NOAA FISHERIES

Office of Aquaculture

Climate Resilience and Aquaculture

Aquaculture is resilient to many effects of climate change, and offers mitigation and adaptation opportunities.

Less fresh water, land resources, and fewer greenhouse gas emissions are required to produce food through aquaculture than traditional agriculture.

Growth of domestic aquaculture presents an opportunity to shorten seafood supply chains and decrease emissions associated with the 85% of seafood currently imported and consumed in the US.

AQUACULTURE AS CLIMATE RESILIENT FOOD PRODUCTION

The global population is expected to reach nearly 10 billion by 2050, straining our food production systems. Traditional land-based agriculture consumes more than half of all arable land and 70 percent of the world's fresh water resources.[1] While the ocean covers nearly three-quarters of Earth's surface, capture fisheries and a small marine aquaculture sector produce only 2 percent of the global food supply according to the Food and Agriculture Organization.

Intensifying droughts, storms, and other climate-related events have revealed substantial vulnerabilities for land-based food production.[2] While not immune to the effects of climate change, ocean-based farming operations generally require less fresh water, land resources, and produce fewer greenhouse gas emissions to produce food.[3,4] Growth of ocean farming of fish, shellfish, and seaweeds can reduce resource pressure and present novel resilience opportunities for a changing environment.

Aquaculture practices allow for control of growing conditions by locating farms in areas with ideal environmental characteristics, and the three-dimensional nature of the ocean allows for optimal vertical positioning where farmers can raise species throughout the water column.[5] This allows for an increase in production in a relatively small footprint.

Selective breeding programs for farmed species can further create opportunities to stay ahead of changes in temperature and pH. Aquaculture species begin life in a hatchery before being moved to farm sites for grow-out. The strict controls and safety measures taken at hatcheries—such as buffering of acidified seawater—allow for a greater survival rates of juvenile shellfish and finfish during their most vulnerable stage of development.

WHY FARM SEAFOOD?

Today, the United States **imports over 85% of the seafood we eat** by value – more than any other country. Global and domestic demand for seafood continues to grow. Even as we maintain and rebuild our wild harvest fisheries, we cannot meet increasing domestic demand for seafood through wild-caught fisheries alone.

Growing the domestic aquaculture industry here in the United States will support healthy people, a healthy planet, and a healthy economy.

U.S. Secretary of Commerce

Wilbur L. Ross, Jr.

Acting Under Secretary of Commerce for Oceans and Atmosphere

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SEAFOOD PRODUCTION THAT INCREASES ADAPTATION

After wild fisheries harvests plateaued in the mid-1980s, many parts of the world turned to aquaculture to meet growing demand for seafood.[6] Climate change is expected to further impact wild-capture fisheries (e.g., shifting fish stocks), and growth in seafood production through aquaculture can help coastal communities adapt and thrive.

Through aquaculture, cultured species can be selected that are optimized for local growing conditions—creating opportunities to breed and develop strains that are resilient to increased temperatures and anticipated future changed environmental conditions.[5] Additionally, aquaculture creates opportunities to recover and enhance wild populations. For example, the NOAA Southwest Fisheries Science Center has developed culture and grow-out approaches for white abalone, an endangered species.[7]

CLIMATE CHANGE MITIGATION BENEFITS OF AQUACULTURE

Aquaculture can produce animal protein with fewer associated greenhouse gas (GHG) emissions than land-based livestock.[3,8,9] Most emissions associated with agriculture relate to conversion of forested lands to agriculture and the production of animal feeds.[8] Production of bivalve shellfish and seaweeds require no feed inputs, while fish require 2-8x less feed than poultry, swine, or cattle—making farmed seafood a climate-smart protein relative to their livestock counterparts.[9]

Protein	Feed Conversion	
Salmon	1.2	It takes 1.2 pounds of feed to produce 1 pound of salmon
Beef	8.7	It takes 8.7 pounds of feed to produce 1 pound of beef
Pork	5.9	It takes 5.9 pounds of feed to produce 1 pound of pork
Chicken	1.9	It takes 1.9 pounds of feed to produce 1 pound of chicken

Seafood is one of the most traded food commodities in the world, often involving long and complex supply chains.[10] The U.S. currently imports over 85 percent of the seafood we consume, relying heavily on foreign processing and shipments that are associated with greater emissions.[11] Growth of domestic aquaculture would place farms and processing closer to major markets, shortening supply chains, and combating the higher fuel consumption associated with foreign imports.

KELP MITIGATES OCEAN ACIDIFICATION AND OFFSETS EMISSIONS

As oceans absorb carbon dioxide from the atmosphere and become more acidic, the calcium carbonate that oysters, corals, and other marine animals require to survive is disappearing.[12,13] Seaweeds, including kelp, remove carbon dioxide from the water, reducing ocean acidification and providing a localized "buffering" effect that benefits many marine species. Seaweeds also produce dissolved oxygen, providing opportunities to mitigate spreading 'dead zones.'

Active research and development programs, such as the Department of Energy ARPA-E MARINER program, are exploring the potential for large-scale cultivation of seaweed for biofuel production—an opportunity to offset emissions from fossil fuels.[14] Additionally, large-scale cultivation of seaweed is being explored as an opportunity to remove and sequester carbon dioxide in the deep ocean.[13]

[1]UNESCO, UN-Water, 2020: United Nations World Water Development Report 2020: Water and Climate Change, Paris, UNESCO. [2]Cottrell, Richard S., et al. "Food production shocks across land and sea." *Nature Sustainability* 2.2 (2019): 130-137. [3]Hilborn, Ray, et al. "The environmental cost of animal source foods." *Frontiers in Ecology and the Environment* 16.6 (2018): 329-335. [4]Gentry, Rebecca R., et al. "Mapping the global potential for marine aquaculture." *Nature Ecology & Evolution* 1.9 (2017): 1317-1324. [5]Griffis, R. and Howard, J. [Eds.]. 2012. Oceans and Marine Resources in a Changing Climate: A Technical Input to the 2013 National Climate Assessment. Washington, DC: Island Press. [6]FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en [7]Available at: fisheries.noaa.gov/resource/document/species-spotlight-priority-actions-2016-2020-white-abalone [8]Froehlich, Halley E., et al. "Comparative terrestrial feed and land use of an aquaculture-dominant world." *Proceedings of the National Academy of Sciences* 115.20 (2018): 5295-5300. [9]Waite, R. et al. 2014. "Improving Productivity and Environmental Performance of Aquaculture." Working Paper, Installment 5 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute. [10]Gephart, Jessica A., and Michael L. Pace. "Structure and evolution of the global seafood trade network." *Environmental Research Letters* 10.12 (2015): 125014. [11]fishwatch.gov/sustainable-seafood/the-global-picture [12]fisheries.noaa.gov/national/aquaculture/seaweed-aquaculture [13]wsg.washington.edu/community-outreach/kelp-aquaculture/ [14]arpa-e.energy.gov/technologies/programs/mariner