LANDING OF SARDINELLA IN GHANA, 2015. PHOTO CREDIT: URI COASTAL RESOURCES CENTER

SECTOR ENVIRONMENTAL GUIDELINE: WILD-CAUGHT FISHERIES AND AQUACULTURE

Partial Update 2024 | Full Update 2018

ABOUT THIS DOCUMENT AND THE SECTOR ENVIRONMENTAL GUIDELINES

USAID has developed sector-specific environmental and social guidance to support activity design, pre-implementation environmental review (including the identification of potential impacts and the design of mitigation and monitoring measures), and the development of environmental mitigation and monitoring plans. **This document presents two sectors—wild-caught fisheries and aquaculture—within the USAID's *Sector Environmental Guidelines***. The Sector Environmental Guidelines for all sectors are accessible at USAID's Sector Environmental Guidelines & Resources webpage.

Purpose. The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally and socially sound design and management of common USAID sectoral development activities by providing concise, plain-language information regarding the following:

- The typical, potential adverse impacts of activities in these sectors, including impacts related to environmental, social, and climate change;
- How to prevent or otherwise mitigate these impacts, both in the form of general design guidance and specific design, construction, and operating measures;
- How to minimize the vulnerability of activities to climate change and the GHG emissions associated with wild-caught fisheries and aquaculture;
- How to minimize social impacts and maximize the benefits to beneficiaries and the local community in the equitable manner; and
- More detailed resources for further exploration of these issues.

Environmental Procedures. USAID's mandatory environmental procedures, as described in Automated Directives System (ADS) 204, require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the Environmental Impact Assessment (EIA) process defined by Title 22, Code of Federal Regulations (CFR), Part 216 (Reg. 216)[1]. They also require that the environmental management and mitigation measures identified by this process be written into award documents, implemented over the life of the project, and monitored for compliance and sufficiency.

The procedures are USAID's principal process to ensure environmentally sound design and management of USAID-funded activities and, thus, to protect environmental resources, biodiversity, ecosystems, ecosystem services, and the health and livelihoods of beneficiaries and other affected groups. These procedures strengthen and sustain development outcomes and help safeguard the good name and reputation of USAID.

The *Sector Environmental Guidelines* directly support environmental compliance by providing information that is essential to assessing the potential impacts of activities and identifying and designing appropriate mitigation and monitoring measures.

However, the Sector Environmental Guidelines are not specific to USAID's environmental procedures. They are generally written and are intended to support environmentally sound design and management of these activities by all actors, regardless of the specific

[1] USAID. 1980. Reg. 216 (22 CFR 216). https://www.usaid.gov/environmental-procedures/laws-regulations-policies/22-cfr-216.

environmental requirements, regulations, or processes that may apply.

Limitations. This document serves as an introductory tool for Agency staff when initiating the design of construction projects. This document is not intended to act as a complete compendium of all potential impacts because site-specific context is critical to determining those impacts. Furthermore, the Guidelines are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

Guidelines Superseded. This SEG replaces the Sector Environmental Guideline: Wild-Caught Fisheries and Aquaculture.

Comments and Corrections. Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: environmentalcompliancesupport@usaid.gov

Advisory. The Sector Environmental Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Sector Environmental Guidelines does not necessarily ensure compliance with USAID environmental procedures or host country environmental requirements.

CONTENTS

ACRONYMS

ADS	Automated Directives System
AOR	Agreement Officer's Representative
BOD	Biochemical Oxygen Demand
BHA	Bureau for Humanitarian Assistance
CDC	Centers for Disease Control and Prevention
CFR	Code of Federal Regulations
CLEER	Clean Energy Emission Reduction
CRM	Climate Risk Management
EAAM	Ecosystem Approach to Aquaculture Management
EA	Environmental Assessment
EBM	Ecosystem-based Fishery Management
ECOS	Environmental Compliance Support
EIA	Environmental Impact Assessment
EJ	Environmental Justice
ESIA	Environmental and Social Impact Assessment
ETP	Endangered, Threatened, and Protected
FAA	Foreign Assistance Act
FAO	Food and Agriculture Organization
GBV	Gender-based Violence
GEEL	Growth, Enterprise, Employment, and Livelihoods
GHG	Greenhouse Gas
GRM	Grievance Redress Mechanism
ILO	International Labor Organization
IP	Implementing Partner
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, Unreported, and Unregulated
LCA	Life Cycle Analyses
LGBTQI+	Lesbian, Gay, Bisexual, Transgender, Queer, and Intersex
NOAA	National Oceanic and Atmospheric Administration
NDCs	Nationally Determined Contributions
PMI	President's Malaria Initiative
PPE	Personal Protective Equipment
PSMA	Port States Measures Agreement
RCP	Representative Concentration Pathway
RFSAs	Resilience Food Security Activities
SDG	Sustainable Development Goal
SEG	Sector Environmental Guideline
SEP	Stakeholder Engagement Plan
SIMP	Seafood Import Monitoring Program
SIRS	Social Impact Risk Initial Screening
SOFIA	State of World Fisheries and Aquaculture
SOPs	Standard Operating Procedures
SSF	Small-scale Fishery
SSP	Socioeconomic Pathway
TB	Tuberculosis
USAID	United States Agency for International Development
USD	United States Dollar
WHO	World Health Organization

1. USING THESE GUIDELINES

The *Sector Environmental Guidelines* are intended for use by the United States Agency for International Development (USAID) and its partners. The following are brief recommendations for each of these user groups:

- **Agency technical or program office staff**, who are designing or providing technical expertise to colleagues and country Missions on fisheries and aquaculture programs and projects, may find Sections 2 through 7 most useful for policy context, an overview of the sector, potential negative environmental impacts, climate change considerations, social impacts, and environmental guidance on project design.
- **Country and regional Mission program staff** (Contracting and Agreement Officer's Representatives, Activity Managers, and Environmental Compliance Officers) also would find Sections 2 through 7 useful for program and project design, including key elements to address in accompanying Initial Environmental Examinations. Section 8 will be most useful for the oversight of Implementing Partners in planning, monitoring, and reporting on environmental mitigation measures during project implementation.
- **Implementing Partners** will benefit from each of the sections of this guide, depending on the needs of the project/activity cycle for design, implementation, monitoring, reporting, or evaluation. The References and Resources section and Annex 1 on ongoing USAID fishery and aquaculture projects also may be most useful for this group of users.

KEY TERMS

Wild-caught fisheries: In this guide, the term "fisheries" refers to wild-caught fisheries (also called capture fisheries). The term covers marine, brackish, and freshwater; commercial and subsistence; and industrial- and small-scale fisheries. In the context of this document, "fisheries" refers to the capture of fish and any aquatic organism, including mollusks, crustaceans, bivalves, and other aquatic invertebrates from environments that are not artificially controlled.

Aquaculture: Aquaculture refers to "the farming of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated."[2]

Small-scale or artisanal fisheries: The characteristics of such fisheries differ among countries; however, the term generally means "traditional fisheries involving fishing households (as opposed to commercial companies), using a relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption."[3] "Women are significant participants in the sector, particularly in post-harvest and processing activities. It is estimated that about 90% of all people directly dependent on capture fisheries work in the small-scale fisheries sector. As such, small-scale fisheries serve as an economic and social engine, providing food and nutrition security, employment and other multiplier effects to local economies while underpinning the

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[2] FAO. 1988. *Definition of aquaculture, Seventh Session of the IPFC Working Party of Expects on Aquaculture*. Bangkok: IPFC/WPA/WPZ, 1-3. Definition taken from https://www.fao.org/3/X6941E/x6941e04.htm.

[3] FAO. 2014. Essential EAFM. *Ecosystem Approach to Fisheries Management Training Course*. Volume 1– For Trainees. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, Bangkok, Thailand: RAP Publication 2014/13, 318. http://www.fao.org/3/a-i3778e.pdf.

livelihoods of riparian communities."[4]

Commercial fishing: This term refers to the catching of wild fish and other aquatic food for commercial profit. The term includes the entire process of catching and marketing fish and shellfish for sale. It refers to fishery resources, fishers, and related businesses.[5] Commercial fishing is done by both industrial- and small-scale fisheries.

Industrial fisheries: Industrial fisheries are involved in commercial fishing on a large scale. "It more generally refers to the high level of technology, investment, and impact it brings to a fishery. With few exceptions, these fisheries use big boats that are worth many millions of dollars and they are equipped with technology capable of efficient, giant catches."[6] They are often equipped with onboard facilities for freezing and processing aquatic food at sea.

Fishing capacity: This term refers to "the ability of a fleet (and all related inputs) to catch fish. Indicators are usually used to gauge capacity levels. The simplest way of doing so is to count the number of boats in a fishing fleet. But more accurate assessments also take into account other variables: the kinds of boats that make up the fleet, including their size; the horsepower of their engines; how many days a year they can operate; and what kind of gear they use."[7] When existing capacity is greater than what is necessary to sustainably harvest a given fish stock, the result is **overcapacity**.[8]

Fishing effort: This term refers to measuring the amount of fishing in an area over a given time period. A common surrogate by which to estimate fishing effort is "the amount of fishing gear of a specific type used on the fishing grounds over a given unit of time."[9]

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[4] FAO. 2015. "Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication." Rome, Italy, 34. http://www.fao.org/3/a-i4356e.pdf.
[5] NOAA. n.d. Understanding Fisheries Management in the United States. Accessed 2024. https://www.fisheries.noaa.gov/insight/understanding-fisheries-management-united-states.
[6] World Fisheries Trust. 2008. "Industrial Fishery: Fishing Methods Fact Card." https://www.worldfish.org/GCI/gci_assets_moz/Fact%20Card%20-%20Industrial%20Fishery.pdf.
[7] FAO. 2004. "Assessing Excess Fishing Capacity at World-Wide Level." https://www.fao.org/fishery/docs/DOCUMENT/news/assess/capa.htm.
[8] FAO. 2002. "Report of the Expert Consultation on Catalysing the Transition Away from Overcapacity in Marine Capture Fisheries." Rome. https://www.fao.org/3/y8169e/y8169e00.htm#Contents.
[9] NOAA. n.d. Understanding Fisheries Management in the United States. Accessed 2024. https://www.fisheries.noaa.gov/insight/understanding-fisheries-management-united-states.

2. THE POLICY CONTEXT AND USAID PROGRAMMING IN WILD-CAUGHT FISHERIES AND AQUACULTURE

The United States Agency for International Development's (USAID) investments in wild-caught fisheries (hereinafter referred to as "fisheries") and aquaculture (or "farmed" fisheries) are made in the context of international, national, and agency guidelines, agreements, and policies. This document refers to fish and other aquatic animals, such as crustaceans, mollusks, bivalves, and other aquatic invertebrates, collectively referred to as "fish." These policies represent the governance framework within which USAID projects in the fisheries and aquaculture sector are designed, implemented, and evaluated for responsible environmental stewardship. Key recent policies are referenced below. Additional resources are found in the References and Resources section.

2.1 INTERNATIONAL GUIDELINES AND AGREEMENTS

United Nations, 2030 Agenda for Sustainable Development, Sustainable Development Goals (SDGs) (2015):

- SDG 2 - Zero Hunger: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture;
- SDG 14 – Life Below Water: Conserve and sustainably use the oceans, seas, and marine resources for sustainable development; and
- SDG 15 - Life on Land: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Food and Agriculture Organization (FAO), Code of Conduct for Responsible Fisheries (1995). Together with the fishing provisions of the UN Convention on the Law of the Sea, the FAO Code of Conduct is the most widely recognized and implemented international fisheries instrument. Its objective is to promote long-term, sustainable fisheries and aquaculture. It prescribes principles and standards for the conservation and management of all fisheries. It also addresses the capture, processing, and trade in fish and fishery products, fishing operations, aquaculture, fisheries research, and the integration of fisheries into coastal area management. The Code of Conduct is voluntary; however, FAO member countries have committed to implementing it.

FAO, Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (The SSF Guidelines) (2015). The Small-Scale Fisheries (SSF) Guidelines are the first internationally agreed-upon instrument dedicated to the small-scale fisheries sector, which recognizes the significant participation of women in the sector. The SSF Guidelines complement the FAO Code of Conduct for Responsible Fisheries.

Port States Measures Agreement (PSMA) to Prevent, Deter, and Eliminate Illegal, Unreported, and Unregulated (IUU) Fishing (entered into force in June 2016 after ratification by a minimum of 25 countries, including the United States). "The PSMA is the first internationally binding treaty aimed at combating IUU fishing. It requires countries to exert greater control on foreign-flagged vessels seeking to enter and use their ports. Operators must submit a request to authorities in these states when they want to land or transship catch. The authorities may refuse entry to vessels known to have engaged in illegal fishing, or immediately inspect them and block their access to port services."[10] FAO indicates that "while there are options for combating IUU fishing at sea, they are often expensive and—especially for developing countries—can be difficult to implement, given the large ocean spaces that need to be monitored and the costs of the required technology."[11]

United Nations, Sustainable Fisheries Agreement (2017). This agreement recalls the relevant provisions of the UN Convention on the Law of the Sea and the relationship with the 1995 Agreement for the Implementation of the Provisions of the UN Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

2.2 U.S. GOVERNING POLICY

Foreign Assistance Act (FAA) of 1961, as amended, Section 117 – Environment and Natural Resources. This section requires USAID to utilize an Environmental Impact Assessment process to evaluate the potential impact of USAID's activities on the environment prior to implementation, and to "fully take into account" environmental sustainability in designing and carrying out its development programs. It states that "[s]pecial efforts shall be made to maintain and, where possible, restore the land, vegetation, water, wildlife, and other resources upon which depend economic growth and human well-being, especially that of the poor."

FAA, Section 118 – Tropical Forests. This section establishes programming mandates related to tropical forests, including mangroves, which are relevant to aquaculture and fisheries. This policy requires that "[e]ach country development strategy statement or other country plan prepared by the Agency for International Development shall include an analysis of (1) the actions necessary in that country to achieve conservation and sustainable management of tropical forests, and (2) the extent to which the actions proposed for support by the Agency meet the needs thus identified."

FAA, Section 119 – Endangered Species. This section establishes programming mandates related to biodiversity and requires that "[e]ach country development strategy statement or other country plan prepared by the Agency for International Development shall include an analysis of (1) the actions necessary in that country to conserve biological diversity, and (2) the extent to which the actions proposed for support by the Agency meet the needs thus identified."

USAID, Biodiversity Policy (2024). "The updated USAID Biodiversity Policy envisions a future in which **biodiversity is conserved so people and nature can thrive**. The Policy provides a blueprint for how the Agency will work to conserve biodiversity in priority places and catalyze nature-positive, equitable development across societal systems. This Policy also emphasizes USAID's recognition of the intrinsic value of nature and the diverse ways in which people value nature, recognizing that human development and survival are inseparable from the health of

[10] The Pew Charitable Trusts. 2017. "Port State Measures Agreement: Why Seafood Buyers Should Help." https://www.pewtrusts.org/~/media/assets/2017/11/eifp_port_state_measures_agreement_why_seafood_buyers_should_help.pdf.
[11] FAO. 2016. "The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all." Rome, Italy, 200. http://www.fao.org/3/a-i5555e.pdf.

biodiverse ecosystems."

USAID, Biodiversity Code *(2024)*. The Biodiversity Code defines four criteria required of programs which use funds designated for biodiversity. Each year, all biodiversity programs are reviewed for consistency with the Code. The four criteria are:

1. "Activities must have an explicit biodiversity objective; it is not enough to have biodiversity conservation result as a positive externality from another activity;
2. Site-based activities must have the intent to impact biodiversity positively in biologically significant areas;
3. Activities must be identified based on an analysis of threats to biodiversity, drivers of these threats, *opportunities for conservation*, and an *evidence-informed* theory of change; and
4. Activities must monitor indicators associated with the stated theory of change for biodiversity conservation results.

U.S. Government, Global Food Security Strategy (2017–2021), supported by the Feed the Future Initiative. The Strategy's vision is "a world free from hunger, malnutrition, and extreme poverty, where thriving local economies generate increased income for all people; where people consume balanced and nutritious diets, and children grow up healthy and reach their full potential; and where resilient households and communities face fewer and less severe shocks, have less vulnerability to the shocks they do face, and are helping to accelerate inclusive, sustainable economic growth." It calls for a comprehensive approach that includes farmers, fishers, foresters, and pastoralists, paying special attention to women, the extreme poor, small-scale producers, youth, marginalized and underrepresented groups and/or people in vulnerable situations, and small and medium enterprises.

National Security Memorandum to Combat Illegal, Unreported, and Unregulated (IUU) Fishing and Associated Labor Abuses *(2022).* The memorandum will address IUU fishing by increasing coordination with diverse stakeholders, launching an IUU Fishing Action Alliance, releasing the National Five-Year Strategy for Combating Illegal, Unreported, and Unregulated Fishing (2022–2026), and proposing a rule to enhance and strengthen the National Oceanic and Atmospheric Administration's (NOAA) ability to address IUU fishing activities and combat forced labor in the aquatic food supply chain.

Presidential Initiative on Combating Illegal, Unreported, and Unregulated (IUU) Fishing and Seafood Fraud *(2014).* The initiative established a Presidential Task Force, co-chaired by the U.S. Departments of State and Commerce, which developed an Action Plan for implementing 15 recommendations, including the roles defined for USAID. The plan identifies actions that will strengthen enforcement; create and expand partnerships with state and local governments, industry, and nongovernmental organizations; and create a risk-based traceability program to track seafood from harvest to entry into U.S. commerce. The *NOAA Seafood Import Monitoring Program (SIMP)* (enacted in January 2017) is one such program. The Task Force Action Plan also highlights the ways in which the United States will work with our foreign partners to strengthen international governance, enhance cooperation, and build capacity to manage fisheries sustainably and combat illegal fishing and seafood fraud.

National Security Memorandum on Combating Illegal, Unreported, and Unregulated (IUU) Fishing and Associated Labor Abuses *(2022)*. The memorandum directs "executive departments and agencies to work toward ending forced labor and other crimes or abuses in IUU fishing; promote sustainable use of the oceans in partnership with other nations and the private sector; and advance foreign and trade policies that benefit U.S. seafood workers."

National Five-Year Strategy for Combating Illegal, Unreported, and Unregulated (IUU) Fishing (2022–2026). The Strategy was developed by the U.S. Interagency Working Group on IUU Fishing, composed of 21 federal agencies, including USAID.

