FOOD COMMUNICATIONS

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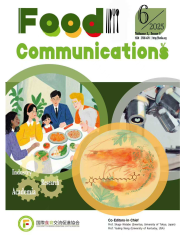

Essay

Interaction of Global Warming and Human Food System: Environmental Education and Food-Nutrition Education are a Common Mission for Humanity

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ABSTRACT

In 2024, the global average temperature surpassed 1.5℃ above pre-industrial levels due to global warming. The food system accounts for one-third of total greenhouse gas emissions, the primary cause of global warming. In this paper, we examine the biomass dynamics of chum salmon (*Oncorhynchus keta*) to explore how global warming impacts food culture. We emphasize the importance of regenerative food production and wise land use in mitigating global warming. Additionally, we discuss how environmental and food education share a common mission: achieving "food and planetary health."

Recently, it has been argued that humans have entered the sixth mass extinction era due to the mass extinction of species, a significant decline in biodiversity (Wilson 1999), the degradation of the Earth's ecosystem (Rockström et al. 2009), and global warming (Leakey & Lewin 1995; Harari 2011, 2015; Wilson 2012). On August 9, 2021, Working Group I of the Intergovernmental Panel on Climate Change (IPCC-WGI) released its Sixth Assessment Report (AR6), stating that there is "no doubt" that human influence has caused warming of the atmosphere, oceans, and land, and predicting that temperatures will continue to rise until at least 2050 and will exceed 1.5 to 2.0 degrees Celsius by the end of this century (IPCC-WGI 2021). Over the past 800,000 years, until about 250 years ago, the concentration of CO_2 in the Earth's atmosphere remained fairly constant, at 180-200 ppm during glacial periods and about 280 ppm during interglacial periods. Since the Industrial Revolution, however, the concentration has continued to rise, reaching 413.2 ppm in 2020 (IPCC-WGI 2021).

1. Impact of human food systems on global warming

Global warming is caused by increases in greenhouse gas (GHG) emissions, primarily CO_2, and the human food system (HFS) is estimated to account for one-third of all GHG emissions (Crippa et al. 2021). In particular, cattle pastures and oil palm forest plantations in the tropics are destroying tropical forests and accelerating the increase in GHG emissions (Pendrill et al. 2019). Meat-based foods place a greater burden on the global environment than plant-based foods due to their much larger land area, water consumption, and GHG emissions (WRI 2016). On the other hand, the production of seafoods (fish and other aquatic species) is faced with

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challenges more than ever from global warming, which contributes to growing stress on the aquatic ecosystems.

According to Hawken (2017), the protein intake requirement for adult is 50 g/day, but the current human population has an average intake of 68 g/day, which is 36% overconsumption. The world's hungry population is 720-810 million people as of 2020 (FAO 2021), while the obese and overweight population has reached more than 1.9 billion people as 2016 (WHO 2021). Meanwhile, the global food waste in 2019 was estimated to be 931 million tons (17% of the total food supply of 5.3 billion tons), equivalent to 121 kg per person (UNEP 2021), and the food loss rate reached 13.8% (FAO 2019). Japan has a low food self-sufficiency rate (calorie equivalent) of 38%, and 63% of its food produced using overseas land and water, resulting in large amounts of GHG emissions from food miles. However, food waste amounts to 6 million tons per year, or about 47 kg per person (Ministry of Agriculture, forestry and Fisheries 2025).

2. Global warming and salmon food culture

In the North Pacific rim, Pacific salmon (*Oncorhynchus* spp.) play an important role as both human food resources and commercial fishery targets. Salmon are a keystone species to sustain and enhance production and biodiversity in the terrestrial ecosystem by returning to spawn in rivers. They are sociocultural keystone species for indigenous people and contribute to environmental education (Kaeriyama and Sakaguchi 2023).Currently, chum salmon (*O. keta*) in Japan continue to decline due to the effects of global warming (Kaeriyama 2022, 2023). The decline of salmon in Honshu Island is more pronounced in the cold-water populations (CWP) on the Pacific coast influenced by the Oyashio Cold Current than in the warm-water populations (WWP) on the Sea of Japan coast influenced by the Tsushima Warm Current, and it is predicted that the CWP may become extinct in about 30 years (Kaeriyama, *personal communication*). A similar phenomenon has been observed along the coast of British Columbia, Canada in the North Pacific Ocean (Kaeriyama 202 2).

