Sustainable Aquaculture Production Systems

U.S. Government's Global Food Security Strategy Activity Design Guidance

This is one of several Activity Design Guidance documents for implementing the U.S. Government's Global Food Security Strategy. The full set of documents is at www.feedthefuture.gov and www.agrilinks.org.

Introduction

Aquatic, or blue, foods are aquatic animals and plants cultivated in (i.e., aquaculture) or captured from (i.e., fisheries) freshwater, marine, or brackish water environments for human food or for animal feed. These foods include marine and freshwater fish, shellfish, aquatic plants, seaweed, and algae. Aquatic foods are essential components of sustainable food systems and critically important to food security, nutrition, and livelihoods. For example, fish provide about 3.3 billion people globally with at least 20 percent of their average, per-capita animal protein intake and are a good source of essential fatty acids and nutrients.[1,2] (Note that this document refers to fish and other aquatic animals, such as molluscs and crustaceans, collectively as "fish.") Seven of the most nutrient-dense sources of animal protein are aquatic foods, namely, small pelagic fish, bivalves, large pelagic fish, aquatic mammals, salmonids, carps, and cephalopods.[3] The health benefits of eating fish include decreased risk of cardiovascular disease, improved maternal health during pregnancy and lactation, and improved cognitive and physical development during early childhood.[1,2]

Remarkably, the High Level Panel for a Sustainable Ocean Economy, an initiative supported by 14 countries—Australia, Canada, Chile, Fiji, Ghana, Indonesia, Jamaica, Japan, Kenya, Mexico, Namibia, Norway, Palau, and Portugal—that account for nearly 40 percent of the world's coastlines, estimates that ocean-based food production could increase by up to six times current levels through a combination of sustainable fisheries management and sustainable finfish and bivalve aquaculture.[4,5] In addition, every $1 invested in sustainably increasing ocean-based food production can yield up to $10 in benefits, such as healthier diets, higher revenue for local communities, and lower greenhouse gas emissions.[5,6] With the human population projected to reach 10 billion by 2050, sustainably increasing ocean-based food production is critical to meeting food security and nutrition needs and may have a comparative advantage over terrestrial animal production systems in increasing animal protein production with less environmental and climate change impacts in certain contexts and geographies.[4,6]

Terminology and Context

Aquaculture Production: Aquaculture is the cultivation (breeding, rearing, and harvesting) of animals and plants in aquatic environments and has experienced rapid growth in recent years with production by weight tripling from 1997 to 2017.[7] Aquaculture can take place in freshwater, marine, or brackish water environments, such as ponds, cages, and tanks. Total aquaculture production is valued at $265 billion annually, and the sector employs about 20.5 million people; women make up an estimated 40 to 80 percent of the aquaculture workforce, depending on the country.[1,8,9]

In countries like Tanzania, Bangladesh, and Nepal, women play a significant role in all aspects of aquaculture, particularly at the household scale.[10,11] Aquaculture's share of fish production varies by region, accounting for about 40 percent in Asia (excluding China, which produces half of the global amount of farmed fish each year) and less than 30 percent in Africa, the Americas, Europe, and Oceania from 2011 to 2020, with capture fisheries producing the remainder.[1] While China is the world's largest aquaculture producer, the sector has seen expansion globally, with growth rates in Africa and South America exceeding those in Asia over the last two decades; Egypt, Chile, India, Indonesia, Vietnam, Bangladesh, and Nigeria are among the top producers globally.[7] Aquaculture consists of diverse production systems across economic and physical scales, from household-managed ponds to large-scale commercial enterprises.[7] In 2020, more than 600 species-groups, including individual species, hybrids, and other taxonomic groups, were produced by aquaculture.[1]

Aquaculture, through its contributions to food security and livelihoods, can help communities adapt to climate change and increase communities' resilience. Aquaculture activities can select species for cultivation that are more resilient to changes in local environmental conditions and implement production systems that may have climate mitigation benefits. For instance, integrated mangrove-shrimp aquaculture systems can support climate mitigation through restoration of mangroves, which can sequester up to four times as much carbon as tropical forests.[12] Conversely, poorly planned aquaculture activities can worsen climate change. For instance, conversion of mangroves for aquaculture has contributed up to 20 percent of annual carbon dioxide emissions associated with land use change in Indonesia.[13]