2.3 USAID STRATEGY AND PROGRAMMING IN WILD-CAUGHT FISHERIES AND AQUACULTURE

USAID's marine biodiversity and other fishery activities aim to conserve biodiversity and increase human well-being through sustainable management of fisheries and conservation of coastal and marine habitats in national waters. Activities span more than 30 countries in Southeast Asia, Africa, Latin America, and the Caribbean and represent USD 50-60 million per year in investments, including freshwater fishery management in Malawi and the Democratic Republic of the Congo. In addition, USAID launched the Save Our Seas Initiative in 2022, representing an over USD 100 million investment. Approaches focus on improving governance, promoting participatory decision-making, and enhancing natural productivity through ecosystem-based management, national-level and community-based fishery management, co-management, marine protected areas, and watershed management, as well as investing in improved aquatic food supply chain transparency and traceability with the goal of using these data to improve legality and sustainability.[12]

USAID activities also include aquaculture or fish farming research in nine countries in Africa and Asia. USAID's aquaculture research activities aim to cultivate international multidisciplinary partnerships to advance novel solutions that support the goals of reducing global hunger, poverty, and undernutrition by developing comprehensive, sustainable, ecologically compatible, and socially viable aquaculture systems. Annex 1 provides a summary of ongoing examples of USAID fishery projects and aquaculture research projects.[13]

Promoting good governance and improving fishery and aquaculture management are priority themes for USAID investments in fisheries and aquaculture. Poor governance and weak management systems in fisheries and aquaculture are the leading causes of overfishing and significant environmental and social impacts from aquaculture. Improving the institutional and regulatory frameworks for fishery management and aquaculture development contributes to the USAID goal of promoting transparent and participatory democracy. This includes strengthening the rule of law (e.g., fisheries enforcement and aquaculture regulation, including land tenure, water rights, and environmental guidelines) and improving civil society engagement (enhanced participation through co-management approaches). Governance and management considerations are therefore woven throughout these *Sector Environmental Guidelines*.

[12] For more information on USAID's marine biodiversity programming, see USAID's Protecting Our Oceans webpage accessible at https://www.usaid.gov/biodiversity/protecting-our-ocean#:~:text=USAID%20promotes%20nature-based%20solutions%20as%20a%20key%20means,supporting%20livelihoods%20and%20human%20adaptation%20to%20climate%20change and USAID's BiodiversityLink website accessible at https://biodiversitylinks.org/.
[13] For more information of USAID's aquaculture programming see the Feed the Future Innovation Lab for Fish webpage accessible at https://www.fishinnovationlab.msstate.edu/.

The type of funding available for a project often factors into the potential for negative environmental or social impacts. The following sections highlight key funding sources and examples of the types of USAID fishery and aquaculture projects funded by each. Figure 1 below illustrates the influence of the source of USAID funding on project objectives. It also illustrates the potential negative environmental impacts to consider under each funding source and shows that climate risk management should be mainstreamed with equal importance regardless of the funding source to enhance the resilience of socioeconomic and environmental systems.

2.3.1 BIODIVERSITY PROGRAMMING

Many USAID fishery projects have been funded entirely, or in some part, with biodiversity funds. For example:

- The Mekong Delta Coastal Habitat Conservation Activity was funded to mitigate threats to coastal biodiversity and fisheries and enhance resilience to climate change in the Mekong Delta by working with businesses, provincial governments, management boards, and fishing communities to test and build on new policy and financing opportunities.
- The Philippine's Sustainable Interventions for Biodiversity, Ocean, and Landscapes has been funded to improve natural resources governance in marine landscapes, stimulate public and private sector investments in natural resources management, and reduce environmental crimes and unsustainable practices.
- Our Fish Our Future will advance sustainable coastal fisheries in 12 Pacific Island nations, with a specific focus on six countries, by addressing the drivers of illegal, unreported, and unregulated fishing and overfishing that are degrading coastal fisheries and biodiversity, negatively affecting community livelihoods, and threatening maritime security and sovereignty.
- The Pacific Coastal Fisheries Management and Compliance activity is funded to advance sustainable coastal fisheries co-management and address the drivers of illegal, unreported, and unregulated fishing that are degrading coastal fisheries and biodiversity and negatively affecting local livelihoods and maritime security.
- The Sustainable Fish Asia Local Capacity Development activity is funded to build the institutional capacity of the Southeast Asian Fisheries Development Center and the Coral Triangle Initiative for Coral Reefs, Fisheries, and Food Security to improve the management of marine biodiversity and fishery resources in the Indo-Pacific region.
- Sustainable Fish Asia Technical Support is funded to promote sustainable fisheries and marine biodiversity conservation in the Indo-Pacific region, address gender inequity and forced labor concerns within regional aquatic food supply chains, and provide technical support services and tools to combat illegal, unreported, and unregulated fishing.
- The Women Shellfishers and Food Security Project is funded to improve food security for women shellfishers in West Africa and simultaneously improve the biodiversity conservation of the ecosystems on which their livelihoods depend.
- The Philippines' Ecosystems Improved for Sustainable Fisheries (ECOFISH) project was entirely funded by biodiversity funds and managed by the USAID/Philippines Mission Economic Growth Office.

- The Oceans and Fisheries Partnership (OCEANS) is entirely funded by biodiversity funds and managed by the Regional Development Mission for Asia.
- The Collaborative Management for a Sustainable Fisheries Future in Senegal (COMFISH) project is funded with Feed the Future and biodiversity funds and is managed by the USAID/Senegal Mission Economic Growth Office.

All activities funded with biodiversity funds must meet the Biodiversity Code and be designed to explicitly reduce key threats to biodiversity, to produce a positive affecting on biodiversity. Biodiversity-funded fisheries projects may focus on improving fishery governance policy and management, including traceability and deterring illegal fishing, for food security, nutrition, resilience, and secure livelihoods. Biodiversity-funded projects may conserve critical habitats and ecosystems—that support fisheries—to increase and maintain the productivity of fisheries. While the intent of a biodiversity project is to benefit the environment, there could be situations where specific activities may have adverse environmental or social impacts. It is important to think through the activity, regardless of its intent, to look for unforeseen negative environmental and social impacts.

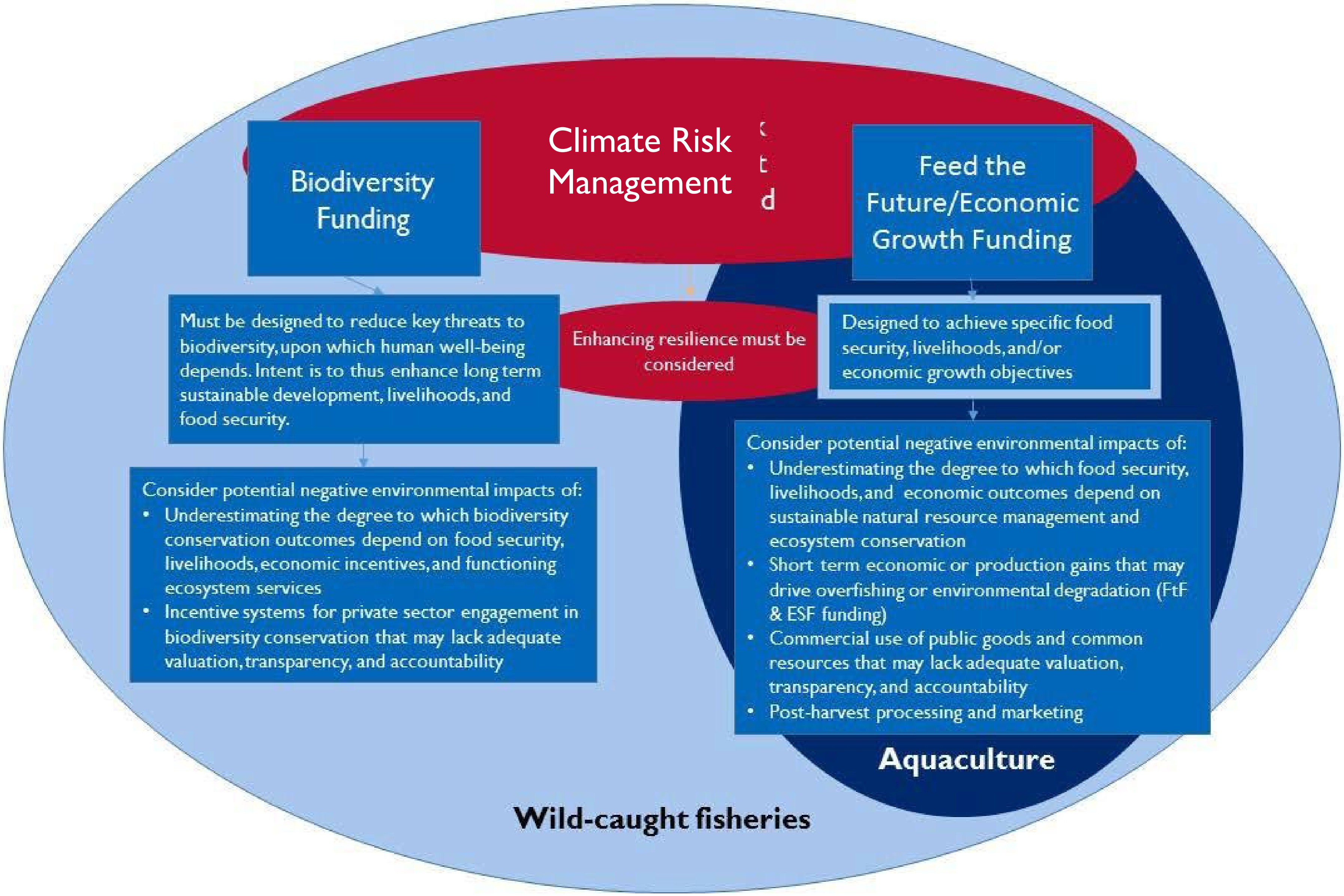
2.3.2 FOOD SECURITY AND ECONOMIC GROWTH PROGRAMMING

Some USAID fishery projects and most aquaculture projects have been funded by Feed the Future or the Economic Support Fund. For example:

- The Ghana Sustainable Fisheries Management Project (SFMP) is funded almost entirely with Feed the Future funds and is managed by the USAID/Ghana Mission Economic Growth Office.
- The Feed the Future Ghana Fisheries Recovery Activity (GFRA) is funded with Feed the Future funds and is managed by the Government of Ghana and relevant stakeholder groups.
- The Feed the Future initiative, overall, is led by the USAID Bureau for Resilience, Environment, and Food Security in Washington, D.C.
- OurFish OurFuture is funded with Feed the Future funds and is implemented in partnership with the University of Rhode Island’s Coastal Resources Center, Locally Managed Marine Area Network, World Wildlife Fund, and The University of the South Pacific
- The Somalia Growth, Enterprise, Employment and Livelihoods (GEEL) project is funded primarily by the Economic Support Fund and is managed by USAID/East Africa, Somalia Unit.
- Bureau for Humanitarian Assistance (BHA) Resilience Food Security Activities (RFSAs) also can support the sustainability and resilience of fisheries.

Projects funded by the Economic Support Fund often have short-term objectives. Both Feed the Future and the Economic Support Fund have specific food security, livelihood, and/or economic growth objectives, which may have negative environmental and social impacts if not implemented with strong governance and management for sustainable, long-term resource use and equity of benefits.

FIGURE 1. THE INFLUENCE OF USAID FUNDING SOURCE ON PROJECT OBJECTIVES AND POTENTIAL NEGATIVE ENVIRONMENTAL IMPACTS TO CONSIDER



3. OVERVIEW OF THE WILD CAUGHT FISHERIES AND AQUACULTURE SECTORS

Net fish export revenues of developing countries reached USD 35 billion in 2019, higher than other agricultural commodities such as meat, tobacco, rice, and sugar, combined. *(FAO, 2021).*

Approximately 71 percent of the Earth's surface is covered in water, of which oceans hold approximately 96.5 percent of the total volume.[14] Thus, it is not surprising that oceans are integral players in climate and weather regulation through the absorption and redistribution of solar radiation from the sun (resulting in the redistribution of moisture and driving weather systems) and from absorption of carbon dioxide from the atmosphere (sequestering carbon dioxide).[15] In addition to affecting climate systems, oceans and freshwater bodies also are affected by climate change. Oceans and freshwater systems are home to complex ecosystems that comprise approximately 20 percent of the world's known plant and animal species, with freshwater habitats containing the greatest animal species richness per area.[16] These aquatic environments also support wild-caught and farmed fresh and saltwater aquatic food production. In this document, the terms "fisheries" and "aquaculture" include growing or catching aquatic food and post-harvest handling and processing.

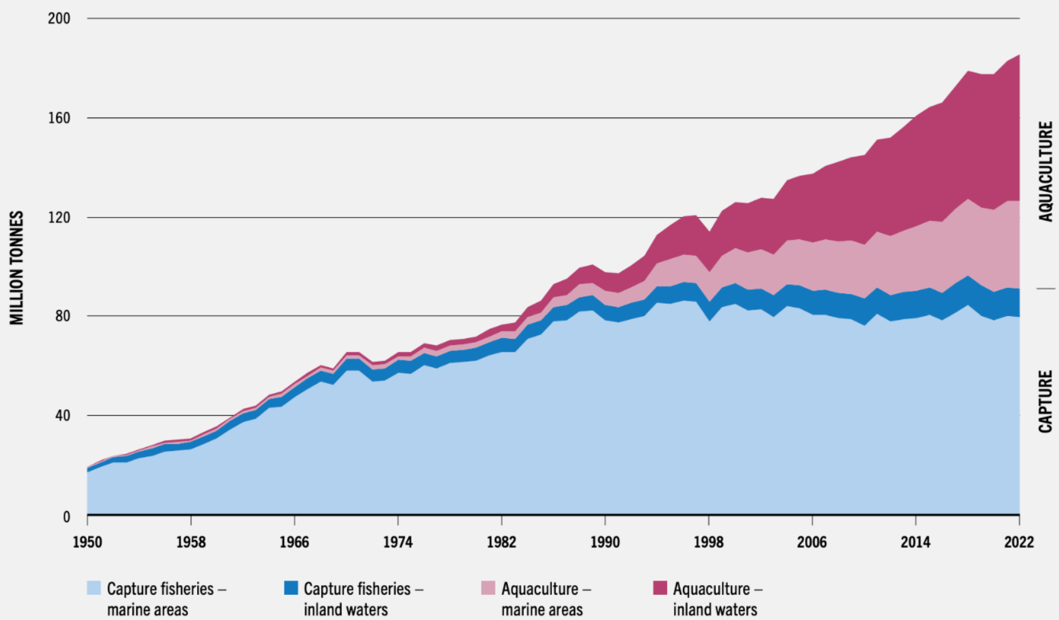
Fish,[17] or aquatic food, is an important food commodity that provides significant employment, economic revenues, and export earnings for many developing countries. As defined in this report, fisheries and aquaculture global fish production has grown steadily for decades to a total of 185 million metric tons in 2022 (Figure 2), with fisheries accounting for 91 million metric tons and aquaculture contributing 94 million metric tons. Developing countries account for 78% of the fish food supply globally.[18] However, a recent study suggests that the official Food and Agriculture Organization (FAO) statistics have underreported the actual fisheries catch. The study estimates that there was a peak of 130 million metric tons more than two decades ago and that catches have declined continuously since then.[19]

World aquatic food capture and production have grown approximately twice as fast as the human population. An increasing amount of the global fish supply is being used for direct human consumption (87% in 2014) as opposed to non-food uses. Until 2000, small-scale fishers contributed more food fish for humans than industrial fisheries.[20] Per capita consumption of fish also has steadily increased from 9.9 kilograms per capita per year in the 1960s to approximately

[14] Water Science School. 2019. How Much Water Is There on Earth? U.S. Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-there-earth.
[15] NOAA. n.d. Understanding Fisheries Management in the United States. Accessed 2024. https://www.fisheries.noaa.gov/insight/understanding-fisheries-management-united-states.
[16] Román-Palacios, C., Moraga-López, D., & Wiens, J. J. 2022. "The origins of global biodiversity on land, sea and freshwater." Ecology Letters 25 (6): 1376-1386. https://onlinelibrary.wiley.com/doi/10.1111/ele.13999?af=R&msockid=27f4aa84b15f6bab1516b947b04d6ac6.
[17] Including wild-caught or farmed fresh and saltwater fish and other edible aquatic animals.
[18] FAO. 2024. The State of World Fisheries and Aquaculture 2024. *Blue Transformation in Action*. Rome, Italy. https://doi.org/10.4060/cd0683en.
[19] Pauly, D. and D. Zeller. 2016. "Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining." *Nature Communications* 7: 10244. doi:10.1038/ncomms10244. https://www.nature.com/articles/ncomms10244.
[20] Teh, L.C.L and Pauly, D. 2018. "Who Brings in the Fish? The Relative Contribution of Small- Scale and Industrial Fisheries to Food security in Southeast Asia." *Frontiers in Marine Science* 5: 44. doi:10.3389/fmars.2018.00044. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2018.00044/full.

20 kilograms per capita per year today.[21] Fish accounts for approximately 20 percent of the global population’s intake of animal protein. However, in many developing countries (including key Feed the Future countries) in coastal West Africa, Bangladesh, Southeast Asia, and the Pacific, fish exceeds 50% of the animal protein supply. Fish is a particularly important source of protein because it contains a rich source of micronutrients and vitamins A, B, and D, as well as essential omega-3 fatty acids.[22] These micronutrients are important in early child development because they improve cognitive function.[23]

FIGURE 2. TRENDS IN WORLD FISHERIES AND AQUACULTURE PRODUCTION[24]



NOTES: Aquatic animals excluding aquatic mammals, crocodiles, alligators, caimans, aquatic products (corals, pearls, shells and sponges) and algae. Data expressed in live weight equivalent.

SOURCE: FAO. 2024. FishStat: Global production by production source 1950–2022. [Accessed on 29 March 2024]. In: FishStatJ. Available at: www.fao.org/fishery/en/statistics/software/fishstatj. Licence: CC-BY-4.0.

Increasing demand for aquatic food from developing countries has increased pressure on the sustainability and resilience of both fisheries and aquaculture systems, as have increased impacts from climate change. The world per capita fish supply stood at a record 20.7 kilograms

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[21] FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.

[22] Kawarazuka, N. and C. Béné. 2011. "The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence." *Public Health Nutrition* 14 (11): 1927-38. doi:10.1017/S1368980011000814. https://www.cambridge.org/core/journals/public-health-nutrition/article/potential-role-of-small-fish-species-in-improving-micronutrient-deficiencies-in-developing-countries-building-evidence/C49790032DD4E921C33CD145402B7C3A.

[23] Oken, E., M.L. Østerdal, M.W. Gillman, V.K. Knudsen, T.I. Halldorsson, M. Strøm, D.C. Bellinger, M. Hadders-Algra, K.F. Michaelsen, and S.F. Olsen. 2008. "Associations of maternal fish intake during pregnancy and breastfeeding duration with attainment of developmental milestones in early childhood: a study from the Danish National Birth Cohort." *The American Journal of Clinical Nutrition* 88 (3): 789-796. https://pubmed.ncbi.nlm.nih.gov/18779297/.

