

Ensuring sustainability of water, aquatic organisms and aquatic foods

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Water covers about 71% of earth's surface, so that the earth is called blue planet. Water is the cradle of life, and it is essential for almost all life on the earth. It not only enables transporting oxygen and nutrients to support the survival of all life including our human being, but also evolves and nourishes a large number of aquatic organisms including about 120 mammals, 910 birds, 120 reptiles, 8,650 amphibians, 36,000 fishes, 150,000 benthic animals, 15,000 to 20,000 plants, as well as innumerable aquatic viruses, bacteria, fungus, phytoplankton, and zooplankton. Significantly, water and aquatic organisms form diverse types of freshwater and marine ecosystems that play vital roles in facilitating biodiversity, regulating climate change, and maintaining ecological balance.¹

As the most important and indispensable natural resource, water provides significant living services, such as drinking, cooking, transportation, hydropower, and biodiversity support. And, most aquatic organisms are the source of foods for our humankind, as a result, the developed capture fisheries played a significant role in keeping our survival and civilization develop-

ment. Owing to the limitation of natural resources and the difficulty to capture, our ancestors had already invented fish aquaculture as early as 8000 years ago when human began to cultivate grains. This should be a significant advancement for civilization development from net-based wild fishing to pond-based aquaculture. To address insufficient food supplies, especially animal-based protein foods, the first-generation leaders of New China made a policy decision to promote aquaculture development since the 1950s, and thereby pull open the prelude of modern innovation in aquaculture. A significant landmark was the breakthrough of artificial propagation of the four domestic fish, such as grass carp, silver carp, big head carp, and black carp, in the early 1960s, and thereby established technological basis for aquaculture industry. Up to 2026, a total of 333 new aquaculture varieties have been improved and applied to different aquaculture paradigms. Thanks to the scientific and technological advances, the output of aquaculture has maintained continuous increases in China and have accounted for about 80% of the total aquatic products in 2020 (Figure 1).²