Sustainable Aquaculture Production Systems: Sustainable, responsible, and adaptive aquaculture can help achieve the U.S. Government's Global Food Security Strategy (GFSS) strategic objectives of poverty reduction, increased resilience, and improved nutrition outcomes.[14] Aquaculture production systems can increase their sustainability by reducing their potential negative impacts on the environment and addressing and adapting to such challenges as diseases, pollution, extreme weather events, climate change, and ocean acidification.[1,7] Opportunities for increasing sustainable production and decreasing the environmental impacts of aquaculture systems include:

- Reducing the feed conversion ratio (e.g., through selective breeding programs and improved feed quality)
- Shifting protein sources in feed from wild-caught fish to more sustainable sources, such as fishery by-products, plants, algae, yeast, or insects
- Integrating aquaculture production systems with other agricultural activities
- Cultivating species that can improve local environmental conditions through what is known as "restorative aquaculture"[15] (e.g., oysters serving as a foundation species that create a habitat for other coastal species and improve water quality through filtration[16])
- Repurposing aquaculture by-products for other industries (e.g., using crushed bivalve shells for construction material or agricultural fertilizer[17])
- Siting aquaculture activities in areas that minimize potential negative impacts on local biodiversity (e.g., siting seaweed farms away from coral reefs can help prevent the reefs' overgrowth by farmed seaweed species[18])

Certification, a process that evaluates whether aquaculture production systems conform to best practices and other requirements specified by certification groups, is increasing in popularity as consumers become more aware of sustainability, legality, quality, and safety issues.[19] Importantly, in addition to being sustainable, aquaculture production systems also need to be practical and well-managed.[20]

Minimizing Food Loss and Waste in Aquaculture Value Chains: Addressing food loss and waste in aquaculture value chains can greatly improve food security by increasing the availability of micronutrients and decreasing the risk of foodborne illnesses (see the U.S. Government's GFSS Activity Design Guidance on Diets and Food Safety). At the same time, it can also decrease greenhouse gas emissions. About 35 percent of the global fish harvest from fisheries and aquaculture is lost or wasted annually.[1] This is particularly an issue in low-income countries with limited availability and access to the technology needed to safely process, preserve, and transport fish.[1] Investments in environmentally sound methods to process, package, preserve, and transport fish—such as the use of fuel-efficient technologies to preserve fish and develop cold chains—can decrease postharvest loss, increase the quality and quantity of fish available for consumption and sale, mitigate food safety risks, and reduce greenhouse gas emissions from rotting fish.[1,9,21] These types of investments are particularly beneficial to women, who are often more vulnerable to the food security and economic impacts of postharvest loss due to their engagement in fish processing, transport, and marketing.[9] Notably, programs targeting private sector actors to adopt more efficient technologies, such as efficient cold chains or dryers, can both decrease food loss and waste and promote better food safety practices.

Linkages to the GFSS: The GFSS recognizes aquaculture as a vital component of agriculture—along with fisheries and land-based agricultural practices, such as farming, forestry, and pastoralism—and supports promoting aquaculture as an important strategy for feeding a growing population while providing employment and income. Investments along aquaculture value chains, including sustainable, responsible, and adaptive aquaculture production systems, are key to achieving the three GFSS objectives:

- **Aquaculture supports inclusive and sustainable agricultural-led economic growth.** Fish and fish products are among the most traded food items globally, with an export value estimated at $151 billion in 2020.[1] Aquaculture can have positive economic impacts on households, primarily through income generation and diversification of livelihoods.[1,11] Positive economic growth from aquaculture, in turn, increases the food security and resilience of households. Inclusion is critical for agricultural-led growth through aquaculture, as over 80 percent of aquaculture production worldwide is small-scale, often from family-owned and -managed farms. Importantly, efforts to empower marginalized groups are key to more equitable sharing of economic benefits from the aquaculture sector and inclusive economic growth.[22,23]
- **Aquaculture contributes to strengthened resilience among people, communities, countries, and systems.** The aquaculture sector enhances resilience primarily by providing incomes for producers, increasing household access to fisheries resources year-round, diversifying livelihoods, and decreasing pressure on wild fish stocks. A robust aquaculture sector can help diversify food systems and complement the crop, fisheries, and terrestrial livestock sectors by providing low-cost, nutrient-rich food.[24] Measures that can increase the contributions of aquaculture to resilience include prioritizing production systems that use feed as efficiently and equitably as possible; farming lower trophic-level species, like shellfish; implementing management practices that minimize environmental impacts and maximize environmental benefits; improving the development, implementation, and enforcement of public and private regulations, codes, and standards for the sectors that support sustainable practices; investing in measures to address pathogens, parasites, and pests; and managing risks from climate change.[7,24]
- **Aquaculture contributes to a well-nourished population, especially among women and children.** Fish are an important source of vital nutrients that are critical for diversified, healthy diets, such as vitamins A, B, and D; minerals like calcium, zinc, and iron; and polyunsaturated fatty acids. The nutrients in fish can help improve maternal and child health and combat a range of health conditions, such as childhood stunting and blindness, rickets, anemia, low birth weight, pregnancy complications, and cardiovascular disease.[2,25] Importantly, the nutritional profile of farmed fish can vary from that of wild fish, based on factors such as species, feeding habits, position in the aquatic food chain, size, geographical origin, and type of feed. Certain types of