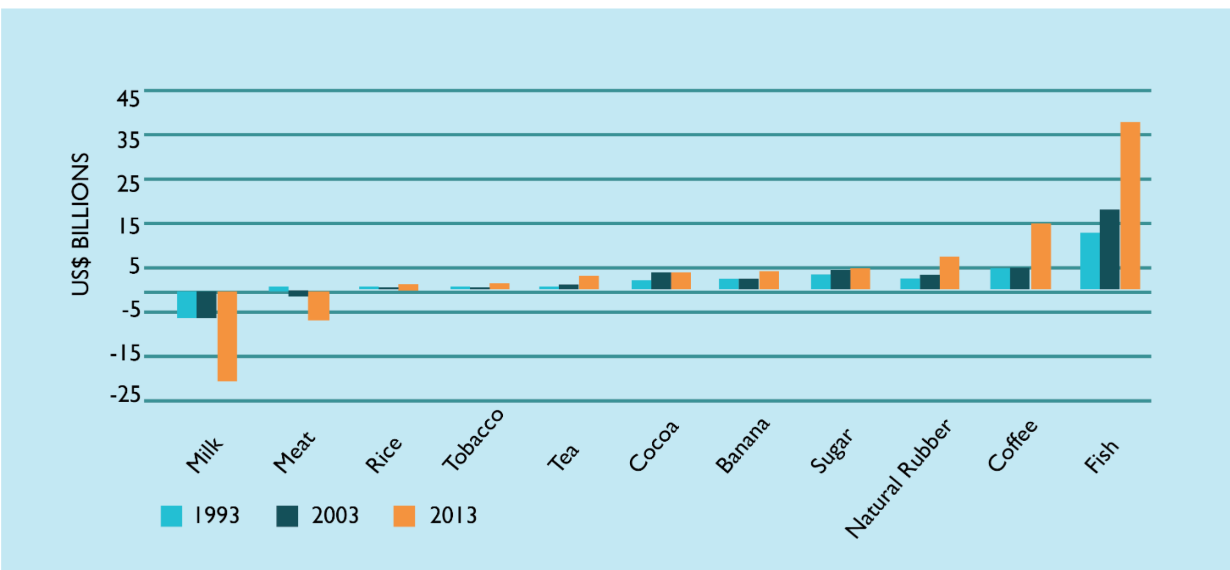
[24] FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.

per capita in 2022. This is double the level in the 1960s due primarily to vigorous growth in the aquaculture sector.[25] While aquaculture has shown large gains in production, most of that (36 percent) comes from China. However, the potential for significant growth in Africa and other parts of the world is high.

For global aquatic food availability to meet the demand of a projected world population of 9.7 billion in 2050, aquaculture production would need to more than double to 140 million metric tons.[26] While capture fisheries production has leveled off and even declined in recent years, more gains could potentially be made by preventing overfishing and illegal fishing and implementing sustainable, climate-resilient fishing practices.

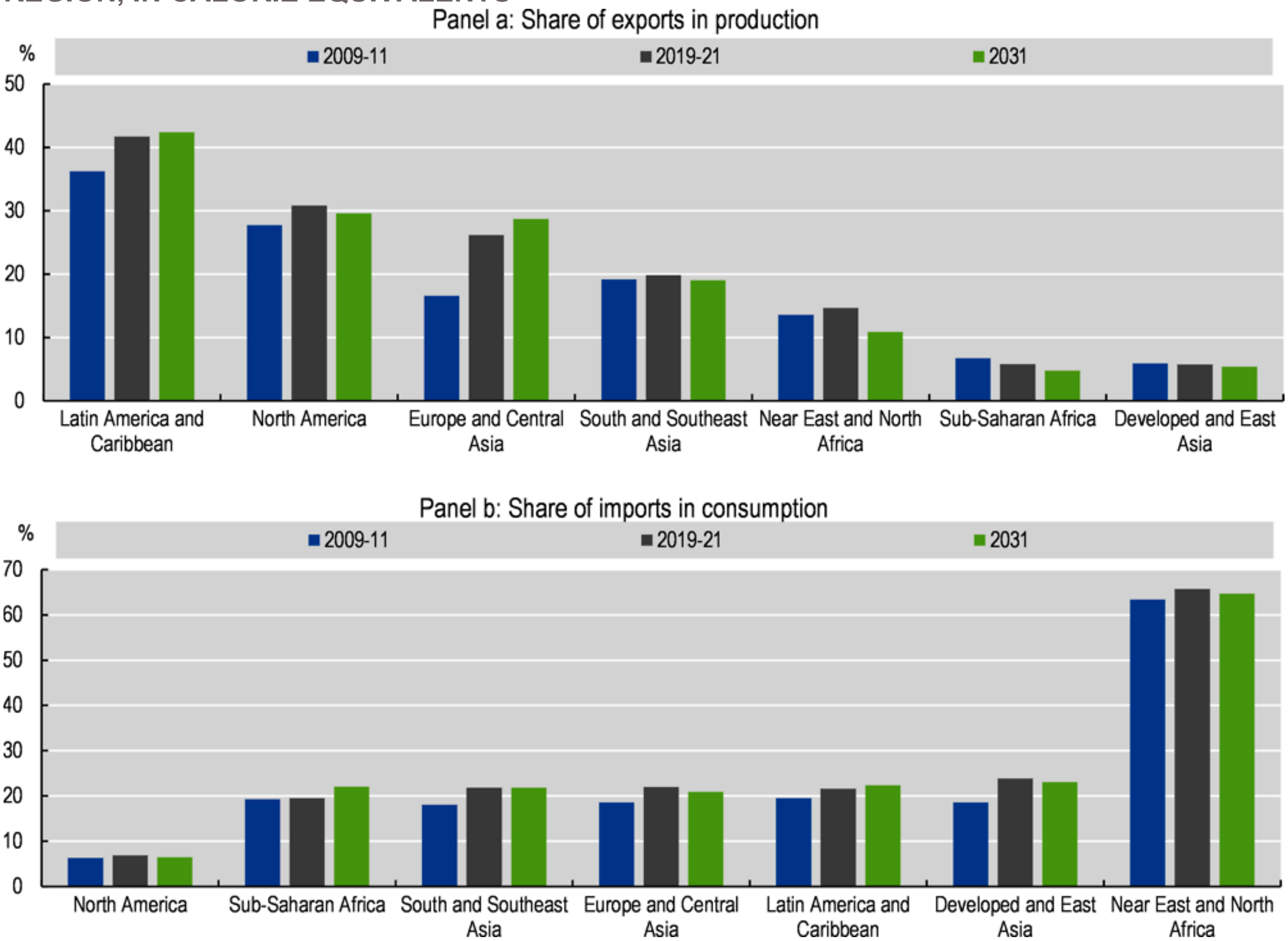
Fish and fish products are among the most traded food commodities in the world. Approximately 78 percent of aquatic food products are exposed to international trade competition. Approximately 38 percent of total fish production is exported—worth USD 192 billion in 2022.[27] The developing countries' share of the global fishery export value has increased to 54 percent in 2014 and is valued at USD 80 billion. An increasing share of the international fish trade belongs to developing countries.[28] The value of net exports of fish from developing countries is greater than that of rice, sugar, and coffee combined (Figure 3). Some developing countries with high per capita consumption are net importers of fish products because the demand far outstrips the local supply.

FIGURE 3. NET EXPORTS OF SELECTED AGRICULTURAL COMMODITIES BY DEVELOPING COUNTRIES[29]



[25] FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.
[26] Waite, R., M. Beveridge, R. Brummett, S. Castine, N. Chaiyawannakarn, S. Kaushik, R. Mungking, S. Nawapakpilai, and M. Phillips. 2014. *Creating a Sustainable Food Future*, No. 5: Improving Productivity and Environmental Performance of Aquaculture. Working Paper. Washington, D.C.: World Resources Institute. http://www.wri.org/sites/default/files/wrr_installment_5_improving_productivity_environmental.
[27] Ibid.
[28] FAO. 2016. "The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all." Rome, Italy, 200. http://www.fao.org/3/a-i5555e.pdf.
[29] FAO. 2016. "The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all." Rome, Italy, 200. http://www.fao.org/3/a-i5555e.pdf.

FIGURE 4. TRADE AS A SHARE OF TOTAL PRODUCTION AND CONSUMPTION BY REGION, IN CALORIE EQUIVALENTS[30]



One of the major challenges of sustainably meeting current and future global aquatic food demand will be the increased negative effects from climate change. The Intergovernmental Panel on Climate Change (IPCC) has documented changes across ocean ecosystems and determined that it is "virtually certain" that there will continue to be profound and pervasive changes in oceans on regional and global levels.[31] Some of these changes include sea level rise, acidification, loss of coastal habitats due to inundation, and accelerating shifts in species distribution and productivity, all of which will significantly affect marine ecosystem services and wild-caught aquatic food production levels.[32] In fact, a recent study indicates that by 2100 increased water temperatures resulting from climate change could result in a 10% to 60%

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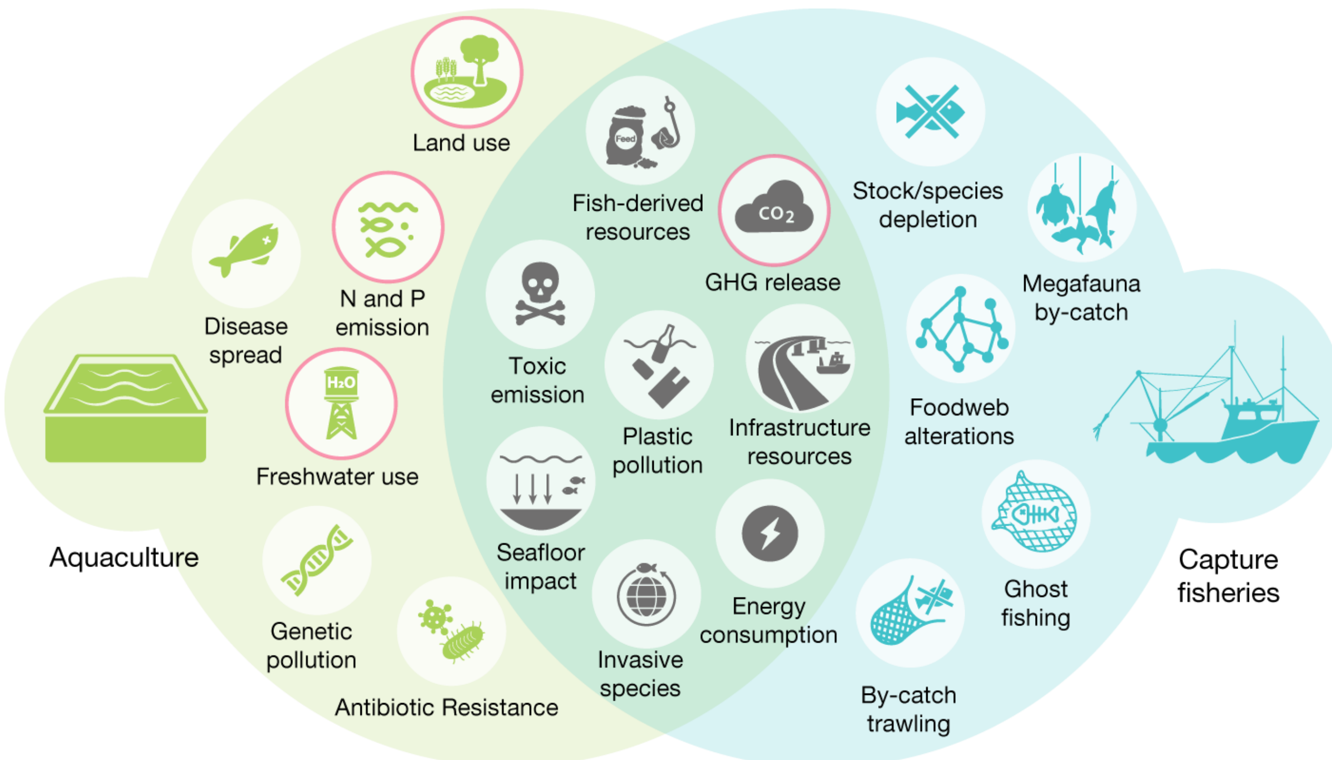
[30] OECD/FAO. 2022. OECD-FAO Agricultural Outlook 2023-2032. https://www.oecd-ilibrary.org/agriculture-and-food/data/oecd-agriculture-statistics_agr-data-en.

[31] Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, et al. 2019. *Changing Ocean, Marine Ecosystems, and Dependent Communities*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 447–587. https://doi.org/10.1017/9781009157964.007.

[32] Mason, Julia G., et al. 202. "Attributes of climate resilience in fisheries: From theory to practice." *Fish and Fisheries* 23.3 522-544. https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12630?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

reduction in marine and freshwater fish species.[33] Reduced stream flow and water levels in rivers and lakes due to increasing temperatures, increasing drought, and changing precipitation patterns also are likely to negatively affect freshwater and saltwater fisheries. Furthermore, major stressors for both fisheries and aquaculture will be exacerbated by climate impacts (see Figure 5).

FIGURE 5. MAJOR STRESSORS STEMMING FROM AQUACULTURE AND CAPTURE FISHERIES[34]



As shown in Figure 5, the world aquatic food supply comes from a combination of fisheries and aquaculture production. While both sectors provide fish to domestic and international supply chains, they are quite distinct in terms of the means of production and environmental considerations for their development and management. Wild-caught fisheries involve managing the sustainable harvesting of a natural renewable resource, while aquaculture is a specialized form of farming. The United States and FAO, as well as some other countries, consider fisheries and aquaculture part of agriculture and they are often managed by one agency as part of an agriculture portfolio. While the production of fish from fisheries and aquaculture is considerably different, the fish produced may be indistinguishable in the post-harvest supply chain.

[33] Dahlke, F. T., Wohlrab, S., Butzin, M., & Pörtner, H. O. 2020. "Thermal bottlenecks in the life cycle define climate vulnerability of fish." *Science* 369 (6499): 65-70. https://www.science.org/doi/10.1126/science.aaz3658.
[34] Gephart, J.A., E. Rovenskaya, U. Dieckmann, M.L. Pace, and Å. Brannström. 2016. "Vulnerability to shocks in the global seafood trade network." *Environmental Research Letters* 11. doi:10.1088/1748-9326/11/3/035008. https://iopscience.iop.org/article/10.1088/1748-9326/11/3/035008.

3.1 WILD-CAUGHT FISHERIES

Wild-caught fisheries accounted for approximately 49% of aquatic food production worldwide in 2022.[35] The sector plays an important role in global and local food security, nutrition, livelihoods, national revenues, and international trade. Sustainable management of fisheries is important from a biodiversity conservation perspective, and healthy, biodiverse ecosystems are important for maintaining the natural productivity of wild-caught fisheries.

3.1.1 THE STRUCTURE OF THE FISHERIES SECTOR

Fish caught from oceans and estuaries are referred to as “marine fisheries,” whereas those caught from rivers, lakes, and reservoirs are categorized as “inland or freshwater fisheries.” The majority of fish are sourced from marine fisheries, accounting for approximately 62% of the total.[36] The productive plankton-rich waters of the continental shelf and continental upwelling areas in the nearshore produce high yields of fish. Therefore, most fish catch is from the exclusive economic zones of nation-states and are under national jurisdiction. However, there also are high seas fisheries, especially for large pelagic species, such as tuna, which are beyond national jurisdictions and are managed by regional fishery management organizations.

Fisheries production is generated from two main subsectors—industrial (or large-scale) and small-scale fisheries. Sustainable certification and traceability programs are more common in the industrial and export sectors; however, more programs are being designed for the small-scale sector as well. The United States Agency for International Development’s (USAID) projects tend to focus more on the small-scale sector as it typically generates more employment and food supply for local markets than the industrial or large-scale sector. However, small-scale fisheries sometimes target export products, and industrial fisheries are often a target for programs trying to address illegal fishing. The two subsectors are often in competition for the same resources and, thus, both need to be addressed in order to achieve sustainable fishery management.

[35] FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.
[36] Ibid.

FIGURE 6. A COMPARISON OF LARGE- AND SMALL-SCALE FISHERIES[37]

FISHERY / BENEFITS	LARGE SCALE	SMALL SCALE
Subsidies	$ $ $ $ $ 25-27 billion	$ 5-7 billion
Number of fishers employed	about 1/2 million	over 12 million
Annual catch for human consumption	about 30 million t	same: about 30 million t
Annual catch reduced to fishmeal and oils	35 million t	Almost none
Annual fuel oil consumption	about 37 million t	about 5 million t
Catch per tonne of fuel consumed	= 1-2 t	= 4–8 t
Fish and other sealife discarded at sea	8–20 million tonnes	Very little

3.1.2 NATURAL CAPITAL AND ECOSYSTEM SERVICES IN THE FISHERIES AND AQUACULTURE SECTOR

Natural capital describes the naturally occurring assets, such as wetlands, mangroves, and coral reefs, which provide a wide range of benefits—or ecosystem goods and services—to

[37] Jacquet, J. and D. Pauly. 2008. "Funding Priorities: Big Barriers to Small-Scale Fisheries." *Conservation Biology* 22 (4): 832–835. doi:10.1111/j.1523-1739.2008.00978.x. https://conbio.onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2008.00978.x.

communities and economies.[38] Examples of ecosystem services include habitat for fish, water quality maintenance, and storm surge protection. The loss of critical ecosystem services, in part due to environmental degradation and climate change impacts, inevitably results in higher costs for fewer benefits.[39] Understanding and assessing these trade-offs is thus critical to sustainable development.

Maintaining healthy aquatic ecosystems is critical to ensuring continued productivity in the fisheries and aquaculture sectors, and the resilience of those communities and populations that rely on both for income and nutrition. Specific examples of the many ecosystem goods and services associated with fisheries and aquaculture systems are provided in Table 1.