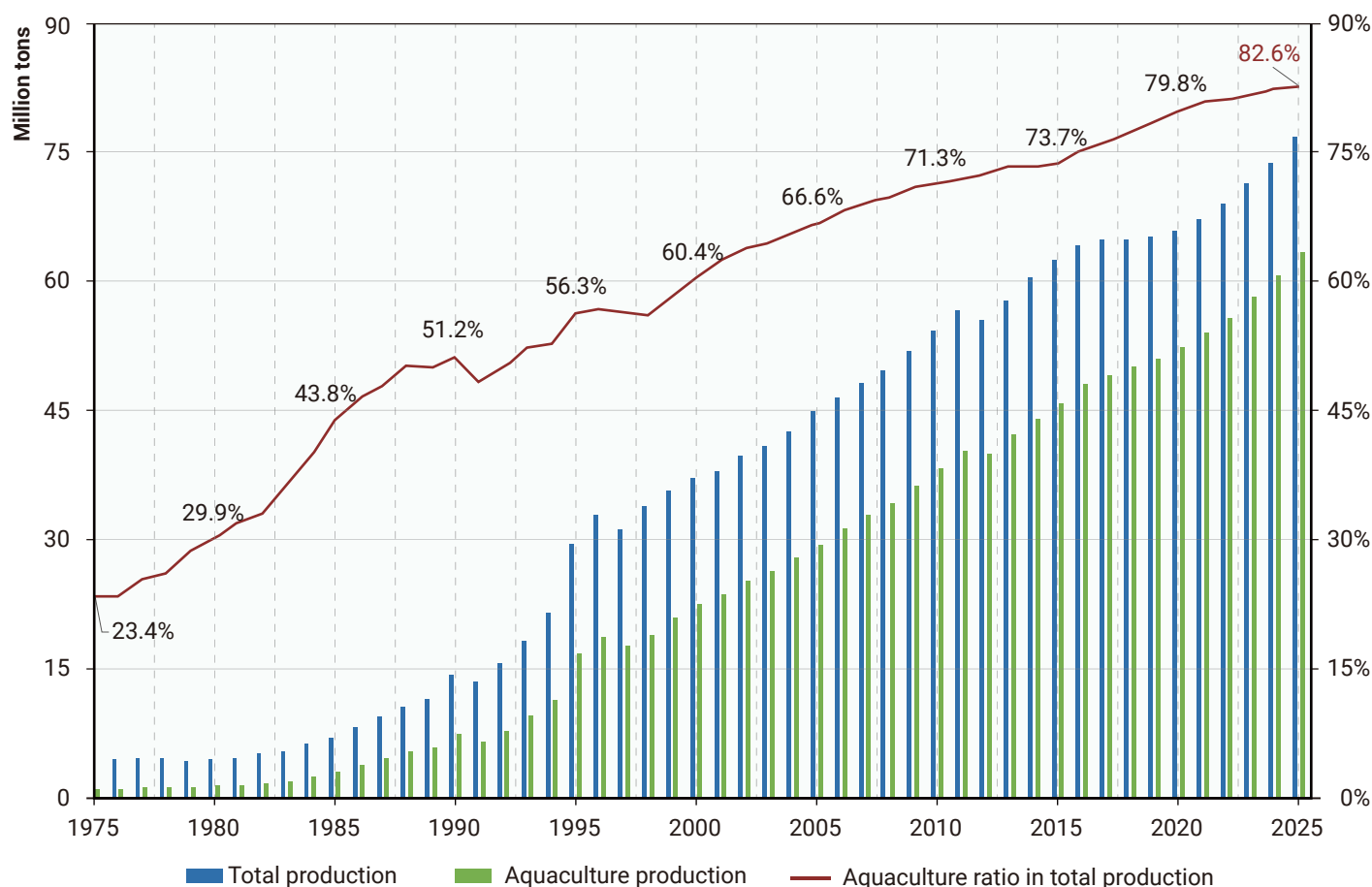


Figure 1. Annual production of aquaculture and total products of aquatic animals in China from 1975 to 2025 The blue bar indicates total production, the green bar shows aquaculture production, and the red line is aquaculture ratio in total production. These data are derived from the annual Chinese Fishery Yearbook over the years.

Actually, Chinese aquaculture success has exerted important effect on the world from the turn of the 21st century. As the fastest-growing food production industry, aquaculture has been highlighted by its lower carbon footprint and environmental impacts.³ In fact, since 1985, the increase amounts of aquatic foods in the world are completely originated from aquaculture, because fishery resources have continuing to decline that lead to the capture fishery decrease. From 2022, FAO has been committed to blue transformation that can meet the double challenges of food security and environment sustainability, because aquatic food systems have been demonstrated to be a powerful solution. Therefore, aquaculture has become an international hot issue because it has great potentials to feed and nourish the world's growing population.

After entering the 21 century, most ecologists and politicians have realized the importance for protecting water, aquatic creatures and ecosystems because about 80% of global wastewater pollutes the aquatic environment, and results in severe decline of aquatic biodiversity.^{1,4} To restore ecosystem integrity and to receive strong support for well-developed aquaculture, Chinese government has implemented a long-term, basin-scale ecological conservation policy, the plan "10-year fishing ban in the Yangtze River" from January 1, 2021. Preliminary results have indicated that the fishing ban has halted biodiversity decline in the Yangtze River. Indeed, the grand plan depends on the prerequisite support of highly developed aquaculture in China and creates a precedent from "capture" to "aquaculture" and then to "protection". This should be a significant contribution of new Chinese wisdom to the protection of water, aquatic organisms and ecosystems.^{2,5}

It is worth noting that China feeds 18% of the world's population with approximately 7% of its freshwater resources, and that Chinese experience in sustainable aquaculture is of reference value for developing countries. However, current climate change, pollution, and overfishing have put unprecedented pressures on global aquatic ecosystems, and aquaculture is also facing severe challenges of growing constraints on natural resources and the environment. As the major source of high-quality animal proteins, highly efficient aquaculture will be more reliant on strategy shift from yield maximization to sustainability optimization, and genetic improvement and modern innovations including feed development, disease control, facilities upgrading and paradigm changes should be given priority attention.²

What are the basic science and policy solutions that would help us improve our water environment to reduce harmful impacts and to ensure sustainability of water, aquatic organisms and aquatic foods? As an expert of fish genetics and aquaculture, I think, four basic science questions should be considered:

(1) Can we discover more effective reproduction strategy in aquatic

animals, and manipulate the potentials for creating novel varieties with multiple superior traits and less environmental impacts? Recent breakthroughs in reproduction mode transition of polyploids have pioneered the approach of precise breeding in fish.

(2) Can we create disease-resistant varieties to lower mortality rates and to reduce the environmental cost of medications? The current technical bottlenecks should be to identify the key causal genes for disease resistance from aquatic animals.

(3) Can we create varieties with higher nutrient absorption ability to reduce nitrogen and phosphorus excretion or are able to rear by low-emission feeds or are better at digesting alternative proteins to reduce competition with human food? To address this issue, the current top priority is to enhance the collaboration between nutrition experts and genetic breeding experts.

(4) How can we develop a controllable fertility biotechnology approach to create sterile aquatic varieties with the improved traits to avoid ecological risks associated with genetic contamination? This should be a main developing direction in the future aquaculture.

In essence, our current goal should be shifted from just maximizing output to optimizing the ratio of product output, and thereby ensure sustainability of water resources, aquatic organisms and aquatic foods. As water is the cradle of all living things, the foundation of life, and the source of civilization, we should cherish water even more, as well as aquatic organisms and aquatic foods.

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DECLARATION OF INTERESTS

Jian-Fang Gui is an Editorial Board member of The Innovation Water and was blinded from reviewing or making final decisions on the manuscript. Peer review was handled independently of this member and their research group.