farmed fish may not provide as much iron, zinc, calcium, and vitamins A and B12 as wild species.[26] Improving the nutritional quality of commonly consumed farmed fish species through approaches such as nutrient fortification of feed is key to optimizing aquaculture's contributions to a well-nourished population and resilient communities.[26,27] Critically, in order to realize the nutritional benefits of consuming fish, food safety risks must also be addressed.

Designing Activities

Investments under the GFSS can support sustainable and resilient aquaculture activities. When designing an aquaculture activity, design teams can consider these five guiding questions:

1. What contextual factors need to be considered before starting this aquaculture activity?
2. How can the activity minimize negative and maximize positive environmental impacts?
3. Who will benefit from the activity and what social, economic, or political factors may influence the distribution of benefits? What objectives should be included to ensure there are inclusive and equitable benefits?
4. Who are effective partners to engage in this activity?
5. What is the role of this aquaculture activity in climate adaptation and mitigation and what options are there for managing climate risks to this activity?

Design considerations in response to these guiding questions are elaborated below:

1. **What contextual factors need to be considered before starting this aquaculture activity?** Aspects to consider include:
    - **Relationships to the broader sustainable food system, any food security and nutrition strategies in the target geography, and local market systems.** For example, will the activity source feed from suppliers whose crops are associated with deforestation or from fisheries that aren't sustainably managed?
    - **Location.** Consider impacts to the tenure status of local people (or entities), potential climate change impacts (e.g., flooding leading to the escape of non-native cultured species into the local environment), proximity to the target community, presence of ecologically sensitive ecosystems that could be damaged by the activity, activity impacts on water availability and quality, etc.
    - **Cultural context.** For instance, is the proposed farmed species a good fit for the target communities in terms of food preferences?
    - **Linkages to sustainable feed systems (such as for other value chains or protein sources).** Sustainable feed production for aquaculture and other agricultural sectors is crucial to lowering the environmental impacts of food production.
    - **Measures to address contextual factors that may impact production.** For instance, how will the activity address local pests and pathogens that threaten cultured species, or the contamination of cultured species due to exposure to environmental hazards within the production area (e.g., heavy metals contaminating filter feeders, such as oysters, and species with high bioaccumulation potential, such as seaweeds)?
    - **Measures to manage risks to aquaculture value chains in the target geography.** Risks to be managed can include disruptions in the supply of key inputs, market or economic shocks, and climate risks.

2. **How can the activity minimize negative and maximize positive environmental impacts?** The potential negative environmental impacts of any aquaculture activity should be considered during the planning process, and the activity should implement measures to minimize these impacts. Factors that may contribute to an aquaculture activity's environmental impacts include: proximity to critical land and seascapes, such as mangroves and coral reefs; the source and associated environmental impacts of feed, water, and other inputs; the potential for eutrophication from nitrogen and phosphorus emissions; and the species farmed and how this might affect local biodiversity.

   Depending on the species, aquaculture production can also have positive impacts on the environment. For instance, a systematic review of over 60 studies found that seaweed and shellfish farming can provide nutritionally rich aquatic foods while enhancing local biodiversity, primarily by providing structured habitats and food for local fauna and enhancing their reproductive processes.[28] Other potential positive environmental impacts from aquaculture can include increased carbon sequestration and decreased ocean acidification through photosynthetic uptake of carbon dioxide by seaweed species, as well as improvements in local water quality through the assimilation of nutrient pollution by shellfish and seaweed species.[29] Participating in an established and reputable aquaculture certification program, such as the Aquaculture Stewardship Council, can help an activity conform to environmental best practices.