TABLE 1. ECOSYSTEM GOODS AND SERVICES SUPPORTING THE FISHERIES AND AQUACULTURE SECTORS

CATEGORY OF GOODS/SERVICES	ECOSYSTEM GOODS AND SERVICES	EXAMPLES IN THE FISHERIES AND AQUACULTURE SECTORS
Provisioning	Food	Fish, shellfish, and seaweed for human consumption
	Medicinal Resources	Marine-derived pharmaceuticals, such as analgesics and anti-inflammatories
	Ornamental Resources	Shells, pearls, or coral that can be turned into jewelry and decorations
	Energy and Raw Materials	Algae used for non-food purposes, such as fertilizer and energy
	Water Storage	Wetlands and healthy ecosystems mitigate droughts and floods and maintain environmental flows.
	Air quality	The ocean produces 50 percent of the oxygen we breathe. Healthy coastal ecosystems purify the air of contaminants (e.g., dust, foul odors).
	Biological Control	Bivalve filtering of coastal water by shellfish may reduce pathogen populations.
	Climate Stability	Marine ecosystems contribute to the global hydrological cycle, extra-regional weather patterns, and local and regional climates. For example, they help moderate temperatures.
	Disaster Risk Reduction	Coral reefs, mangrove forests, and kelp forests dampen and attenuate waves, reducing breaking wave velocity and protecting coastal communities and ecosystems.
	Genetic Transfer	Dispersal of gametes, larvae, and

[38] Hattam, C., Atkins, J.P., Beaumont, N., Börger, T., Böhnke-Henrichs, A., Burdon, D., de Groot, R., Hoefnagel, E., Nunes, P.A., Piwowarczyk, J., Sastre, S., and M.C. Austen. 2015. "Marine ecosystem services: Linking indicators to their classification." *Ecological Indicators* 49: 61-75. http://dx.doi.org/10.1016/j.ecolind.2014.09.026.
[39] World Bank. 2016. *Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs*. Washington, D.C.: Wealth Accounting and the Valuation of Ecosystem Services Partnership (WAVES). http://documents.worldbank.org/curated/en/995341467995379786/Managing-coasts-with-natural-solutions-guidelines-for-measuring-and-valuing-the-coastal-protection-services-of- mangroves-and-coral-reefs.

CATEGORY OF GOODS/SERVICES	ECOSYSTEM GOODS AND SERVICES	EXAMPLES IN THE FISHERIES AND AQUACULTURE SECTORS
		angiosperm by currents and tides support basic reproductive processes and intra-species diversity.
	Soil Formation	Detritus (whale falls) and other nutrients support benthic food webs.
	Sand Replenishment	Erosion of coral reefs and calcareous algae supplies sand for beaches, which is good for tourism.
	Water Quality	Nutrient cycling in ocean waters supports healthy marine habitats. Bivalve filtering in coastal waters improves water quality.
	Water Capture, Conveyance, and Supply	Tides move water throughout intertidal zones, supporting intertidal species and habitat. Surface water flows are a major source of water for all terrestrial uses.
	Navigation	Navigable waters enable the movement of fishing vessels.
	Habitats and Nurseries for Marine Life	Mangroves, seagrass beds, rivers, and coral reefs provide habitats that are critical for sustaining populations of fish and shellfish throughout their life cycles. This includes species that are critical to ecosystem function, but without direct economic or cultural value.
Supporting	Aesthetic Value	Healthy marine, coastal, and freshwater ecosystems are valued simply because they are visually appealing.
	Cultural Value	There are traditional and cultural values associated with coastal and marine habitats. Furthermore, there are traditional livelihoods and use of fish, shellfish, and seaweed that are valued because of the history associated with them.
Cultural	Recreation and Tourism	Recreational fishing is a popular pastime. Coastal and marine habitats also are popular tourist attractions.
	Science and Education	Research on aquatic ecosystems informs engineering and education. Aquaculture systems are researched for potential innovations, as well as the monitoring of externalities.

3.1.3 FISHERIES' CONTRIBUTION TO EMPLOYMENT

The fisheries sector, including associated post-harvest activities, such as fish processing and marketing, provides full- or part-time employment for an estimated 260 million people in marine fisheries and 25 million people in inland fisheries, with about half of them being women.[40]

3.1.4 THE ROLE OF WOMEN IN FISHERIES

While women play many roles in the fisheries supply chain, men are primarily engaged in harvesting at sea, boat building, and engine maintenance and repair. Women are mainly engaged in processing and marketing; however, they also can be primary producers. For example, women often harvest shellfish and other organisms by walking along the shoreline (referred to as "gleaning"). They also use small dugout canoes in intertidal areas. Some women own fishing vessels and, in many countries, they finance fishing trips, thereby guaranteeing a source of fish for their processing and marketing operations. In the freshwater aquaculture supply chain, women may play a role in small-scale aquaculture and post-harvest commercial and artisanal processing; however, as aquaculture investments scale up, oftentimes women may be limited to lower paid jobs due to gender-based barriers, and sometimes they lack the opportunity to access jobs such as the senior staff of aquaculture operations and managerial positions or become executives. Therefore, the need to consider gender equality and empowerment in the fisheries sector, by means of including a gender-inclusive lens in designing and planning for fishery and aquaculture projects, is key.[41]

3.1.5 THE FISHERIES VALUE CHAIN

The fisheries value chain starts with inputs used to harvest the fish on the water, including boats, nets, and human resources. Inputs, in conjunction with appropriate harvesting practices, can affect the productivity, size, and quality of the wild-caught fish, and thus the rest of the value chain. After harvesting, the value chain requires onboard handling and storage, followed by offloading at shore-based or beach landing sites where it is processed or sold fresh to wholesale or retail markets before reaching consumers. Industrial vessels can have sophisticated processing facilities onboard for gutting, filleting, or freezing fish, whereas small-scale fisheries may only bleed, gut, or ice fish before landing on shore and often do not use ice at sea. Onshore processing varies; however, for small-scale fisheries, a large volume is sold and consumed fresh, smoked, or dried. Poor onboard handling and processing techniques can lead to large losses in the value and quantity of the catch. Onboard handling and processing are areas where significant improvements and added value can be achieved.

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[40] Teh, L.C.L. and U.R. Sumaila. 2013. "Contribution of Marine Fisheries to Worldwide Employment." *Fish and Fisheries* 14 (1): 77–88. https://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2011.00450.x?msockid=27f4aa84b15f6bab1516b947b04d6ac6.; Funge Smith, S. and A. Bennett. 2019. "A Fresh Look at Inland Fisheries and Their Role in Food Security and Livelihoods." *Fish and Fisheries* 20 (6): 1,176–95. https://onlinelibrary.wiley.com/doi/10.1111/faf.12403?msockid=27f4aa84b15f6bab1516b947b04d6ac6.; Kruijssen, F., I. Tedesco, A. Ward, L. Pincus, D. Love, and A.L. Thorne-Lyman. 2020. "Loss and Waste in Fish Value Chains: A Review of the Evidence from Low and Middle-Income Countries." *Global Food Security* 26. https://www.sciencedirect.com/science/article/pii/S2211912420300882?via%3Dihub.

[41] Brugere, C. and M. Williams. 2017. "Women in aquaculture profile." GAF. https://www.genderaquafish.org/women-in-aquaculture.htm; Awuor, F. J. 2012. "The role of women in freshwater aquaculture development in Kenya." *Aquatic Ecosystem Health & Management* 24(1): 73-81. https://scholarlypublishingcollective.org/msup/aehm/article-abstract/24/1/73/173879/The-role-of-women-in-freshwater-aquaculture; FAO. 2016. *Promoting gender equality and women's empowerment in fisheries and aquaculture*. FAO Family Farm Knowledge Platform. https://www.fao.org/family-farming/detail/en/c/472871/.

Fishery management projects sometimes focus only on the sustainable harvesting of fish at sea and instituting governance reforms that move the system toward secure tenure and managed access to fishing grounds; however, integrated projects also may consider sustainable harvesting controls, as well as post-harvest value chain improvements. This can include improving labor practices, for example, by addressing child labor and the trafficking of persons, which is a problem in many fisheries.

3.1.6 TRENDS IN FISHERIES PRODUCTION AND LOST ECONOMIC POTENTIAL

As shown in Figure 2 above, worldwide production from fisheries has seen little growth over the past decade due to poor management and industrial fleets moving from one fishing area to another. Fisheries, as a sustainable and renewable natural resource, must be managed so as not to exceed maximum sustained yields. FAO estimates that the proportion of fish stocks that are underfished was approximately 11 percent in 2021. The proportion of fish stocks considered to be overfished has increased to 50.5 percent in 2021, a 20 percent increase from 2013.[42] Fisheries in developing countries are most vulnerable to declining catches due to threats such as poor management, illegal fishing, and climate change. Management effectiveness is weakest in low-income developing countries (see Figure 7).

FIGURE 7. THE EFFECTIVE MANAGEMENT OF THE WORLD'S FISHERIES[43]

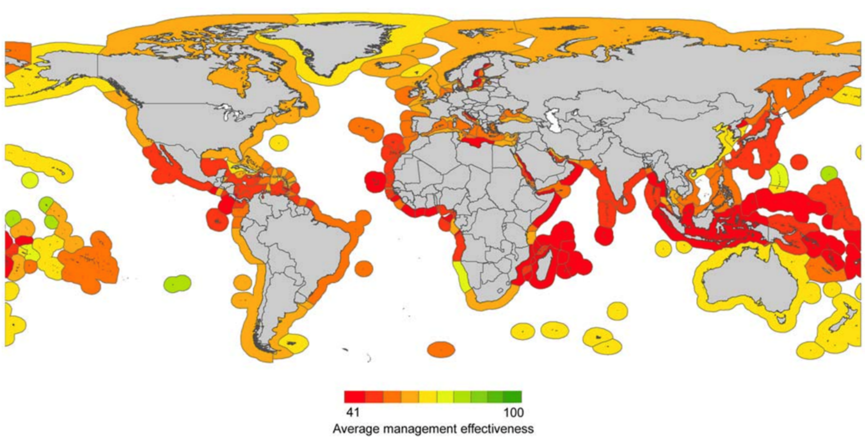

Figure 4. Overall management effectiveness of the world's exclusive economic zones. This map shows the average, for each surveyed area, of their scores on the scales of scientific robustness, policymaking transparency, implementation capability, fishing capacity, subsidies, and access to foreign fishing.
doi:10.1371/journal.pbio.1000131.g004

With effective management, it is possible to increase the natural productivity of fisheries. Improved management of fisheries alone can provide an additional 16 million metric tons of annual fish catch per year.[44] World Bank has estimated that, with proper management, it may be

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[42] FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.

[43] Mora C., R.A. Myers, M. Coll, S. Libralato, T.J. Pitcher, R.U. Sumaila, D. Zeller, R. Watson, K.J. Gaston, and B. Worm. 2009. "Management Effectiveness of the World's Marine Fisheries." *PLoS Biology* 7 (6). https://doi.org/10.1371/journal.pbio.1000131.

[44] Costello, C. D. Ovando, T. Clavelle, C.K. Straus, R. Hilborn, M.C. Melnychuk, T.A. Branch, S.D. Gaines, C.S. Szuwalski, R.B. Cabral, D.N. Rader, and A. Leland. 2016. "Global fishery prospects under contrasting management

possible to recuperate the USD 83 billion that is lost annually in the marine fisheries sector due to depleted fish stocks and excessive fishing effort.[45] For example, the USAID/Philippines ECOFISH Project (2012–2017) worked with the U.S. Department of Agriculture's Bureau of Fisheries and Aquatic Resources to increase fish biomass by 24 percent and employment by 12 percent by improving management of more than 1.8 million hectares of municipal water.[46]

3.1.7 ECO-LABELING IMPACT INVESTING AND FAIR TRADE

Eco-labeling, in the form of third-party certification schemes, is growing in the United States and Europe due to increased demand from retailers and importers for certified sustainable supply chains. Most certification schemes, such as the Marine Stewardship Council, are designed for large-scale fisheries in northern countries. A growing number of small-scale fisheries in developing countries are striving to meet certification standards. Certification is costly and most certified developing country fisheries have high-value, single-species product for export. However, the overwhelming volume of fishery landings in developing countries are lower value products, destined for local and regional markets, where local certification schemes may be more appropriate.

Associated with eco-labeling are fair trade fishery schemes that seek to ensure environmentally sustainable supply chains, as well as reach social responsibility, economic development, and empowerment standards that benefit local fishers. One example is Fair Trade Seafood.[47,48]

Impact investing is an innovative approach used to promote sustainable fisheries. Impact investing seeks financial capital to invest in organizations, companies, and communities to improve sustainable fishery supply chains alongside a financial return. One example of this is the Sustainable Ocean Fund,[49] which will provide private debt investments in Latin America, Africa, and Asia to sustainable businesses and organizations that catalyze behavior change for sustainable fisheries and generate long-term revenue streams for those involved in fisheries. Another example is the Meloy Fund,[50] which is investing in small-scale fisheries in the Philippines and Indonesia. Principles for Investments in Sustainable Wild-Caught Fisheries[51] were recently released by these impact funds and by multiple donors and organizations and can serve as useful guidance for all fishing investments.

3.1.8 CLIMATE CHANGE CONTEXT

As described above, oceans are critical players in global carbon sequestration, making them one of the world's largest carbon sinks. With climate changed-induced increases in global temperatures and the potential for increased storm intensity and frequency, the effects of climate change on oceans, rivers, and freshwater lakes and ponds will continue to have significant impacts on the ecological integrity of aquatic ecosystems, as well as adverse effects

regimes." *PNAS* 113 (18): 5125-5129. doi:10.1073/pnas.1520420113. https://www.pnas.org/doi/full/10.1073/pnas.1520420113.

[45] World Bank. 2017. The Sunken Billions Revisited: Progress and Challenges in Global Marine Fisheries. Washington, D.C.: *Environment and Sustainable Development series*. https://openknowledge.worldbank.org/bitstream/handle/10986/24056/9781464809194.pdf?seque nce=8.

[46] USAID. 2017. "Ecosystems Improved for Sustainable Fisheries (ECOFISH) Project Completion Report." Washington, D.C.,140.

[47] See http://www.fishchoice.com/seafood-program/fair-trade-seafood.

[48] See also McClenachan et al. (2016) for an overview of the fair-trade concept.

[49] See https://rmportal.net/biodiversityconservation-gateway/legality-sustainability/fisheries- development/project-search/add-a-project-activity/sustainable-ocean-fund.

[50] See https://www.thegef.org/project/ngi-meloy- fund-fund-sustainable-small-scale-fisheries-southeast-asia.

[51] See http://www.fisheriesprinciples.org/.

on commercial and local fisheries. Effects such as ocean acidification, which is a result of increased levels of carbon dioxide dissolved in warmer seawater, can have adverse effects on marine populations. For example, increased acidity reduces the ability of bivalves and crustaceans to develop an exterior shell (e.g., clam shells), decreasing their population, which, in turn, can reduce food availability for the larger species that feed on them, resulting in broader ecosystem disruptions.[52] Acidification also has been proven to affect coral reefs because carbon dioxide functions as a bleaching agent for corals, ultimately destroying a major ecosystem for many species.[53] These effects are further exacerbated by the continuing increased rate of ocean carbon uptake and the consequent increasing acidification of the ocean.[54]

Increasing global temperatures have played a significant role in the overall fish stock composition in oceans; rivers; and freshwater lakes, rivers, and ponds. Changes in fish migratory patterns are a critical direct impact of increasing water temperatures, with native fish species seeking refuge in new areas after their native habitats have been disrupted by becoming too warm.[55] Increasing temperatures also negatively affect fish growth and phenology.[56,57] This risk will increase as ocean warming continues, with climate models projecting that the ocean will warm by two to four times under the low (representative concentration pathway [RCP] 2.6) emissions scenario and five to seven times under the high (RCP 8.5) emissions scenario by 2100, compared with observed changes since 1970.[58] Furthermore, marine heat waves have negatively affected marine species and ecosystems in all ocean basins over the past two decades, and are projected to further increase in frequency, duration, spatial extent, and intensity.[59]

The potential for increased storm intensity and frequency also has had adverse effects on marine ecosystems and fishing communities, particularly those that are located along the coast. Storm surges, inundation, and high winds affect major fish habitats, such as marshes, mangroves, and wetlands. This can result in changes to overall fish biomass. Coastal storms also can affect the structural integrity of marine fisheries, affecting fishing effort, navigation, damage to or loss of fishing equipment and infrastructure, and the safety of fishers.[60] Water cycle variability and its associated extremes are projected to increase faster than mean changes

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[52] NOAA. 2019. "How Will Changing Ocean Chemistry Affect the Shellfish We Eat?" https://www.fisheries.noaa.gov/feature-story/how-will-changing-ocean-chemistry-affect-shellfish-we-eat.

[53] Anthony, K. R. N., D. I. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg. 2008. "Ocean Acidification Causes Bleaching and Productivity Loss in Coral Reef Builders." *PNAS*. https://www.pnas.org/doi/full/10.1073/pnas.0804478105.

[54] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[55] Morley JW, Selden RL, Latour RJ, Fro¨licher TL, Seagraves RJ, Pinsky ML. 2018. "Projecting shifts in thermal habitat for 686 species on the North American continental shelf." *PLOS ONE*. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0196127.

[56] Yousefi, Masoud, Arash Jouladeh-Roudbar, Anooshe Kafash. 2020. "Using endemic freshwater fishes as proxies of their ecosystems to identify high priority rivers for conservation under climate change." *Ecological Indicators* (112): 1470-1600. https://www.sciencedirect.com/science/article/abs/pii/S1470160X20300741?via%3Dihub.

[57] Huang, Minrui, Liuyong Ding, Jun Wang, Chengzhi Ding, & Juan Tao. 2021. "The impacts of climate change on fish growth: A summary of conducted studies and current knowledge." *Ecological Indicators* (121): 1470-1600. https://www.sciencedirect.com/science/article/pii/S1470160X20309158?via%3Dihub.

[58] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[59] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[60] Heck, Nadine, Michael W. Beck, Borja Reguero. 2021. "Storm Risk and Marine Fisheries: A Global Assessment." *Marine Policy* 132. https://www.sciencedirect.com/science/article/abs/pii/S0308597X21003092?via%3Dihub.

in most regions under all emissions scenarios.[61] The intensity and magnitude of storm surge and precipitation rates are projected to increase with a 2°C rise in average global temperature.[62]

The loss of habitat, changes in ecological productivity, and declining ecosystem services can have detrimental effects on marine and freshwater ecosystems, as well as the overall social fabric of surrounding communities.[63,64] With changes in the overall health of marine and freshwater species and shifts in migratory patterns, the wild-caught fisheries sector is expected to face increased challenges in adapting to climate change impacts. Climate change will challenge both the governance and institutional frameworks used to manage fisheries[65,66] and the broader societal goals related to fisheries, such as the United Nations Sustainable Development Goals of poverty reduction, food security, and ocean health.[67] For more information on climate impacts on fisheries and aquaculture, see Table 3.

3.1.9 THE SOCIOECONOMIC CONTEXT

In many small-scale fishing communities around the world, the fisheries sector is a way of life and may be a traditional livelihood that is passed on from one generation to the next; however, there may be few alternatives or little desire to engage in non-fisheries related livelihoods. Resource-dependent coastal communities are highly vulnerable to overfishing, which can cause significant social and economic hardship and conflict. While fisheries' country context varies greatly from place to place, most USAID fishery programs are designed to promote sustainable fishing and sustainable livelihoods. They often include components related to strengthening governance and natural resources management; increasing climate resilience; improving post-harvest value chains; developing and diversifying livelihoods; combating illegal, unreported, and unregulated fishing; improving product traceability; and addressing child labor and trafficking in the sector.

