

# Meeting Protein and Energy Needs for 10 Billion People While Restoring Oceans

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## ABSTRACT

Shellfish and seaweed farming provide resources, opportunities, and solutions to address a wide range of seemingly intractable global problems. Installed and managed properly, aquaculture operations can be restorative to ocean environments, counter climate change, and relieve pressure to farm sensitive terrestrial environments. For these reasons, there is growing social acceptance and political pressure for marine aquaculture expansion, and State, Federal, and International, as well as eNGO-led initiatives are underway. Now is the time to invest in multi-disciplinary science-based teams that can signpost the sustainable pathway for marine aquaculture by developing monitoring and modeling tools and protocols for measuring associated ecosystem impacts and beneficial services. The yield on that investment will be healthy food and more carbon-neutral bio-fuels grown in ways that help heal our oceans. A sustained commitment by the United States now to develop the science and technology for future ocean farms will find an enthusiastic audience in young researchers and technologists around the world, who seek better ways to improve people's lives through their science and problem solving.

## Vision and Potential Transformative Impact

Farming the oceans, or marine aquaculture, is a logical step to enhance production of protein and bio-fuel feedstocks with a smaller ecological footprint than is possible on land. Without a significant shift to marine farming we may deplete most of Earth's ecologically sensitive lands and biodiversity via expansion of terrestrial farming for a projected population of nearly 10 billion by 2050. Our current agricultural practices also contribute nearly 30% of anthropogenic greenhouse gases. Most marine aquaculture emits far less per unit output, and can sequester carbon and enhance water quality. Our vision for marine aquaculture is to be as much an environmentally restorative practice for stressed marine ecosystems as it is a supply of human food and bio-fuels.

The logical aquaculture species to expand are shellfish and seaweeds that don't require any artificial inputs or feed. Both can help remove excess carbon and nitrogen from coastal waters. Shellfish produce healthy proteins, while seaweeds produce complex carbohydrates and micronutrients important to human and livestock health, and potential feedstocks for bio-fuel. Despite many years of moderate scale aquaculture, there are still scientific questions to be answered and social barriers to be overcome before marine aquaculture can fulfill its full potential.

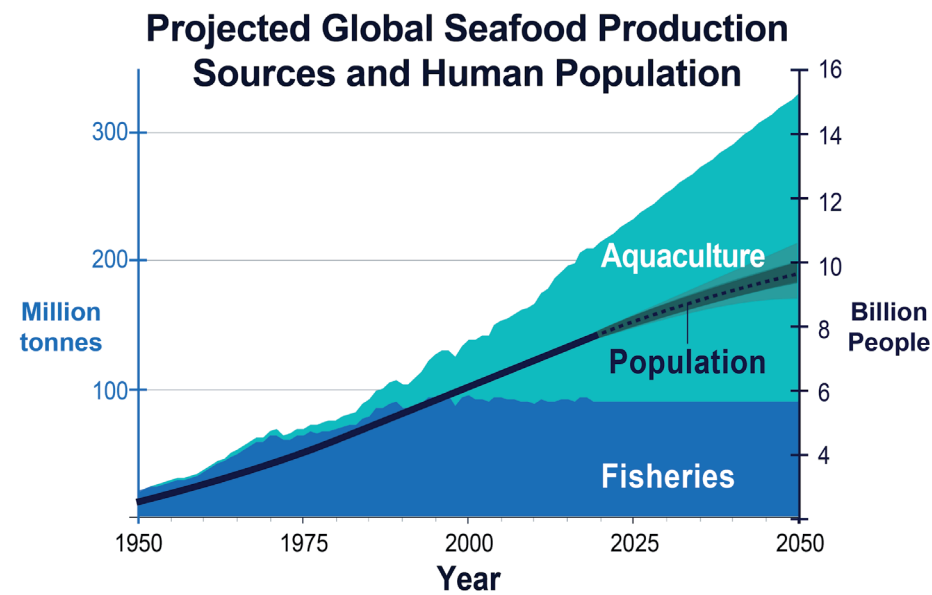


FIGURE 1. Adapted from: United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423); and FAO FIGIS, OECD-FAO Agricultural Outlook, Rabobank 2019. <https://research.rabobank.com/publicationservice/download/publication/token/hhUMgJyn9L5GVd7zYki2>.