3. **Who will benefit from this activity and what social, economic, or political factors may influence the distribution of benefits? What objectives should be included to ensure there are inclusive and equitable benefits?** Aquaculture activities have the potential to benefit local communities by providing food, employment, income, and opportunities to improve gender equity. However, cultural and gender norms can lead to unequal access to resources and decision-making power.[30] To realize the full spectrum of inclusive and equitable benefits, aquaculture activities should engage and support organizations that represent the interests and rights of the poor, women, Indigenous peoples, youth, and other marginalized and underrepresented groups and ensure their meaningful participation during all stages of activity planning and implementation. Specific questions to ask include:

   - How will the activity benefit or disadvantage poor households or groups and those in vulnerable situations?
   - How will the activity benefit or disadvantage women, youth, Indigenous peoples, persons with disabilities, and other marginalized and underrepresented groups?
   - How will the activity support local champions and agents of change?
   - How will the activity impact gender and power dynamics (e.g., by benefitting one group over another or by increasing the likelihood of gender-based violence) and monitor any shifts in these dynamics? How can any negative impacts be mitigated and any progress be harnessed?
   - What are the barriers and opportunities to increasing the participation and employment of marginalized communities across aquaculture value chains?
   - How will the activity build social capital and agency for women, youth, Indigenous Peoples, persons with disabilities, and other marginalized and underrepresented groups?

4. **Who are effective partners to engage in this activity?** Key objectives that guide the U.S. Agency for International Development's (USAID) partnerships are to promote local leadership; increase equity and inclusivity in partner relationships; implement bold, creative, and innovative approaches; lower barriers for potential partnerships; and identify new sources of funding to

sustain partnerships and scale impact. As such, USAID's aquaculture activities often involve working with a variety of partners, including local organizations, government ministries, universities and research institutions, the private sector, the Food and Agriculture Organization of the United Nations (FAO), public international organizations (PIOs), and nonprofit groups. USAID specifically prioritizes partnerships with locally led organizations and those that are connected to or have a deep knowledge of the communities in which activities are based in order to build local capacity and ownership. Locally led organizations may include community-based aquaculture production cooperatives. Government partners can include ministries that oversee agriculture, food safety, trade, gender or women's affairs, as well as public research institutes and universities. The private sector can be a particularly important partner in improving sustainability of aquaculture activities through strategies such as developing open-source traceability systems, using sustainably sourced feed, and focusing on improving social, environmental, and production practices within an entire production geography.

5. **What is the role of this aquaculture activity in climate adaptation and mitigation and what options are there for managing climate risks to this activity?** As noted previously, aquaculture can contribute to climate adaptation and mitigation and serve as an important source of local resilience. Hence, USAID activities should consider the current and potential role of aquaculture in climate adaptation and mitigation, given the local context. At the same time, the impact of climate stressors—including higher water temperatures, extreme weather events, changes in rainfall patterns, sea level rise, and ocean acidification—as well as knock-on effects, like uncertainty in the availability of external production supplies,[31] should also be assessed and climate considerations should be integrated into aquaculture production plans. Activities should also consider climate impacts to seafood value chains more broadly. For instance, how could the activity build resilience to the parts of the value chain that are most vulnerable to climate shocks? Successful adaptation strategies will need to be tailored to the local context and target vulnerable producer groups.[13] USAID's Climate Risk Screening and Management Tools, including the Agriculture Annex, can help activity designers assess, address, and adaptively manage climate risks to aquaculture and associated value chains in their target geography.[32]

Programming in Practice

USAID's investments in aquaculture, which total about $8.5 million annually in nine countries, focus on optimizing the human well-being co-benefits of fish farming through sustainable, responsible, and adaptive management approaches along the value chain. The following programming examples span the diversity of USAID aquaculture activities across the Feed the Future, biodiversity, and humanitarian assistance portfolios:

- **Feed the Future Innovation Lab for Fish (Fish Innovation Lab) (2018–2023):** The Fish Innovation Lab leverages the expertise of several U.S. universities and research institutions to improve food security, nutrition, and livelihoods by supporting aquaculture production systems and sustainable fisheries in Feed the Future focal countries. For example, Cambodia's Bighead Catfish Culture Project (2020–2023) focuses on developing and scaling up cost-effective feeds and building the capacity of local institutions to conduct research on aquaculture-related topics. Through this activity, the Fish Innovation Lab is helping Cambodia decrease its reliance on wild fish to produce feed to increase the sustainability of bighead catfish aquaculture and reduce pressure on wild fisheries in the Lower Mekong River Basin.[33] (Funding source: Feed the Future.)