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[61] IPCC. 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.
[62] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.
[63] Badjeck, Marie-Caroline, Edward H. Allison, Ashley S. Halls, and Nicholas K. Dulvy. 2010. "Impacts of Climate Variability and Change on Fishery-Based Livelihoods." *Marine Policy* 34 (3): 375–383. https://www.sciencedirect.com/science/article/abs/pii/S0308597X09001237?via%3Dihub.
[64] Stanford, Richard J., Budy Wiryawan, Dietriech G. Bengen, Rudi Febriamansyah, and John Haluan. 2017. "The Fisheries Livelihoods Resilience Check (FLIRES Check): A Tool for Evaluating Resilience in Fisher Communities." *Fish and Fisheries* 18 (6): 1011–25. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12220?msockid=27f4aa84b15f6bab1516b947b04d6ac6.
[65] Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., eds. 2018. Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. *FAO Fisheries and Aquaculture Technical Paper* No. 627. Rome: FAO, 628. https://openknowledge.fao.org/server/api/core/bitstreams/9aeb8ade-a623-4954-8adf-204daae3b5de/content.
[66] Ojea, E., Pearlman, I., Gaines, S. D., & Lester, S. E. 2017. "Fisheries regulatory regimes and resilience to climate change." *Ambio* 46: 399-412. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5385667/.
[67] Singh, G. G., Hilmi, N., Bernhardt, J. R., Montemayor, A. M. C., Cashion, M., Ota, Y., Acar, S., Brown, J. M., Cottrell, R., Djoundourian, S., González-Espinosa, P. C., Lam, V., Marshall, N., Neumann, B., Pascal, N., Reygondeau, G., Rocklöv, J., Safa, A. 2019. "Climate impacts on the ocean are making the Sustainable Development Goals a moving target travelling away from us." *People and Nature* 1 (3): 317–330. https://doi.org/10.1002/pan3.26.

3.2 AQUACULTURE

3.2.1 TRENDS IN AQUACULTURE PRODUCTION

In the most recent State of World Fisheries and Aquaculture (SOFIA) report by the United Nations' Food and Agriculture Organization (2022), a number of trends and projections about fishery and aquaculture production are presented. Key report findings related to aquaculture are as follows:

- Total fishery and aquaculture production has reached a record high of 214 million tons in 2020, comprising 178 million tons of aquatic animals and 36 million tons of algae. The sector will play an increasingly important role in providing food and nutrition for humans in the future. The amount destined for human consumption (excluding algae) in 2020 was 20.2 kilograms per capita, more than double the average of 9.9 kilograms per capita in the 1960s. Furthermore, there was an estimated 58.5 million people employed in the primary sector and an estimated 600 million people dependent, at least partially, on fisheries and aquaculture. International trade in fishery and aquaculture products generated around USD 151 billion in 2020, down from the record high of USD 165 billion in 2018, mainly due to the COVID-19 pandemic.
- Global aquaculture production reached a record high of 122.6 million tons in 2020, with a total value of USD 281.5 billion. Global aquaculture production grew in all regions except Africa, due to a decrease for the two major producing countries, Egypt and Nigeria. Asia continued to dominate world aquaculture, producing 91.6% of the total.
- Global consumption of aquatic foods (excluding algae) has increased at an average annual rate of 3.0% since 1961, compared with a population growth rate of 1.6%. Rising incomes and urbanization, improvements in post-harvest practices, and changes in dietary trends are projected to drive a 15% increase in aquatic food consumption to supply, on average, 21.4 kilograms per capita in 2030.
- Fishery resources continue to decline due to overfishing, pollution, poor management, and other factors; however, the number of landings from biologically sustainable stocks is on the rise. Rebuilding overfished stocks could increase fishery production by 16.5 million tons and raise the contribution of marine fisheries to the food security, nutrition, economic growth, and well-being of coastal communities. Additionally, FAO's outlook for fisheries and aquaculture to 2030 projects an increase in production, consumption, and trade, with total production of aquatic animals expected to reach 202 million tons in 2030. It is vital that this growth goes hand in hand with safeguarding ecosystems, reducing pollution, protecting biodiversity, and ensuring social equity.
- Fisheries and aquaculture provided a primary source of income and livelihoods for an estimated 58.5 million people in 2020, with 21 percent being women. In comparison, in 2018, 18 million people globally (33 percent) were employed in the aquaculture sector, with 19 percent of those being women. With projections for growth in the sector, aquaculture is a major source of income for millions of people.[68] In 2020, the main producers in the fisheries and aquaculture sectors were Asian countries (70 percent of total fishery and aquaculture production of aquatic animals), followed by countries in the Americas (12 percent), Europe (10 percent), Africa (7 percent), and Oceania (1 percent). Asia produces more from aquaculture than from capture, and when the top producer is excluded in each region, Asia still has a high aquaculture share (44.7 percent) (see Figure 8).

[68] FAO. 2020. "FAO Policy on Gender Equality 2020–2030." Rome. http://www.fao.org/3/cb1583en/cb1583en.pdf.

FIGURE 8. CONTRIBUTION OF AQUACULTURE TO TOTAL FISHERIES AND AQUACULTURE PRODUCTION (EXCLUDING ALGAE) BY REGION, 2000–2020. DATA IN MILLION TONS EXPRESSED IN LIVE WEIGHT EQUIVALENT.[69]

[69] FAO. 2022. The State of World Fisheries and Aquaculture 2022. Rome: Towards Blue Transformation. https://doi.org/10.4060/cc0461en.

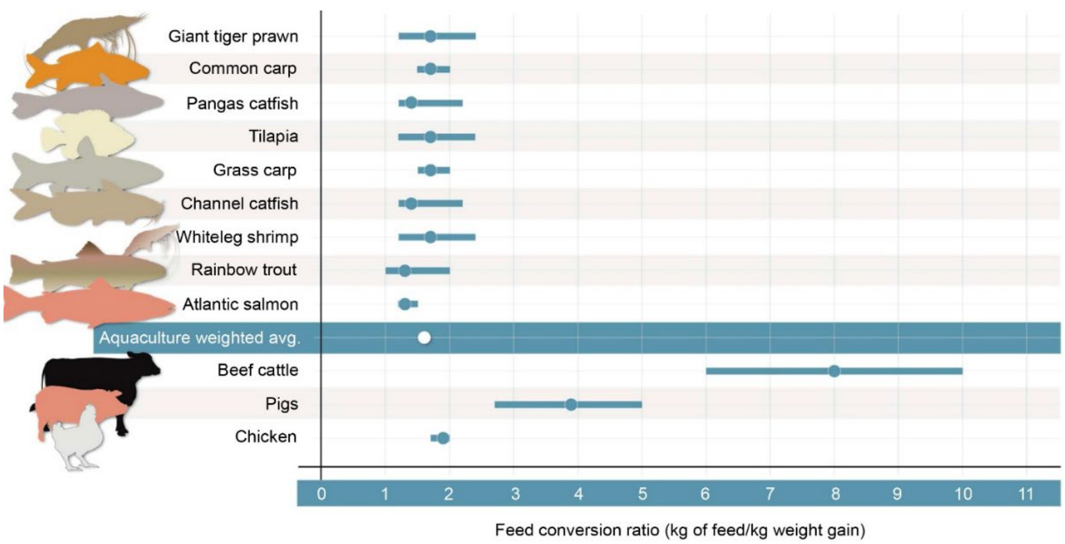
3.2.2 COMMON SPECIES CULTURED

Commonly cultured organisms in tropical countries include tilapia, catfish, shrimp, milkfish, oysters, and seaweed. In tropical developing countries, shrimp is a large source of revenue from exports, whereas tilapia is important for both local food security and exports. Aquaculture occurs in freshwater, brackish water, and marine ecosystems and the type of species grown depends on the ecosystem type and other local factors.

3.2.3 AQUACULTURE PRODUCTION SYSTEMS

While much of the freshwater and brackish water farming is carried out in ponds, there is significant growth in cage culture in rivers, lakes, and reservoirs, as well as in recirculating aquaculture systems. Marine culture of finfish[70] is carried out in cages, while seaweed and bivalves (e.g., oysters) use off-bottom trays, rafts, and bottom-culture methods. Aquaculture includes fish that require feed as input (e.g., salmon, tilapia, shrimp) and those that do not require feed (e.g., oysters and seaweed, which filter their nutrient needs from the water). Farmed fish, such as tilapia, tend to have better feed conversion ratios (the estimated feed required to gain 1 pound of body mass) than most other farmed animals (Figure 9) and they produce fewer greenhouse gas (GHG) emissions. Carnivorous fish, such as salmon and grouper, tend to have higher feed conversion ratios than tilapia and milkfish. Feed conversion ratios are an important measure of farming efficiency, and since some feed is based on wild-caught fishmeal, there are environmental concerns regarding sustainability. Some farming systems, such as tilapia and milkfish, do not require feed. These types of fish can be grown in ponds solely using fertilizers to create plankton for feed. The lowest impact aquaculture systems are those that require no feed inputs, such as oysters or seaweed. These aquaculture products receive all their nutrient requirements from the water column.

FIGURE 9. FEED CONVERSION RATIO OF VARIOUS AQUATIC AND TERRESTRIAL FARMED ANIMALS. DOTS REPRESENT MEANS AND BARS REPRESENT RANGE. LOWER VALUES SIGNIFY HIGHER FEED CONVERSION EFFICIENCY.[71]



Aquaculture also can be classified as intensive or extensive production systems. Extensive systems have low seed-stocking densities; minimal, if any, feed requirements; and produce low yields per hectare. Intensive systems have high seed-stocking densities, high feeding requirements, and often require special aeration and filtration systems. Intensive systems have higher yields per hectare but are often more susceptible to disease. Intermediate or semi-

[70] Finfish are fish with backbones, such as tilapia or carp, as opposed to invertebrates (or shellfish), such as shrimp, crabs, and oysters.

[71] Fry, Jillian P., Nicholas A. Mailloux, David C. Love, Michael C. Milli, and Ling Cao. 2018. "Feed conversion efficiency in aquaculture: do we measure it correctly?" *Environmental Research Letters*. https://iopscience.iop.org/article/10.1088/1748-9326/aaa273#:~:text=The%20most%20widely%20used%20measurement%20is%20called%20the,are%20more%20efficient%20compared%20to%20pigs%20and%20cattle.

intensive systems often are recommended because they minimize the risk of disease, require moderate inputs, and can provide higher yields than extensive systems.

Aquaculture systems can be classified as open cycle or closed cycle. Open-cycle systems rely on open water exchanges with a river or estuary. They risk the transfer of disease to wild populations, as well as hybrid or non-endemic species being released to the natural environment. Closed-cycle systems, such as recirculating aquaculture systems can be built inside warehouses and recirculate water with only occasional wastewater discharges or external water intake. Closed-cycle systems also can refer to the farmed organism's reproductive system, whereby the life history and farming system does not rely on the use of wild broodstock or fingerlings for breeding and stocking. Closed-cycle systems tend to have fewer potential environmental impacts.

While USAID fishery programs focus on restoring and enhancing the productivity and sustainability of wild-caught fisheries, aquaculture programs focus mainly on increased production and addressing issues of seed quality (i.e., the quality of the strain of fingerlings stocked in ponds), disease management, and feed sustainability. Aquaculture development programs that establish and expand production areas require careful attention to environmental concerns.

Third-party certification schemes are common in aquaculture. One example is the Aquaculture Certification Council,[72] which applies "best aquaculture practices" and certifies farms, processing plants, and feed and seed producers for environmental sustainability, social welfare, food safety, and animal welfare criteria.

[72] For more information see the Best Aquaculture Practices website accessible at https://bapcertification.org/.

4. POTENTIAL ADVERSE IMPACTS OF THE FISHERIES AND AQUACULTURE SECTORS

4.1 THE IMPACTS OF FISHERIES

The potential impacts of USAID programs on the fisheries sector may vary based on the system (freshwater or marine), and the unique characteristics of each ecosystem, the type of fishery, and the technologies used need to be considered when predicting the impacts.

4.1.1 OVERFISHING

Overfishing occurs when the fish catch exceeds the threshold required to sustain the maximum biological or economic yield of fish. Overfishing reduces the size of the stock in a body of water and eventually reduces the potential yields that can be harvested on an annual basis. The goal of most fishery management programs is to prevent overfishing and sustain or rebuild stocks at levels that produce the maximum yields or catch of fish.

Overfishing is a common result of open access to a fishery where entry is not sufficiently controlled or where other management measures are not sufficient to control catch. In open access situations, which are the norm for most small-scale fisheries, capacity can be controlled by, for example, limiting the number and size of vessels and gear. However, even with a limited number of boats, vessels can increase fishing effort by spending more days fishing and increasing the crew size, the size of the gear, and the size of the engines.

Overfishing affects the structure of the entire marine ecosystem.[73,74] When overfishing occurs, it can have negative effects on species diversity, create changes in ecological trophic structures, and have unintended cascading effects on other aquatic life.[75,76]

4.1.2 SUBSIDIES

Fishing subsidies can cause or exacerbate overfishing. They are a common practice in developed and developing countries alike. Fishing subsidies can take many forms and can be grouped into positive, negative, or neutral subsidies. Positive subsidies enhance fishery management and include investments in scientific stock assessments and fishery enforcement capabilities. Neutral subsidies are those that have no effect on fishing effort. Negative subsidies are typically input subsidies for fuel, gear, or vessels.

Negative subsidies distort markets, reduce the costs of fishing, and drive overfishing. In open access regimes, these subsidies allow more vessels and fishing effort to be used and thereby exacerbate overfishing. It can be argued that where sufficient fishing effort or catch controls are in place, or where fisheries are underdeveloped and not fully exploited, input subsidies will not

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[73] Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. "Fishing Down Marine Food Webs." *Science* 279 (5352): 860-863. https://www.science.org/doi/10.1126/science.279.5352.860.

[74] Myers, R.A., J.K. Baum, T.D. Shepherd, S.P. Powers, and C.H. Peterson. 2007. "Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean." *Science* 315: 1846-1850. https://www.science.org/doi/10.1126/science.1138657.

[75] Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan. 2001. "Historical overfishing and the recent collapse of coastal ecosystems." *Science* 293 (5530): 629-637. https://www.science.org/doi/10.1126/science.1059199.

[76] Daskalov, G.M., A.N. Grishin, S. Rodionov, and V. Mihneva. 2007. "Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts." *Proceedings of the National Academy of Sciences* 104 (25): 10518–10523. https://www.pnas.org/doi/full/10.1073/pnas.0701100104.

exacerbate overfishing.[77,78] However, few developing countries have been able to implement catch controls or quota-based systems for their industrial fleets or small-scale fisheries. Although fewer and fewer fisheries are underexploited,[79] developing countries often use input subsidies as a strategy to maintain the employment and incomes of fishers, and thus gain votes, in spite of the potential impacts on the sustainability of the fishery.[80,81] Input subsidies are popular politically and are difficult to remove once instituted. Fuel subsidies comprise the largest portion of capacity-enhancing subsidies, but input subsidies also include subsidies to management, ports and harbors, and fleet enhancement.

Subsidies in fisheries also have become a contentious topic in World Trade Organization negotiations where many experts recommend phasing out negative subsidies.[82] In some cases, input subsidies are viewed as supporting illegal fishing because they support distant-water fishing fleets operating far from home. The position of the U.S. Government is to support the prohibition of harmful fishing subsidies during World Trade Organization and trade agreement negotiations.

4.1.3 FUEL CONSUMPTION AND ITS CONTRIBUTION TO GHG EMISSIONS

Despite being a relatively small sector, the global fisheries sector contributes a noteworthy amount of GHG emissions as a result of fossil fuel consumption. An analysis of global fisheries' energy use based on time series estimates from 1950 through 2016 found that total carbon dioxide emissions from the industrial fishing sector were 159 million tons in 2016, compared with 39 million tons in 1950.[83] In contrast, the small-scale fishing sector emitted 48 million tons in 2016, compared with 8 million tons in 1950.[84] A separate analysis quantified fuel inputs and GHG emissions for the global fishing fleet from 1990 through 2011, finding that emissions grew by 28% during that period, with little coinciding increase in production.[85] This growth was primarily driven by increased harvests from crustacean fisheries, which tend to be the most fuel intensive.

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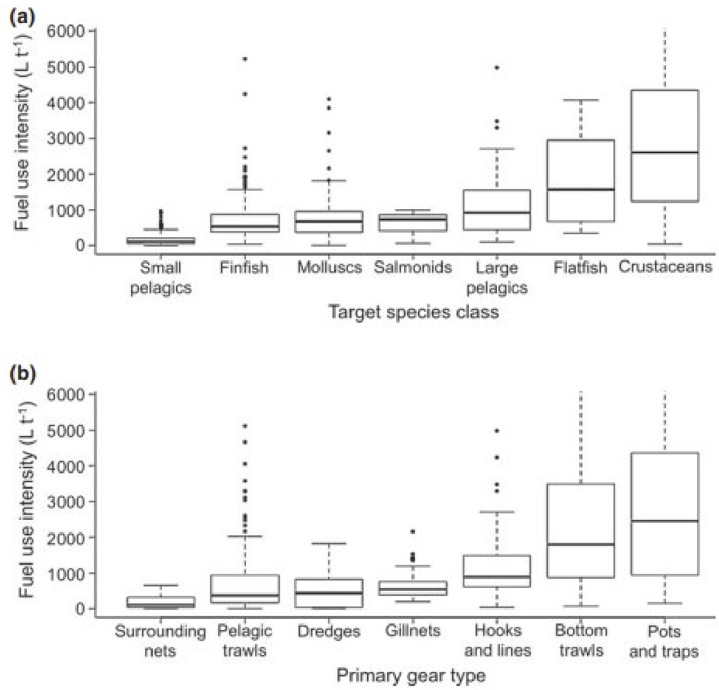
77 Porter, G. 2001. "Fisheries Subsidies, Overfishing and Trade." *United Nations Environment Programme*. https://digitallibrary.un.org/record/469468?v=pdf.
78 Cox, A. and U.R. Sumaila. 2010. "A Review of Fisheries Subsidies: Quantification, Impacts, and Reform." Oxford University Press 99-112.
79 FAO. 2024. "The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action." Rome, Italy, 2022. https://openknowledge.fao.org/handle/20.500.14283/cd0683en.
80 Schuhbauer A., D. J. Skerritt, N. Ebrahi, F. Le Manach and U. R. Sumaila. 2020. " The Global Fisheries Subsidies Divide Between Small- and Large-Scale Fisheries." *Frontiers in Marine Science* 7:539214. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2020.539214/full.
81 Sumaila, U. R., N. Ebrahim, A. Schuhbauer, D. Skerritt, Y. Li, H. S. Kim, T. G. Mallory, V. W. L. Lam and D. Pauly. 2019. "Updated estimates and analysis of global fisheries subsidies." *Marine Policy* 109:103695. https://www.sciencedirect.com/science/article/pii/S0308597X19303677?via%3Dihub.
82 Ibid.
83 Greer, Krista, Dirk Zeller, Jessika Woroniak, Angie Coulter, Maeve Winchester, M. L. Deng Palomares, and Daniel Pauly. 2019. "Global trends in carbon dioxide (CO2) emissions from fuel combustion in marine fisheries from 1950 to 2016." *Marine Policy*. https://www.sciencedirect.com/science/article/pii/S0308597X1730893X.
84 Greer, Krista, Dirk Zeller, Jessika Woroniak, Angie Coulter, Maeve Winchester, M. L. Deng Palomares, and Daniel Pauly. 2019. "Global trends in carbon dioxide (CO_2) emissions from fuel combustion in marine fisheries from 1950 to 2016." *Marine Policy*. https://www.sciencedirect.com/science/article/pii/S0308597X1730893X.
85 Parker et al. 2018. "Fuel use and greenhouse gas emissions of world fisheries." *Nature Climate Change* 8: 333-337. https://doi.org/10.1038/s41558-018-0117-x.

