical models to study regime shifts of lakes. Sometimes regime shifts cannot be reversed and water quality is lost for a long time. The long-term losses may have important economic consequences.

An economic perspective is essential to lake management as well. While lakes provide drinking water supply and other benefits, they will be polluted if chemical fertilizers are used in the agriculture in the surrounding areas. Carpenter has worked with economists to analyze the economic tradeoffs of agriculture and clearn water to derive economically rational decisions while taking that balance into consideration. The results derived from Professor Carpenter's mathematical models were used in setting various management goals for Lake Mendota.

"There is no doubt that the planetary boundary of the phosphorus global cycle has reached a critical state. However, a number of tools have already been developed and available to solve the problem, and we have seen reports of case studies where the situations improved successfully. Technology to use phosphorus wisely and

minimize consumption can also be developed. So, what is most important is a change in our mindsets; that is, everyone must understand the current situation, change their mindset, and take action. Each and every one of us must act so that people living on Earth can continue to live in the same way in the future."

Professor Carpenter emphasizes that it is people in their 20s to 40s, who will play the leading role in changing the future of the earth. He has high expectations for those generations and is holding "scenarios workshops" in various locations to change their consciousness.

The future will change if we "take action"

Scientists, sociologists, artists, and ordinary people living in the community gather to discuss the future of the Earth. Based on the results of these discussions, we will work together to create a story about our future, spinning a story that appeals to the emotions while incorporating quantitative analysis based on mathematical models and scientific findings. That is what the scenarios workshop is for.

"The process of creating a story together is crucial. If the story appeals to the emotions, it will lead to the next action. This is because emotion and motion are two sides of the same coin, and when people are moved by emotions, they take action."

The workshops should include as broad participation as possible, including entrepreneurs. The participation of writers and other artists as the storytellers of the created stories are also necessary because those people can reach out to people's emotions. It is the role of scientists and engineers to give a realistic support to the story and put it into action.

“I am seventy right now; a person who is thirty right now will be my age, 40 years from now, in 2060. By then, we will have seen immense change in the world—we will have seen the sea level rise so that some coastal areas are flooded, some devastating heatwaves, floods from major shifts in rainfalls, more extreme rains, and more typhoons... I believe we will come to a point where people around the world, all 10 billion and others saying, “Enough! Enough! We are going to fix this.”

Specific measures to tackle the environmental problems, not just the water pollution problem in the lakes, are already evident. We do not need to burn harmful substances to create energy. There are technologies that enable us to preserve water quality and effectively use resources while maintaining food production. The challenge is a matter of scaling them up and building smarter systems.

Professor Carpenter wrapped up the interview with these words:
“Each and every one of us must consider the future of the Earth as our own future and act on. Good people should be able to work together, and when they do, we will surely achieve a bright future. I believe that so I am optimistic about the future.”

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