- **Bangladesh Aquaculture and Nutrition (2018–2023):** The Bangladesh Aquaculture and Nutrition activity builds on the successes of the six-year USAID Aquaculture for Income and Nutrition project that helped improve the livelihoods of small-scale fish farmers through increased production and quality of carp, shrimp, and tilapia. The activity takes a market systems approach that focuses on identifying private sector investors and building capacity among existing value chain actors to increase aquaculture productivity, strengthen aquaculture market systems, and increase nutrition awareness and practices. The activity is particularly focused on expanding opportunities for women and youth within the aquaculture sector and increasing their awareness and adoption of nutrition-related behaviors.[34] (Funding source: Feed the Future.)
- **Securing Water for Food—Integrated Aquaculture and Crop Production in West Africa (2014–2020):** Through USAID's Grand Challenges for Development, the Integrated Fish and Crop Production activity supported integrated fish and crop production in Ghana, Guinea, Liberia, and Sierra Leone to alleviate poverty and improve the livelihoods of rural farmers. SkyFox, the lead implementer, developed an innovative method that involves building hilltop aquaculture ponds that produce up to two tons of catfish a year and provide nutrient-rich water to irrigate crops at the base of the hill. In Ghana, the initiative engaged over 10,000 end users and a performance evaluation in 2019 found multiple benefits, including the cultivation of new crops during the dry season, reduction in the need for fertilizer, and increased income and crop yields. A 2020 performance evaluation of Securing Water for Food found that among the 11 initiatives it supported, this one resulted in the greatest income improvement for the poor and the second highest improvement in income for women.[35,36] (Funding source: Feed the Future.)
- **Nosy Manga (2021–2026):** The Nosy Manga ("Blue Island")—Restorative Aquaculture for Nature and Communities activity focuses on promoting sustainable farming of native seaweed and sea cucumber species in Madagascar. Both are examples of aquaculture species that require minimal inputs and have the potential to produce climate mitigation benefits and positive outcomes for the local environment. Nosy Manga is part of a larger portfolio at USAID known as Health, Ecosystems, and Agriculture for Resilient, Thriving Societies (HEARTH), which integrates human health and well-being with environmental conservation through the creation of public-private partnerships. The goals of Nosy Manga are to: (1) define and strengthen a contractual aquaculture model in which farmers and the private sector jointly agree on best environmental farming practices, (2) alleviate poverty of targeted coastal communities through new income-generating opportunities, and (3) guarantee conditions for sustainable production in targeted areas.[37] (Funding source: Biodiversity.)
- **Resilensia Di'ak (ReDi) (2019–2020):** The *Resiliensia Di'ak* (Good Resilience) activity helped poor and vulnerable rural farming households in Timor-Leste become more food secure by improving their resilience and reducing their exposure to recurring natural disasters. Implementers assisted with in-land aquaculture pond construction, restoration and maintenance, and water canalization quality and water quality management. This was paired with tilapia fingerling distribution through smart subsidies and technical training on feed management, including commercial feed options and supplementary local feed production. Local feed production included integrated aquaculture systems, where waste vegetables from established permagardens or manure from livestock was used as a supplementary fish food. Results included strengthened aquaculture skills, improved resilience capacity, enhanced well-being, and increased income and food security.[38] (Funding source: Humanitarian assistance.)

Additional Resources and Tools

Activity Design

- USAID's Sector Environmental Guidelines: Wild-Caught Fisheries and Aquaculture
- FAO Aquaculture
- FAO Aquaculture Development: Ecosystem Approach to Aquaculture
- The Global Principles of Restorative Aquaculture Report
- The Future of Food from the Sea
- USAID Marine Tenure Resources

Gender and Social Inclusion

- Integrating Gender Equality and Women's Empowerment Across the Program Cycle, Including Guidance on the Mandatory Gender Analysis (ADS 205)
- Suggested Approaches for Integrating Inclusive Development Across the Program Cycle and in Mission Operations (ADS 201 Additional Help)
- USAID Optional Social Impact Assessment Framework
- New Partnerships Initiative

Climate Change

- USAID Climate Risk Screening and Management Tools Agriculture Annex
- The Ocean as a Solution to Climate Change: Five Opportunities for Action (see Sustainable Food section)
- Unpacking the United Nations Framework Convention on Climate Change (UNFCCC) Global Stocktake for Ocean-Climate Action

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For further assistance related to these Activity Design Guidance documents, please contact ftfguidance@usaid.gov.