The type of gear used and the type of fish targeted influence energy efficiency in fisheries (Figure 10), with some life cycle assessments estimating that up to 75 percent of fishery emissions come from fishing vessel fuel consumption.[86] Small pelagic, finfish, and mollusk fisheries have lower fuel intensity than large pelagic and crustacean (e.g., shrimp) fisheries.[87] Gill nets and hook-and-line fisheries are more efficient than bottom trawling and pots and trap lines. There is conflicting evidence as to whether small-scale fisheries are more fuel efficient than large-scale fisheries.[88] The gear type and target species seem to be a better determinant of fuel efficiency. One study found that shifting to passive gear may reduce fuel use intensity but emphasized that attention should be paid to effective means of assisting this transition.[89] Emissions reductions also may be achieved through the use of electrification, hydrogen, sustainable bio-based feedstocks, product substitution, and carbon capture utilization and storage in aquaculture production practices.[90] Furthermore, feed production in aquaculture also may contribute to GHG emissions from aquaculture, including feed efficiency and breeding goals.[91]

FIGURE 10. FUEL USE INTENSITY RELATED TO (A) SPECIES CLASS AND (B) GEAR TYPE. BOXES REPRESENT 25TH AND 75TH PERCENTILES, AND DOTS REPRESENT OUTLIERS (PARKER AND TYEDMERS 2015).



Changes in fisheries due to climate change also may affect fuel use efficiencies. For example, if warming waters cause fish to migrate further out to sea to deeper waters, this could result in

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[86] Bianchi, M., Hallström, E., Parker, R.W.R. et al. 2022. "Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice." *Communications Earth & Environment* 3. https://doi.org/10.1038/s43247-022-00516-4.

[87] Parker, W.R. and P.H. Tyedmers. 2015. "Fuel consumption of global fishing fleets: current understanding and knowledge gaps." *Fish and Fisheries* 16: 684-696. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12087?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

[88] Marine Stewardship Council. 2016. Large vs small scale fishing – which is more sustainable? https://www.msc.org/media-centre/news-opinion/news/2020/02/21/large-vs-small-scale-fishing-which-is-more-sustainable.

[89] Berkes, Fikret, and Mina Kislalioglu. 1989. "A comparative study of yield, investment and energy use in small-scale fisheries: Some considerations for resource planning." *Fisheries Research*. https://www.sciencedirect.com/science/article/abs/pii/0165783689900556.

[90] Maulu, S. et al. 2021. "Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations." *Frontiers in Sustainable Food Systems* 5. https://doi.org/10.3389/fsufs.2021.609097.

[91] Sae-Lim, P., A. Kause, H. A. Mulder, I. Olesen. 2017. "Breeding and Genetics Symposium: Climate change and selective breeding in aquaculture." *Journal of Animal Science* 95 (4): 1801–1812. https://doi.org/10.2527/jas.2016.1066.

increased fuel use per kilogram of fish harvested. Hence, fishery management policies can have an effect on fuel efficiency and GHG emissions.

4.1.4 THE CAPTURE OF ENDANGERED, THREATENED, AND PROTECTED SPECIES

Endangered, threatened, and protected aquatic and marine species, such as marine mammals (e.g., dolphins, whales), turtles, sea birds, and sharks, can be affected by the use of fishing gear that intentionally or unintentionally captures these species. Endangered species of sharks, marine mammals, and sea turtles are particularly susceptible to drift gill nets. Surface gill nets also can entangle sea birds that dive into the water to feed off of fish caught in the nets. Trawling nets can capture sea turtles, which drown before the catch is hauled into the boat.

In addition, marine fisheries contribute to plastic pollution in the ocean through the loss or abandonment of fishing gear. This 'ghost gear' makes up a large proportion of ocean plastics, and can lead to the phenomenon of ghost fishing, wherein abandoned gear entraps fish, turtles, sea birds, sharks, and other marine life, leading to suffocation, starvation, and predation.[92] The impact of plastic pollution on marine species varies depending on the size of plastics, and ingestion of micro- and nano-plastics as well as chemical exposure to toxins can exert more stress on already declining populations.[93]

4.1.5 DESTRUCTIVE FISHING PRACTICES

Destructive fishing practices are those that indiscriminately damage or destroy habitat or fish populations.[94,95] Examples include bottom trawling; the use of explosives, such as dynamite; and the use of chemicals, such as cyanide. Homemade bombs or actual explosives are used to stun and kill fish in the water. The fish are then harvested with nets. Bomb fishing damages coral reefs by breaking coral colonies that are very slow growing and could take decades to recover. Bombs also indiscriminately kill all fish in the vicinity of the blast, including small juveniles and species that are not targeted by the fishers. Many fish float to the surface; however, others sink to the bottom and are not recovered by fishers. In most countries, this practice is banned.

The use of chemicals, such as cyanide, for fishing also falls into the category of destructive practices. Cyanide, which is commonly used to stun and collect live fish for aquariums and restaurants, is harmful because it kills coral reefs. While there is little evidence of poisoning among people who eat cyanide-caught fish, there is a risk, especially among those who ingest a large amount.

[92] Richardson, K., B. D. Hardesty and C. Wilcox. 2019. "Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis." *Fish and Fisheries*, 20(6):1218–1231. https://onlinelibrary.wiley.com/doi/10.1111/faf.12407?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

[93] Tekman, M. B., B. A. Walther, C. Peter, L. Gutow and M. Bergmann. 2022. "Impacts of plastic pollution in the oceans on marine species, biodiversity and ecosystems." 1–221, WWF Germany, Berlin. Doi:10.5281/zenodo.5898684. https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Plastik/WWF-Impacts_of_plastic_pollution_in_the_ocean_on_marine_species__biodiversity_and_ecosystems.pdf.

[94] Russ, G.R. and A.C. Alcala. 1989. "Effects of intense fishing pressure on an assemblage of coral reef fishes." *Marine Ecology Progress Series* 56 (1&2): 13-27. https://www.int-res.com/articles/meps/56/m056p013.pdf.

[95] Harborne, Alastair R., Alison L. Green, Nate A. Peterson, Maria Beger, Yimnang Golbuu, Peter Houk, Mark D. Spalding et al. "Modelling and mapping regional-scale patterns of fishing impact and fish stocks to support coral-reef management in Micronesia." *Diversity and Distributions* 24, no. 12 (2018): 1729-1743. https://onlinelibrary.wiley.com/doi/10.1111/ddi.12814?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Another destructive practice is trawling, which can damage seagrass beds, patch reefs of soft corals, and coral reefs by using dragger chains on the bottom of the net.[96,97] Liners are often placed in the bag end to catch very small fish and to cheat on minimum mesh size regulations. Due to these environmental concerns, bottom trawling is banned or regulated in most countries.

4.1.6 ILLEGAL, UNREPORTED, AND UNREGULATED FISHING

Illegal, unreported, and unregulated (IUU) fishing robs the world's oceans of 28 million tons of aquatic food annually, bringing financial losses to a staggering USD 41 billion per year.[98] IUU fishing has been gaining increasing attention from the United States Government as a threat to national security, food security, and stability.[99] While illegal fishing in developing countries is a problem in both the small-scale and industrial sectors, the industrial sector presents particular challenges.

Illegal fishing severely affects the livelihoods of fishers and other fisheries sector stakeholders and exacerbates poverty and food insecurity. It undermines the accuracy of fisheries' stock assessments and fishery management and threatens the stability of coastal communities that rely on fish as a source of food and livelihoods. Illegal fishing undermines effective national fisheries control and management, global trade, equity, and the ecosystem, yet it continues to spiral and grow disproportionately in the exclusive economic zones of developing countries. Understanding and mapping IUU fishing networks, pathways, beneficiaries, hot spots, and typical business models are critical to improving strategies for enforcement and control.

4.1.7 OTHER HARMFUL FISHING PRACTICES

The use of fine mesh nets is common in small-scale fisheries. Fine mesh nets, which capture high proportions of juveniles, are considered harmful because they do not allow enough juveniles to reach maturity and reproduce. In some cases, mosquito bed nets are repurposed into fishing nets, including many donated treated bed nets from malaria prevention programs (such as in Lake Victoria and Lake Malawi).[100, 101] Hence, program activities from another sector can spill over and have negative effects.[102]

Some programs have adopted net replacement programs where the destructive gear can be turned in for a more environmentally friendly gear. However, these programs must be designed carefully because sometimes fishers turn in old worn nets that are at the end of their productive use. In those cases, the net replacement becomes a subsidy for new nets, which may reduce destructive fishing but still contribute to overfishing—too many nets chasing too few fish. There

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[96] McManus, John W., Rodolfo B. Reyes Jr, and Cleto L. Nanola Jr. "Effects of some destructive fishing methods on coral cover and potential rates of recovery." *Environmental Management* 21, no. 1 (1997): 69-78. https://link.springer.com/article/10.1007/s002679900006.

[97] Pitcher, C.R., N. Ellis, W.N. Venables, T.J. Wassenberg, C.Y. Burridge, G.P. Smith, M. Browne, F. Pantus, I.R. Poiner, P.J. Doherty, J.N.A. Hooper, and N. Gribble. 2016. "Effects of trawling on sessile megabenthos in the Great Barrier Reef and evaluation of the efficacy of management strategies." *ICES Journal of Marine Science 73* (Supplement 1): S115-S126. https://academic.oup.com/icesjms/article/73/suppl_1/i115/2573860.

[98] Temple, A. J., D. J. Skerritt, P. E. C. Howarth, J. Pearce and S. C. Mangi. 2022. "Illegal, unregulated and unreported fishing impacts: A systematic review of evidence and proposed future agenda." *Marine Policy*, 139:105033. https://www.sciencedirect.com/science/article/abs/pii/S0308597X2200080X?via%3Dihub.

[99] See http://www.nmfs.noaa.gov/ia/iuu/iuu_overview.html.

[100] USAID. 2024. "Environmental Assessment for Broad Distribution of Long-Lasting Insecticide Nets in Malawi with Focus on the Impacts of Misuse for Fishing." 379p.

[101] USAID. 2022. "Scoping Statement: Distribution of LLNs in Malawi."

[102] Reeves, R.R., K. McClellan, and T.B. Werner. 2013. "Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011." *Endangered Species Research* 20: 13-97. https://www.int-res.com/articles/esr_oa/n020p071.pdf.

also have been cases where new gill nets, intended for offshore pelagic species believed to be underexploited, were used to target sea turtles for a lucrative but illicit trade in turtle meat and shells.

4.1.8 IMPACTS ON NATURAL CAPITAL AND ECOSYSTEM SERVICES

The fisheries sector is especially dependent on the ability of aquatic ecosystems to provide habitat for the fish species being harvested, as well as their food sources, and any other species that support the stability and resilience of those ecosystems.[103] Ensuring the long-term productivity of a fishery requires an understanding of these relationships, as well as an ongoing awareness of the general health of that ecosystem as a whole, because focusing on species in isolation may ignore critical food web dynamics.[104] Each fishery produces a different (although overlapping) bundle of ecosystem services, based on the ecosystem functions present at each. For a complete mapping of ecosystem goods and services to the negative effects within capture fisheries and aquaculture, see Annex 2.

Ecosystem services are critical to both wild-caught fisheries and open aquaculture systems. Overfishing and bycatch degrade the ecological and economic viability of capture fisheries, reducing natural productivity, genetic diversity, reproductive rates, or growth and maturation processes, all of which threaten food security. Abandoned fishing gear (e.g., ghost nets), collisions with sea life, and the use of toxic substances (e.g., cyanide) all degrade the provision of ecosystem services.

The overharvesting of low-level food web species (e.g., krill, anchovies) for aquaculture feedstock may impair the larger food webs, which capture fisheries rely on. The introduction of exotic or invasive species for aquaculture also may lead to direct predation on commercially or culturally significant species. Finally, aquaculture systems may divert scarce water from natural systems and direct human use.

Regulating and supporting services provide a foundation for provisioning services. Overfishing and overharvesting may disrupt the food web in ways that allow aggressive feeders (e.g., sea urchins) to decimate ecosystems. This effect is known as a trophic cascade, where removing top predators, such as sharks, can reduce the productivity of seagrass meadows and coral reefs. Trawling may damage habitat for the lower-level aquatic food web (e.g., eelgrass, benthic communities) that supports the food chain.

The destruction of reefs, shoals, and nearshore habitat may harm critical breeding and nursery habitat for commercial and other critical species. Shipwrecks and fuel and oil spills may degrade water quality locally or regionally, while lost fishing gear may reduce the natural productivity of habitats, foul boat propellers, or even present a navigational hazard.

Converting mangrove and other wetland ecosystems to aquaculture disrupts soil-building processes (important for carbon sequestration) and often leads to significant erosion, reducing storm surge protection for coastal communities. The overstocking of aquaculture pens allows pathogenic organisms to thrive; however, suspended solids often degrade water quality. Excess nutrients often produce algal blooms and eutrophication, which, in turn, reduces dissolved oxygen in both natural and cultivated systems.

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[103] Harvey, B. 2001. "A Primer for Planners: Biodiversity and Fisheries. Biodiversity Planning Support Programme." Global Environmental Facility. www.cbd.int/doc/nbsap/fisheries/Main-Report-Fish.pdf.
[104] Mormorunni, C. L. 2001. "The Spot Prawn Fishery: A Status Report." Asia Pacific Environmental Exchange, *Earth Economics*, Tacoma, WA.

The cultural services provided by marine and freshwater ecosystems are often key to local economic resilience. Coral reefs and clean beaches have strong appeal for both tourists and local residents, often supporting significant recreational economies. Overharvesting for commercial markets or subsistence can seriously degrade not only ecosystem function but also the aesthetic appeal for both tourists and residents. Poorly designed aquaculture systems may affect recreation and displace traditional livelihoods. Furthermore, seascapes, ocean and freshwater systems oftentimes hold intrinsic value for members of the local community and are important cultural heritage resources. For more guidance on Cultural Heritage, see footnote 105.

Finally, the impacts of climate change may add to and exacerbate the adverse effects on fisheries listed above.[106] For example, if there are changes in natural fish migration due to changes in water temperature at the same time as there is overfishing, the result will be even greater impacts on ecosystem health, including even larger reductions in the abundance of fish. Climate change is accelerating the effects on ecosystems worldwide; fish stocks depend on many of these systems. For example, marine heat waves have negatively affected marine organisms and ecosystems in all ocean basins over the past two decades, including critical species, such as coral, seagrasses, and kelp, and these events are projected to increase in frequency, duration, and spatial extent and intensity in the coming decades.[107] Important breeding grounds for fisheries in coral reefs have been significantly affected by mass coral bleaching and coral die-off.[108] Rising atmospheric carbon dioxide concentrations also are projected to lead to higher ocean temperatures and acidification, which have profound negative impacts on coral reefs and other marine communities near the seafloor.[109]

4.1.9 SOCIAL IMPACTS RELATED TO FISHERY MANAGEMENT

While the emphasis of this guide is on potential environmental impacts, program designers also must be cognizant of the potential social impacts of proposed activities. Designers need to ask who will benefit from the interventions. Will they benefit the poor and/or shift the power dynamics? How will the interventions target and benefit marginalized and underrepresented groups and/or people in vulnerable situations? If an activity incorporates gender equity objectives, care should be taken to ensure that women accrue equal benefits from the activity. In addition, child labor and human trafficking are known problems in small-scale local supply chains, as well as international and industrial supply chains. Program designers need to be cognizant of—and address or at least take action not to exacerbate—these issues.

4.2 THE IMPACTS OF AQUACULTURE

Just like all other food production processes, producing seafood through aquaculture results in impacts. The environmental, climate, and social impacts associated with aquaculture are often related to a lack of good management at the appropriate scale. They may occur as a

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[105] USAID. 2023. *Guide to Encountering and Working with Cultural Heritage*. https://www.usaid.gov/sites/default/files/2023-10/USAID-Cultural-Heritage-Guide-September-2023.pdf.

[106] Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, et al. 2019. *Changing Ocean, Marine Ecosystems, and Dependent Communities*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 447–587. https://doi.org/10.1017/9781009157964.007.

[107] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[108] Hamilton, M., Robinson, J.P.W., Benkwitt, C.E. et al. 2022. "Climate impacts alter fisheries productivity and turnover on coral reefs." *Coral Reefs* 41: 921–935. https://doi.org/10.1007/s00338-022-02265-4.

[109] IPBES. 2016. *The methodological assessment report on scenarios and models of biodiversity and ecosystem services*. Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 348. https://doi.org/10.5281/zenodo.3235428.

consequence of inappropriate design, site selection, construction, farm operations, or processing and other supply chain activities. Many impacts, such as disease outbreaks, water diversion and use, and habitat loss and degradation, are cumulative over time and are exacerbated by climate change. Sustainable aquaculture requires not only consideration of impacts at the farm level but also cumulative impacts at the larger landscape and watershed scales. Expansion beyond a system's carrying capacity will have negative consequences, even with well-run individual aquaculture operations.[110,111] One example is large-scale fish die-offs in enclosed water bodies (e.g., bays, small coves, lakes) where excessive permitting of fish cage culture farms resulted in increased nutrient loading from feed and fish excrement. That, in turn, resulted in anoxic water conditions, leading the fish to suffocate and die within a day.[112,113] These die-offs led to millions of dollars of lost production. The die-offs also have downstream impacts on feed suppliers, processors, and marketers. Thus, one needs to be aware of the cumulative impacts, not just of disease, but also large-scale water diversion and habitat loss. Potential impacts can be characterized qualitatively; however, it is best if they can be quantified and monetized as well. Quantification and monetization are valuable tools because they support the consideration of net impacts.[114] Fish feed management also can have a considerable impact on the sustainability of fish cage aquaculture.[115]

Climate impacts on aquaculture include increases in water temperature, increases in ocean acidity, decreases in oxygen content, and changes in water cycle variability. Increasing water temperatures could alter the optimal temperature range of certain species, making it increasingly difficult to maintain farming operations as changes in the immediate environment can affect some farmed species of fish. The potential for eutrophication as a result of increased temperatures also affects aquaculture. Changes in the level of dissolved oxygen can result in fish deaths and exacerbate disease risk.[116] The risk of increased storm intensity and frequency is another threat. Storm surges, inland flooding, and saltwater intrusion can damage the structural integrity of aquaculture farms. Such impacts can result in the loss of fish stock, damage to facilities and equipment, and a high risk to employees, which ultimately affects the strength of farming operations and the surrounding communities that rely on farmed fish.[117]

Aquaculture is also a source of GHG emissions, the majority of which result from electricity and fuel use and feed production. In a metanalysis of Life Cycle Analyses (LCAs) looking at the environmental impacts of aquiculture production for five categories of seafood,[118]it was found

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[110] Beveridge, M.C.M. 1984. "Cage and pen fish farming: Carrying capacity models and environmental impact." *FAO Fisheries Technical Paper* (255): 131. https://www.fao.org/4/AD021E/AD021E00.htm.