We conducted a survey of archaeological artifacts from the Jomon Period (16-2.8 kyr BP) in Japan to identify the distribution of chum salmon and clarify cases where past warming affected their distribution (Kaeriyama 2022). Chum salmon were widely distributed throughout northern Japan from the Middle Jomon Period on wards (5.5-2.8 kyr BP). Salmon relicts were discovered in Hokkaido and Honshu (Aomori and Nagano prefectures and Tokyo) from the Incipient and Initial Jomon periods (16-7 kyr BP). In the Early Jomon period (7-5.5 kyr BP), salmon were distributed from Aomori to Toyama prefectures on the Sea of Japan side (11 remains) in both Honshu and Hokkaido. However, remains were not found on the Pacific side except for the northern area that was affected by the Tsushima warm current in Honshu during this period. The Early Jomon period is called the "Jomon Transgression" period because global temperatures were about 2°C higher than today (Watanabe et al. 2003) and sea levels were several meters higher than today (Yamada 2019). Although salmon fossils have been found in Hokkaido and on the Sea of Japan and the current situation of chum salmon is approaching that side of Honshu, salmon fossils on the Pacific side of Honshu disappeared during the Jomon Transgression. Over the past century, the global average temperature has increased by 1°C, and the current situation of chum salmon is approaching that of the Jomon Transgression. During the Jomon Transgression, temperatures increased by 2°C over 2000 years. In other words, the rate of temperature increase was 1°C every 1000 years. Currently, however, temperatures have risen by approximately 1°C every 100 years. Therefore, the current rate of temperature increase is ten times faster than during the Jomon Transgression period. These facts suggest that southern chum salmon populations may not be able to adapt to near-future environmental conditions due to global warming (Figure 1).

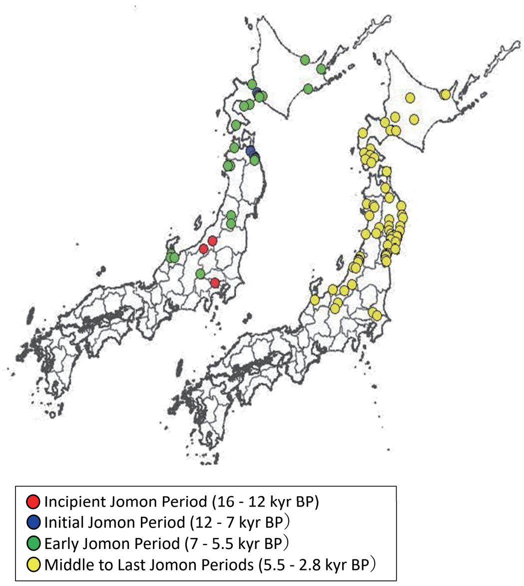

Figure 1. Locations of archaeological remains where relicts of vertebrae and skeletons for chum salmon were excavated during the Jomon Period (16–2.8 kyr BP). (Kaeriyama 2022)

According to Suhara (2023), the Jomon people on the Pacific coast of northern Honshu did not eat salmon in the Early Jomon period, but instead ate warm-current fish such as tuna, skipjack tuna, and red sea bream in the summer and herring in the winter. However, they began to eat salmon in the Middle Jomon period, and salmon became their staple food in the Late Jomon period. In this light, it can be stated that human food culture has changed in response to environmental factors in ecosystems and landscapes, both from a geological and anthropological perspective. Therefore, with human wisdom, we should consider CO_2 zero emission more seriously.