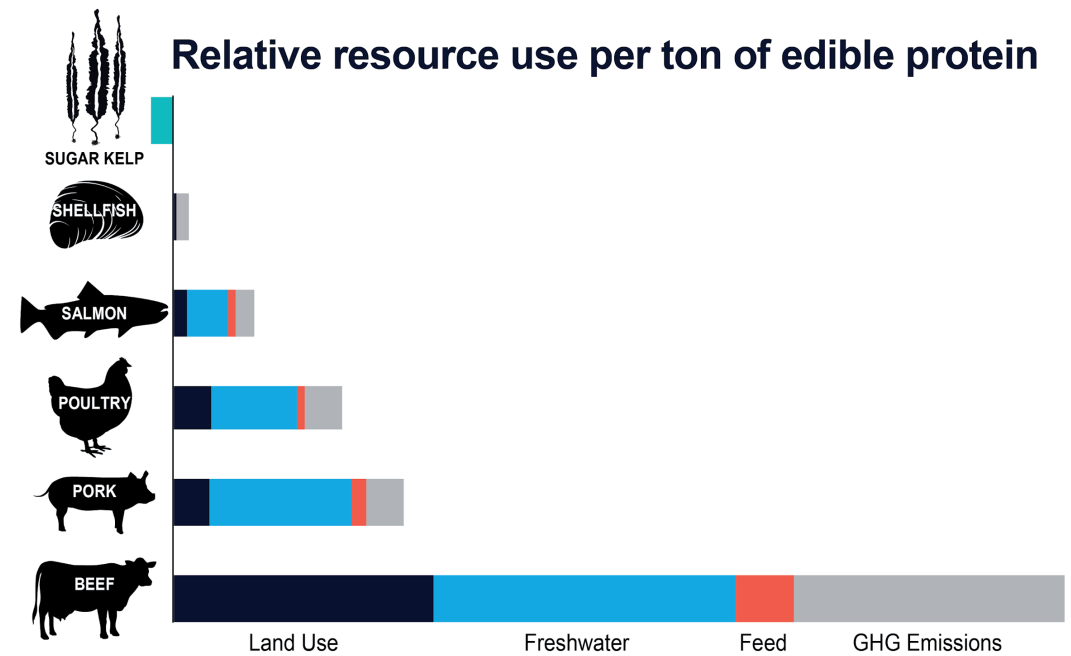


FIGURE 2. Adapted from: Pahlow, M., van Oel, P.R., Mekonnen, M.M., & Hoekstra, A.Y. 2015. Increasing pressure on freshwater resources due to terrestrial feed ingredients for aquaculture production. *Sci. Total Environ.* 356:847–857. <https://doi.org/10.1016/j.scitotenv.2015.07.124> and Waite, R., Beveridge, M., Brummett, R., Chaiyawannakarn, N., Kaushik, S., Mungkung, R., ... Phillips, M. 2014. Improving Productivity and Environmental Performance of Aquaculture. Working Paper, Installment 5 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute (WRI).

## Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public-Private Partnerships

Aquaculture is the fastest-growing food production sector globally. U.S. research and technology development has enabled much of this growth, even though U.S. aquaculture output has lagged the global industry. Currently, shellfish and seaweed aquaculture are a small fraction of U.S. agriculture production, but shellfish farming has quintupled regionally in the last 10 or 15 years, while seaweed production has doubled every year or two over the last five.

A recent Executive Order prompted NOAA to streamline regulations and create Aquaculture Opportunity Areas in Federal waters. The AQUAA Act now pending in Congress will provide more resources for marine aquaculture expansion, including aquaculture research. The DOE has invested about \$50M in the last three years in the MARI-NER Program to develop tools and networks for fostering sustainable seaweed aquaculture. Several members of this Ocean-Shot have already designed and/or implemented aquaculture projects in the United States and internationally.

## Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences

Optimizing the siting, design, engineering, husbandry, harvesting, and ecosystem stewardship of large-scale future ocean farms will require collaboration across many disciplines and industries. Sectors outside the traditional ocean sciences that can play a key role include agriculture, breeding and genetics, robotics, and biofuel processing, as well as naval architecture and the offshore industry. Multi-disciplinary teams can signpost the sustainable path by early development of monitoring and modeling tools and protocols for measuring

ecosystem impacts and services (e.g., ocean acidification, nutrient extraction/deposition, carbon sequestration, impact or enhancement of fishery resources) associated with marine aquaculture.

## Opportunities for International Participation and Collaboration

International eNGOs like The Nature Conservancy and World Wildlife Fund are already supporting initiatives to promote shellfish and seaweed marine aquaculture, and investing in research and enterprises. Oceans 2050 Foundation is a collaborative international initiative that cites Regenerative Ocean Farming and Blue Carbon Sequestration as two of its objectives. Foundations with considerable resources like Jeff Bezos's Earth Fund are making major international investments in seaweed farming as a nature-based climate solution. All these initiatives and several more in Europe and Asia-Pacific regions require tools this Ocean-Shot develops to verify or certify the intended environmental benefits derived from aquaculture projects.

## Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers, and Technologists

U.S. scientists and engineers are global leaders in the discovery and understanding of fundamental ocean processes, and have partnered with agencies, researchers, and indigenous people around the world to advance aquaculture technologies. A sustained commitment by the United States to develop the science and technology for future ocean farms will find an enthusiastic audience in young researchers and technologists around the world, who seek better ways to improve peoples' lives through their science and problem solving. Helping feed and power the world while restoring the ocean will be a clarion call to some of the best minds of this and future generations. 