[111] McKindsey, C.W., H. Thetmeyer, T. Landry, and W. Silvert. 2006. "Review of current carrying capacity models for bivalve aquaculture and recommendations for research and management." *Aquaculture* 261 (2): 451-462. https://www.sciencedirect.com/science/article/abs/pii/S004484860600487X?via%3Dihub.

[112] Rice, M.A. and A.Z. DeVera. 1998. "Aquaculture in Dagupan City, Philippines." *World Aquaculture* 29 (1): 18-24. https://www.researchgate.net/publication/258767267_Aquaculture_in_Dagupan_City_Philippines.

[113] San Diego-McGlone, M.L., R.V. Azanza, C.L. Villanoy, and G.S. Jacinto. 2008. "Eutrophic waters, algal bloom and fish kill in fish farming areas of Bolinao, Pangasinan." *Marine Pollution Bulletin* 57: 295-301. https://www.sciencedirect.com/science/article/abs/pii/S0025326X08001811?via%3Dihub.

[114] Hanley, N., R. Faichney, J. Shortle, and A. Monroe. 1998. "Economic and environmental modeling for pollution control in an estuary." *Journal of Environmental Management* 52: 211-225. https://www.sciencedirect.com/science/article/abs/pii/S0301479797901754?via%3Dihub.

[115] Cho et al. 1994. "Development of high nutrient- dense, low pollution diets and prediction of aquaculture wastes using biological approaches." *Aquaculture* 124: 293-305. https://www.sciencedirect.com/science/article/abs/pii/0044848694904030.

[116] Soto, D., Brugere, C. n.d. "The Challenges of Climate Change for Aquaculture." FAO Aquaculture Newsletter. https://www.fao.org/3/i0305e/i0305e16.pdf.

[117] The WorldFish Center. 2007. The Threat to Fisheries and Aquaculture from Climate Change. *The WorldFish Center*. https://www.worldfishcenter.org/publication/threat-fisheries-and-aquaculture-climate-change.

[118] Categories include marine fishes, freshwater fishes, diadromous fishes, crustaceans and mollusks

that an average of 4.4 tons carbon dioxide equivalent (CO_2e) is generated per ton of seafood produced, the majority of which resulted from feed production.[119] See Section 5.1 for more details.

The type of potential impacts of aquaculture development depends on the type of farming system— whether it is an open or closed system and whether it is a pond, cage, or bottom culture in a natural environment. The species farmed and feed type impact the efficiency with which feed is converted to aquaculture production. More efficient feed conversion can reduce waste production and pollution generation.[120]

4.2.1 HABITAT LOSS, DEGRADATION, AND CHANGE

Potential habitat loss and change are important considerations in the siting and construction of aquaculture farms and facilities. Many brackish water areas have seen large-scale conversion of mangrove forest ecosystems for the development of shrimp ponds. It is one of the primary causes of mangrove habitat loss and has led to extensive destruction of mangrove systems, especially in Southeast Asia and Latin America.[121,122] Mangrove ecosystems produce critical ecosystem services (e.g., coastal protection from storm surges, disaster mitigation, nursery habitat for pelagic and demersal species, carbon storage and sequestration). Some of these benefits accrue locally (e.g., disaster mitigation), while others are indirect, such as essential fish habitats that generate estuarine-dependent fishery yields. Habitat loss and degradation are not only a concern for pond development, they also can occur because of excess cage culture densities that affect water quality and the associated aquatic vegetation.[123] Additionally, stake and line methods of seaweed farming alter bottom habitats and affect seagrass, coral reefs, and reef flat habitats. Some bivalve farming structures can alter bottom habitats by increasing the sedimentation of rivers and estuaries.[124,125] Cage culture or floating systems in natural water bodies, if in sufficiently dense quantities, may affect and impede the water flows of some systems. Excess feed use can also degrade bottom habitats. Furthermore, climate change impacts, such as sea level rise, coastal storm surge, and extreme precipitation events, can change habitats, and these impacts are projected to increase with further atmospheric

[119] Bohnes F.A., Hauschild M.Z., Schlundt J. and Laurent A., 2018. Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development. Reviews in aquaculture, 1-19. DOI: 10.1111/raq.12280.
https://onlinelibrary.wiley.com/doi/10.1111/raq.12280?msockid=27f4aa84b15f6bab1516b947b04d6ac6.
[120] Boyd, C.E., C. Lim, J. Queiroz, K. Salie, L. De Wet, and A. McNevin. 2008. *Best management practices for responsible aquaculture*. USAID/Aquaculture Collaborative Research Support Program, Corvallis, Oregon: Oregon State University, 47. https://pdf.usaid.gov/pdf_docs/PNADM906.pdf.
[121] Primavera, J.H. 2005. "Overcoming the impacts of aquaculture on the coastal zone." *Ocean & Coastal Management* 49: 531-545. https://www.sciencedirect.com/science/article/abs/pii/S0964569106000755.
[122] Berlanga-Robles, C.A., A. Ruiz-Luna, G. Bocco and Z. Vekerdy. 2011. "Spatial analysis of the impact of shrimp culture on the coastal wetlands on the Northern coast of Sinaloa, Mexico." *Ocean & Coastal Management* 54: 535-543. https://www.sciencedirect.com/science/article/abs/pii/S0964569111000494.
[123] Cromey, C.J., T.D. Nickell, and K.D. Black. 2002. "DEPOMOD modelling the deposition and biological effects of waste solids from marine cage farms." *Aquaculture* 214: 211-239.
https://www.sciencedirect.com/science/article/abs/pii/S004484860200368X.
[124] Bindu, M.S. and I.A. Levine. 2011. "The commercial red seaweed Kappaphycus alvarezii—an overview on farming and environment." *Journal of Applied Phycology* 23: 789–796. https://link.springer.com/article/10.1007/s10811-010-9570-2.
[125] Kaiser, M.J., I. Laing, S.D. Utting, and G.M. Burnell. 1998. "Environmental impacts of bivalve mariculture." *Journal of Shellfish Research* 17: 59-66.
https://www.researchgate.net/publication/258998107_Environmental_impacts_of_bivalve_mariculture.

warming.[126] Integrated agriculture-aquaculture farming techniques can be used in an effort to increase food production while decreasing waste and environmental impact.[127]

4.2.2 DIVERSION AND WATER FLOW CHANGES THAT IMPACT DOWNSTREAM USERS AND ECOSYSTEMS

Although sustainable aquaculture can be designed to use very little water, many forms of aquaculture require a large amount of water in order to be productive. Inland and brackish water pond systems require the diversion of water into the system to fill the ponds and flush out waste. Water diversion from small streams and rivers can be significant, especially during low rainfall and flow periods. An additive impact of extensive pond development is reduced water flow downstream from aquaculture operations. Intensification of aquaculture operations and integrated agriculture-aquaculture systems may be considered as a strategy to conserve water resources.[128] Water diversion can reduce the productivity of natural ecosystems and disrupt other natural resources-dependent livelihoods. Thus, water use and productivity should be considered at a watershed or basin scale.

4.2.3 WATER POLLUTION

Sustainable aquaculture farms follow best management practices that calculate the correct amount of feed to administer so that there is little or no buildup of fecal matter. However, some systems that are not fully closed will discharge waters to adjacent water bodies to eliminate the buildup of waste or for water exchange when dissolved oxygen levels may be low. Furthermore, increased stormwater runoff, increased river flow, and increased intensity of precipitation events can cause flooding, contamination, and sedimentation. The water cycle is projected to become more variable, and the severity of very wet and very dry extreme events are increasing in a warmer climate, thus increasing the risk of water pollution.[129] The discharge may have high levels of nutrients that can affect the aquatic environments of local water bodies, contributing to algal blooms and die-off of submerged vegetation due to lack of sunlight, as well as the discharge of farm pathogens into the natural environment.[130] Die-off of submerged vegetation

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[126] IPCC. 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

[127] Hasimuna, O. J., S. Maulu, K. Nawanzi, B. Lundu, J. Mphande, C. J. Phiri, E. Kikamba, E. Siankwilimba, S. Siavwapa and M. Chibesa. 2023. "Integrated agriculture-aquaculture as an alternative to improving small-scale fish production in Zambia." *Frontiers in Sustainable Food Systems* 7:1161121. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2023.1161121/full.

[128] Ahmed, N., J.D. Ward, and C.P. Saint. 2014. "Can integrated aquaculture-agriculture (IAA) produce "more crop per drop"?" *Food Security* 6 (6): 767-779. https://www.researchgate.net/publication/267335842_Can_integrated_aquaculture-agriculture_IAA_produce_more_crop_per_drop#:~:text=The%20practice%20of%20pond-based%20IAA%20and%20rice-fish%20farming,recognized%20that%20IAA%20produces%20%E2%80%9Cmore%20crop%20per%20drop%E2%80%9D.

[129] IPCC. 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

[130] Banas, D., G. Masson, L. Leglize, and J-C Pihan. 2002. "Discharge of sediments, nitrogen (N) and phosphorus (P) during the emptying of extensive fishponds: effect of rainfall and management practices." *Hydrobiologia* 472: 29–38. https://link.springer.com/article/10.1023/A:1016360915185.

also will contribute to increased biochemical oxygen demand (BOD) and further algal blooms, causing a negative feedback loop and affecting native fish populations.

Excessive nutrient loading can reduce dissolved oxygen levels and result in the die-off of aquatic organisms, including fish. Hence, discharge and associated water pollution are a concern when feed is used during the growing process. Some closed systems that use tanks also discharge water from time to time, leading to nutrient, pesticide, and/or pathogen contamination. Feed management and consideration of the cumulative impacts of multiple farms and carrying capacity are important to prevent water contamination from pond discharges.[131] Another risk is when fish farms use chemicals and pesticides to kill pathogens or predatory species when preparing ponds before stocking. This may contaminate the water body with discharges of pond water. It is recommended that biodegradable or photodegradable pesticides be used for pond preparation activities and that discharges occur only after non-toxic levels are reached.[132]

4.2.4 INTRODUCTION OF NON-ENDEMIC AND INVASIVE SPECIES TO WILD SYSTEMS

Aquaculture can potentially involve culturing non-native species. For example, the most widely consumed tilapia species (a native species from Africa) is not native to most of the world. However, it can now be found in virtually every freshwater aquatic system around the world due to its extensive promotion as the aquatic equivalent of chicken. Virtually anything that is cultured in a pond or cage, or even a closed tank system, is vulnerable to accidental escape and possible introduction to the natural environment. Non-natives species can become invasive and displace native species as the dominant type in local systems. They also can have food web cascades,[133] which, in turn, can impact other livelihoods, such as fishing. However, in some cases, such as the recent accidental introduction of the invasive Charru mussel into the Philippines from South America, the introduced species may have potential as a fishery species. In the Philippines, the Charru mussel quickly became commercially exploited by shellfishers and mussel farmers, even though it was considered a pest by some oyster farmers.[134]

The following factors are important when selecting a species to culture:

- Is it a native species? If it is non-native, what are the potential risks should it become invasive? Can adequate safeguards be established? Is the species low on the trophic level?
- Are there well-established hatchery techniques or will the aquaculture operation be dependent on wild-harvested larvae, fry, or juveniles?
- Does the species thrive in crowded spaces/captivity? Is the species capable of rapid and uniform growth (which will ensure the efficient use of facilities and food)? Is the fish

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131 Hlaváč, D., Z. Adámek, P. Hartman, and J. Másílko. 2014. "Effects of supplementary feeding in carp ponds on discharge water quality: a review." *Aquaculture International* 22 (1): 299-320. https://link.springer.com/article/10.1007/s10499-013-9718-6.

132 Anyusheva, M., M. Lamers, Ng. La, V.V. Vien Nguyen and T. Strek. 2012. "Fate of Pesticides in Combined Paddy Rice–Fish Pond Farming Systems in Northern Vietnam." *Journal of Environmental Quality* 41 (2): 515-525. https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/jeq2011.0066.

133 De Silva, S.S., T.T.T. Nguyen, G.M. Turchini, U.S. Amarasinghe, and N.W. Abery. 2009. "Alien species in aquaculture and biodiversity: A paradox in food production." *AMBIO* 38: 24–28. https://pubmed.ncbi.nlm.nih.gov/19260343/#:~:text=However%2C%20voluntary%20and%20or%20accidental%20introduction%20of%20exotic,biodiversity%2C%20is%20an%20imperative%20for%20a%20sustainable%20future.

134 Rice, M.A., P.D. Rawson, and A.D. Salinas and W.R. Rosario. 2016. "Identification and salinity tolerance of the western hemisphere mussel, Myrella charruana (D'Orbigny, 1842) in the Philippines." *Journal of Shellfish Research* 35 (4): 865-873. https://www.semanticscholar.org/paper/Identification-and-Salinity-Tolerance-of-the-Mussel-Rice-Rawson/046accf1b610dab3c14999ce2b78c035f7ec8a94.

cannibalistic? (If so, it is likely to reduce the survival rate.)

- How efficient is the food conversion ratio (i.e., the ratio of the dry weight of food to the wet weight gain of fish)? Does the species need artificial feed and, if so, is it amenable to artificial feeding? (Fish that are lower in the food chain may not need artificial feed.) How hardy and disease resistant is the fish? Can it survive in sub-optimal conditions and conditions that are likely to result as the climate changes (e.g., high/low temperatures, low dissolved oxygen, high pH, low/high salinity)?
- Is the fish marketable and is there local and/or international demand for the species?
- What is the level of meat recovery? Species with a large proportion of meat relative to the total body weight are the most desirable.

4.2.5 INTRODUCTION OF DISEASES, PARASITES, AND PATHOGENS TO WILD POPULATIONS

Biosecurity is another concern, where diseases in aquaculture systems, along with pathogens, predators, and parasites, can be released into the ecosystem, with adverse effects on fisheries, coral reefs, and other species. Climate change may exacerbate the risk of disease in aquaculture through changes in the distribution, prevalence, and virulence of pathogens and changes in the susceptibility of the host species.[135] In particular, the prevalence of disease and pests in aquaculture crops has increased in the past decade, reducing their quantities and commercial value.[136] The importation of brood stock or seed stock also is a concern because if the stock is not quarantined properly, it could introduce new diseases, pathogens, and parasites that affect the local brood stock and native species if the imported stock escapes into the natural environment. Even when native species are cultured, if the strain is a captive breed and escapes into the wild and interbreeds with wild strains, there are concerns about potential genetic dilution of wild strains. When the potential risks of diseases and pathogens carried by aquaculture are known, spatial planning may be used to mitigate the impact on wild fish populations.[137]

4.2.6 USE OF UNDERUTILIZED FISH BYCATCH FROM FISHERIES AND FISH MEAL AS A PROTEIN SOURCE IN FISH FEED

As discussed earlier, cage culture of high-value carnivorous fish species in tropical waters often uses underutilized fish bycatch from the capture sector as a feed source. While this may be considered efficient utilization of a bycatch with low value and no direct human consumption, the use of bycatch and wild fish promotes sustained rates of fishing effort in degraded fishery ecosystems. This prevents fishery recovery and can disrupt ecosystem functions. If the fish used in fish meal originates from subsidized trawling fleets, it creates demand and increased pressure to target stocks that have been overfished. In cases where overfishing is mainly caused by excessive trawling, the elimination of fish meal markets would make trawling unprofitable. This would lead many trawlers to go out of business, which, in turn, would reduce the fishing effort. The use of well-formulated fish feed, or the culture of species that do not

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[135] Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, J., Hofmann, E.E., Lipp, E., Osterhaus, A.D.M.E., Overstreet, R., Porter, J.W., Smith, G.W., & Vasta, G.R. 1999. "Emerging marine diseases - climate links and anthropogenic factors." *Science* 285: 1505– 1510. https://www.researchgate.net/publication/345986294_Emerging_Marine_Diseases-Climate_Links_and_Anthropogenic_Factors.

[136] Ward, GM, Faisan, JP, Cottier-Cook, EJ, et al. 2020. "A review of reported seaweed diseases and pests in aquaculture in Asia." *Journal of the World Aquaculture Society* 51: 815– 828. https://doi.org/10.1111/jwas.12649.

[137] Gentry, R., S.E. Lester, C.V. Kappel, T.W. Bell, J. Stevens, and S.D. Gaines. 2016. "Offshore aquaculture: Spatial planning principles for sustainable development." *Ecology and Evolution* 7 (2): 1- 11. https://onlinelibrary.wiley.com/doi/10.1002/ece3.2637.

require any feed, is preferred as they will almost always have better feed conversion ratios than low market-value fish.

Fish meal or fish oils originate from the wild harvesting of fish species, such as sardines, anchovies, and other small pelagics, which are high in oil and fat content. The fish are processed and reduced to fish meal that goes into feed for cultured finfish, shrimp, and other livestock. The harvest of small pelagics for fish meal may limit the fish and protein available for local consumption. It also may drive up demand for and the price of captured fish, which, in turn, may fuel overfishing.[138,139] Overfishing of "forage fish" is a growing concern because small pelagics are critical components of natural food chains.[140] During the past 20 years, there has been considerable progress in aquaculture feed development, substantially reducing the requirement for fish meal.[141,142] The use of feed with high vegetable or other innovative sources of protein, such as insect meal,[143] should be strongly encouraged. Projects should avoid promoting the development of fish meal plants and the use of wild fingerlings or juveniles for seed stock.