3. Regenerative food production and land use to mitigate global warming

Mitigating global warming requires 1) reducing future GHG emissions to essentially zero, 2) capturing CO_2 already emitted into the atmosphere, and 3) sequestering and releasing the captured CO_2 back into the atmosphere (Edahiro 2024).
Hawken (2017) estimates that the most feasible CO_2 reduction is 1,051 gigatons (Gt), and that improvements in food systems could reduce CO_2 emissions by 472 Gt (34% of the total), including 322 Gt from food-related sources and 150 Gt from land-related sources. At the heart of this is regenerative food production (Hawken 2017, 2021). The main components are (1) seaforestation and (2) blue carbon for marine ecosystems,as well as (3) no-till farming, (4) use of cover crops, (5) crop rotation, (6) no use of chemical fertilizers, insecticides and pesticides, (7) use of compost, (8) rotational grazing, (9) agroforestry, (10) silvopasture and (11) use of biochar for terrestrial ecosystems. Holistic management is important to absorb and sequester more atmospheric carbon both in the oceans and on land. The basic principles are to 1) not disturb the land, 2) cover the land, 3) increase diversity, 4) maintain "living roots" in the soil, and 5) incorporate animals (Brown 2018).

4. Conclusion: knowing contentment

The Paris Agreement set the goal of keeping the global temperature increase less than 2°C above pre-industrial levels and to strive to limit it to 1.5°C. However, last year the global average temperature exceeded 1.5°C above pre-industrial levels for the first time in recorded history (Copernicus Climate Change Service 2025). The IPCC (2023) states, "Climate change is a threat to human well-being and the health of the planet. There is a rapidly closing window of opportunity to secure a livable and sustainable future for all".
From this perspective, we can state that our current food system has a significant impact on individuals, in terms of poor eating habits and lifestyle-related diseases; on society, in terms of poverty, hunger and obesity, and the destabilization of world order; and on the planet, in terms of global warming and loss of biodiversity. Originally, "food" means "food for life," and the Japanese phrase "*itadakimasu*" (thank you for your life) expresses gratitude for food. It is often said that the kanji character "food" is composed of "person" and "good". In Japan, the food and nutrition education ("*Shokuiku*") is the basis of human life, and is positioned as the foundation of intellectual, moral and physical education (Act No. 63 of 2005: Basic Act on Food and Nutrition Education). The "resources" we have on earth, such as food and water, are limited (carrying capacity). We are now challenged to use our carrying capacity wisely and sustainably by "knowing contentment", which is, to be satisfied with having enough and not to over consume. In this sense, "healthy eating" requires both "human health" and "Earth health". Therefore, when considering "food and Earth health" at the educational level, "environmental education" and "food and nutrition education" should serve as a common mission with a synergistic effect, and the issue can be modeled from the hierarchical structure of ecology (individual --> human society --> biosphere --> earth ecosystem) (Figure 2). To achieve the SDGs of "no one will be left behind," we believe that caring for "healthy people and global ecosystems" is essential to the survival of *Homo sapiens* on this planet.

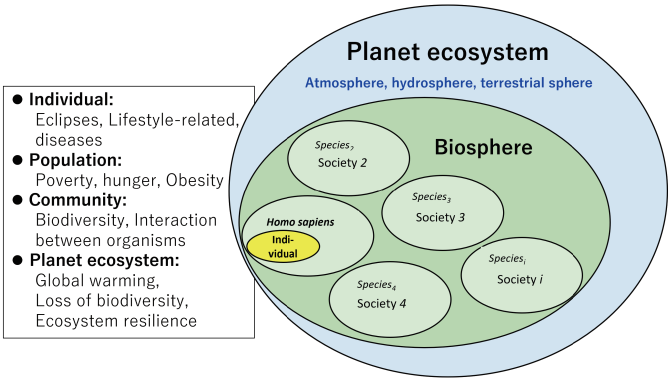

Figure 2. Synergy between environmental education and food-nutrition education to assess the health of food and the planet. (Xiao et al. 2022)

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