Some aquaculture operations rely on a wild source of juveniles or fingerlings as seed stock for their operations. Examples include tilapia, salmon, grouper, lobsters, milkfish, sea cucumbers, and shrimp. In some cases, such as lobster, the research and development of technology and processes to allow for a closed breeding cycle do not yet exist. In other cases, closed breeding cycles have been successfully implemented but are not yet cost effective for producing juveniles for stocking in ponds or cages at scale. In yet other cases, there may not be an available supply of hatchery-raised seed stock in the growing area. Where seed supply from hatcheries is not available, a demand is created for a fishery for juveniles that are then grown out in cages or ponds. Generally, the harvesting of juveniles from the wild is a bad fishing practice that affects the health of wild stocks.[144]

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[138] Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchenko, H. Mooney and M. Troell. 2000. "Effect of aquaculture on world fish supplies." *Nature* 405: 1017-1024. https://www.nature.com/articles/35016500.

[139] Davis, D.L., C.L. Miller and R.P. Phelps. 2005. "Replacement of fish meal with soybean meal in the production diets of juvenile red snapper, Lutjanus campechanus." *Journal of the World Aquaculture Society* 36: 114-119. https://www.researchgate.net/publication/227636454_Replacement_of_Fish_Meal_with_Soybean_Meal_in_the_Production_Diets_of_Juvenile_Red_Snapper_Lutjanus_campechanus.

[140] Pikitch, E.K., K.J. Rountos, T.E. Essington, C. Santora, D. Pauly, R. Watson, U.R. Sumaila, P.D. Boersma, I.L. Boyd, D.O. Conover, P. Cury, S.S. Heppell, E.D. Houde, M. Mangel, E. Plaganyi, K. Sainsbury, R.S. Steneck, T.M. Geers, N. Gownaris, and S. B. Munch. 2012. "The global contribution of forage fish to marine fisheries and ecosystems." *Fish and Fisheries* 15 (1): 43-63. https://www.researchgate.net/publication/235417776_The_global_contribution_of_forage_fish_to_marine_fisheries_and_ecosystems.

[141] Hansen, A.C., G. Rosenlund, O. Karlsen, W. Koppe and G.I. Hemrea. 2007. "Total replacement of fish meal with plant proteins in diets for Atlantic cod (Gadus morhua L.): Effects on growth and protein retention." *Aquaculture* 272: 599-611. https://www.sciencedirect.com/science/article/abs/pii/S0044848607008812#:~:text=No%20effects%20were%20seen%20when%20soybean%20meal%20%287%E2%80%9330%25,meal%20with%20plant%20protein%20in%20diets%20for%20cod.

[142] Moutinho, S., S. Martinez-Llorens, A. Tomas-Vidal, M. Jover-Cerda, A. Oliva-Teles, and H. Peres. 2017. "Meat and bone meal as partial replacement of fish meal in diets of gilthead seabream (Sparus aurata) juveniles: Growth, feed efficiency, amino acid utilization, and economic activity." *Aquaculture* 468 (1): 271-277. https://www.sciencedirect.com/science/article/abs/pii/S0044848616307293.

[143] Sanchez-Muros, M.J., F.G. Barroso, and F. Manzano-Agugliaro. 2014. "Insect meal as a renewable source of food for animal feeding." *Journal of Cleaner Production* 65: 6-27. https://www.sciencedirect.com/science/article/abs/pii/S095965261300841X.

[144] Hair, C.A., J.D. Bell, P.J. Doherty. 2002. "The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fisheries." *Responsible Marine Aquaculture (CABI Publishing)* 327-254. https://www.cabidigitallibrary.org/doi/10.1079/9780851996042.0327.

4.3 POST-HARVEST IMPACTS FROM PROCESSING PLANTS AND OTHER SUPPORTING INFRASTRUCTURE

The potential for the environmental and climate impacts of post-harvest interventions is similar for aquaculture and wild-caught fisheries. Once the fish are transported off the boat or from the pond or cage, they enter a supply chain that ends on the consumer's plate.

GHG emissions are produced from the transportation required throughout post-harvesting, along with infrastructure and equipment, cold storage, the energy used for food conversion from raw materials to final products, and the energy used for refrigeration and cooking along the supply chain.[145] One study estimated that fisheries consumed 40 billion liters of fuel in 2011 and generated a total of 179 million tons of carbon dioxide equivalent (CO_2e).[146] However, there are many measures that processing plants and other supporting infrastructure can take to reduce emissions. For example, the reduction of vessel emissions can be achieved with the adoption of electric motors, more efficient engines and larger propellers, better vessel shape, hull modifications, and reduced speed.[147] Using renewable energy sources also can help reduce emissions at all points on the supply chain. While difficult to quantify, one study estimates that 11 percent of all GHG emissions from food waste come from fish and aquatic foods,[148] underscoring the potential for addressing post-harvest losses (e.g., through technological improvements of the cold chain) for climate change mitigation.

Improvements in small-scale infrastructure for the sorting, cleaning, icing, displaying, and selling of fish or the construction of small-scale processing plants may be included in projects. The improvement of small-scale processing is a good way to add product value and quality, generating increased profits for small-scale fish processors, who typically are small- and medium-scale, women-owned enterprises. It also can contribute to improved food safety with cleaner, fresher, and more nutritious fish food products provided to local markets. However, proper management and regulation of total processing capacity—in both small- and large-scale fishing and fish farming—are needed to ensure that the demand for fish by processing facilities does not exceed the carrying capacity of fisheries and aquaculture facilities.

4.3.1 THE DEVELOPMENT OF POST-HARVEST FACILITIES

The development of shore-based post-harvest handling and processing infrastructure has the same general environmental concerns as any small-scale infrastructure development, including the selection of facility siting in non-hazardous zones and avoiding wetland or mangrove forest areas. Facility renovation and construction could disturb existing landscapes, habitats, and

[145] U.S. EPA. 2021. From Farm to Kitchen: The Environmental Impacts of U.S. Food Waste. U.S. Environmental Protection Agency Office of Research and Development. https://www.bing.com/search?q=131.+From+Farm+to+Kitchen%3A+The+Environmental+Impacts+of+U.S.+Food+Waste&cvid=6666285a1643438c9a85629a569054f5&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIHCAEQRRj8VdIBBzgxOWowajmoAgCwAgA&FORM=ANAB01&PC=U531.

[146] Parker, Robert WR, Julia L. Blanchard, Caleb Gardner, Bridget S. Green, Klaas Hartmann, Peter H. Tyedmers, and Reg A. Watson. "Fuel use and greenhouse gas emissions of world fisheries." *Nature Climate Change* 8, no. 4 (2018): 333-337. https://www.nature.com/articles/s41558-018-0117-x.

[147] International Maritime Organization. 2023. "2023 IMO Strategy on Reduction of GHG Emissions from Ships." https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx.

[148] Guo, Xuezhen, Jan Broeze, Jim J. Groot, Heike Axmann, and Martijntje Vollebregt. 2020. "A worldwide hotspot analysis on food loss and waste, associated greenhouse gas emissions, and protein losses." *Sustainability*. https://www.researchgate.net/publication/344856881_A_Worldwide_Hotspot_Analysis_on_Food_Loss_and_Waste_Associated_Greenhouse_Gas_Emissions_and_Protein_Losses.

sensitive ecosystems; degrade water resources; cause sedimentation to surface waters; and contaminate groundwater and surface water.

Runoff from cleared ground or materials stockpiled during construction can result in sedimentation/fouling of surface waters. Construction may result in standing water at the site, creating breeding habitats for mosquitoes and other disease vectors. Local procurement of construction materials (e.g., timber, fill, sand, gravel) may have adverse local impacts. In coastal areas, the construction of fish processing and landing facilities requires consideration of proper setback from the high-tide line in erosion-prone areas and away from estuarine flood zones. Sea level rise means increasing rates of erosion and flooding, which also need to be factored into facility siting and local zoning procedures.[149]

4.3.2 WATER AND SANITATION ISSUES RELATED TO LANDING AND POST-HARVEST PROCESSING SITES

Processing and landing beach infrastructure require proper drainage and disposal of waste with high organic loads to avoid the pooling of water that can breed mosquitoes and flies, in turn, creating health impacts.[150] Typically, such facilities have a water supply, toilets, and showers for people, which are the required safeguards for handling runoff and waste. The withdrawal of excessive amounts of fresh water may exacerbate saltwater intrusion into the local aquifer.[151] Fish processing plants, even small-scale plants, tend to generate large amounts of organic liquid and solid waste effluents, which must be properly treated and not discharged untreated into nearby receiving water. Hence, this type of beach infrastructure needs proper waste storage and disposal capabilities.[152,153]

4.3.3 IMPACTS RELATED TO SMOKING AND OTHER FISH PROCESSING

The smoking of fish may have safety and health risks for fish processors. Depending on the type of oven used, smoking fish can add high concentrations of polycyclic aromatic hydrocarbons, which are carcinogens, to the final product.[154] Fish processing also may generate odor pollution. Additionally, inefficient smokers that use wood can contribute to deforestation, especially in the absence of proper management of wood sources. As previously discussed, when the overall catches decline, processing plants that convert wild-caught fish to fish meal may see a decrease in available fish. This disrupts the livelihoods of small-scale aquatic food processors.

Increasing the value of fish products through improved processing, packaging, and marketing means increased fish prices at the retail level. This can, in turn, drive up the price of fish sold off the boats. The increase in demand for the raw product may create an incentive for increasing fishing effort in an attempt by fishers to earn more profits. Increased fishing effort that spurs

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[149] For guidance on small-scale construction activities, see http://www.usaidgems.org/Sectors/construction.htm.
[150] Dwyer P.G., Knight J.M., Dale P.E.R. 2016. "Planning Development to Reduce Mosquito Hazard in Coastal Peri-Urban Areas: Case Studies in NSW, Australia." *Water Science and Technology Library* 72. https://link.springer.com/chapter/10.1007/978-3-319-28112-4_33.
[151] Klassen, J. and D.M. Allen. 2017. "Assessing the risk of saltwater intrusion in coastal aquifers." *Journal of Hydrology* 551: 730-745. https://www.sciencedirect.com/science/article/abs/pii/S0022169417301233.
[152] Muthukumaran, S. And K. Baskaran. 2013. "International Biodeterioration & Biodegradation Organic and nutrient reduction in a fish processing facility – A case study." *International Biodeterioration & Biodegradation* 85: 563-570. https://www.sciencedirect.com/science/article/abs/pii/S0964830513001194.
[153] For a review of environmental guidelines on water and sanitation and solid waste management see: http://www.usaidgems.org/Sectors/watsan.htm and http://www.usaidgems.org/Sectors/solidWaste.htm.
[154] Tongo, I., O. Ogbeide, and L. Ezemonye. 2017. "Human health risk assessment of polycyclic aromatic hydrocarbons (PAHs) in smoked fish species from markets in Southern Nigeria." *Toxicology Reports* 4: 55-61. https://www.sciencedirect.com/science/article/pii/S221475001630110X.

additional pressure on exploitation can exacerbate overfishing and ultimately result in dwindling landings of fish.[155]

4.4 INTERACTIONS BETWEEN FISHERIES AND AQUACULTURE

There are many interactions between fisheries and aquaculture in the post-harvest supply chain.[156] One concern for the aquaculture sector is the use of fish meal, which is described in Section 4.2. There is an argument that wild-caught and low-cost fish should be reserved for direct consumption in poor nations.[157] The anchovy stock and other forage fish also are important because they help sustain healthy coastal ecosystems and fish, such as sharks and tuna.[158]

The number of wild-caught fish used for the production of fish meal has declined steadily[159] as soy-based and other vegetable-based protein sources replace fish meal in many feed formulations. However, this has increased the demand for soy and, thus, the conversion of forests and the release of GHG stores in places, such as the Amazon, for soy farms. This underscores the need for broader food sector commitments, otherwise reductions in emissions associated with aquaculture producers may be outweighed by shifts in other sectors. In West Africa, a large percentage of small pelagic stocks, which are fish that typically occupy the mid and upper layers of the ocean, such as herring and mackerel, are locally processed and often transported far inland to supply protein in the Sahel region, where they are consumed as a cheap source of animal protein (see Figure 11). In this region, the diversion of fish to become fishmeal is a threat to food security.[160] As described in Section 4.2, the introduction of non-native species for aquaculture is a concern due to the risk of incidental or intentional wild release, where they can become invasive and affect native species, and alter local aquatic ecosystems and wild fish productivity. There also are concerns regarding farm-raised animals

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[155] Brush, C.G., A. deBruin, and F. Welter. 2009. "A gender-aware framework for women's entrepreneurship." *International Journal of Gender and Entrepreneurship* 1 (1): 8-24. https://www.researchgate.net/publication/235302742_A_Gender-Aware_Framework_for_Women's_Entrepreneurship.

[156] Alongi, D.M. 2002. "Present state and future of the world's mangrove forests." *Environmental Conservation* 29 (3): 331-349. https://www.researchgate.net/publication/231955066_Present_State_and_Future_of_the_World%27s_Mangrove_Forests.

[157] Robinson, J.P.W., D.J. Mills, G.A. Asiedu, K. Byrd, M. del Mar Mancha Cisneros, P. J. Cohen, K. J. Fiorella, N. A. J. Graham, M. A. MacNeil, E. Maire, E. K. Mbaru, G. Nico, J. O. Omukoto, F. Simmance and C. C. Hicks. 2022. "Small pelagic fish supply abundant and affordable micronutrients to low- and middle-income countries." *Nature Food* 3:1075–1084. https://www.nature.com/articles/s43016-022-00643-3.

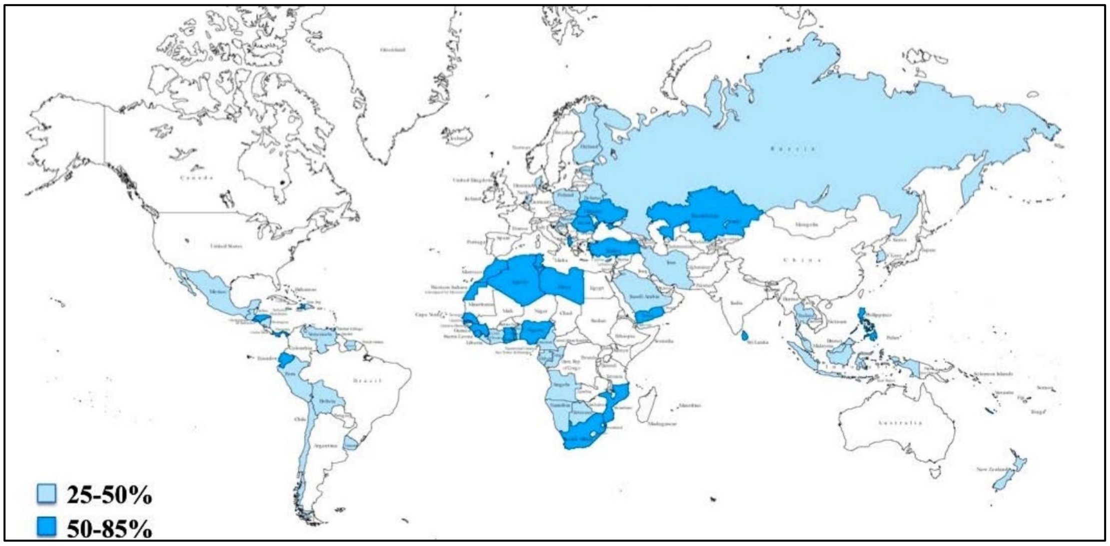
[158] Pikitch, E.K., K.J. Rountos, T.E. Essington, C. Santora, D. Pauly, R. Watson, U.R. Sumaila, P.D. Boersma, I.L. Boyd, D.O. Conover, P. Cury, S.S. Heppell, E.D. Houde, M. Mangel, E. Plaganyi, K. Sainsbury, R.S. Steneck, T.M. Geers, N. Gownaris, and Munch. 2012. "The global contribution of forage fish to marine fisheries and ecosystems." *Fish and Fisheries* 15 (1): 43-63. https://onlinelibrary.wiley.com/doi/10.1111/faf.12004.

[159] FAO. 2016. "The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all." Rome, Italy, 200. http://www.fao.org/3/a-i5555e.pdf.

[160] Ayilu, R.K., T.O. Antwi-Asare, P. Anoh, A. Tall, N. Aboya, S. Chimatiro, and S. Dedi. 2016. Informal artisanal fish trade in West Africa: Improving cross-border trade. Program Brief, Penang, Malaysia: WorldFish. https://digitalarchive.worldfishcenter.org/handle/20.500.12348/3864.

transmitting diseases and parasites to wild stocks, or genetic degradation of wild stocks by farm-raised genetic strains due to inbreeding after accidental releases to the wild.[161,162,163]

FIGURE 11. THE CONTRIBUTION OF SMALL PELAGIC FORAGE FISH TO THE TOTAL FISH FOOD SUPPLY[164]



Aquaculture also can pose threats to critical habitats that serve as essential wild fish habitat during critical life stages. Large tracts of mangrove forests have been converted to shrimp ponds in Asia and Latin America even though they play an important role as nursery grounds for many commercially important species of fish. For example, a study in Mexico showed direct links for the extent of mangrove habitat to fish landings: Each hectare of mangrove contributed USD 37,500 in fishery landings.[165] In India, 1 hectare of mangroves has been shown to increase the marginal output of marine fisheries by 1.86 tons per year.[166]

Although Henriksson et al. (2017) have pointed out that some properly managed coastal ponds established in mangroves have been operated for many decades with minimal environmental

161 Di Cicco, E., Ferguson HW, Schulze AD, Kaukinen KH, Li S, Vanderstichel R, et al. 2017. "Heart and skeletal muscle inflammation (HSMI) disease diagnosed on a British Columbia salmon farm through a longitudinal farm study." *PLoS ONE* 12 (2). https://doi.org/10.1371/journal.pone.0171471.
162 Johansen, L. H., Jensen, I., Mikkelsen, H., Bjørn, P. A., Jansen, P. A., & Bergh, Ø. 2011. "Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway." *Aquaculture* 315 (3-4): 167-186. https://doi.org/10.1016/j.aquaculture.2011.02.014.
163 Krkosek, M., Lewis MA, Morton A, Frazer LN, Volpe JP. 2006. "Epizootics of wild fish induced by farm fish." *Proceedings of the National Academy of Science* 103 (42). https://doi.org/10.1073/pnas.0603525103.
164 Tacon, A. G. J., and M. Metian. 2009. "Fishing for Feed or Fishing for Food: Increasing Global Competition for Small Pelagic Forage Fish." *Ambio*. https://www.researchgate.net/publication/38039402_Fishing_for_Feed_or_Fishing_for_Food_Increasing_Global_Competition_for_Small_Pelagic_Forage_Fish.
165 Aburto-Oropeza, O., E. Ezcurrat, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2001. "Mangroves in the Gulf of California increase fishery yields." *PNAS* 105 (30). https://www.semanticscholar.org/paper/Mangroves-in-the-Gulf-of-California-increase-yields-Aburto%E2%80%90Oropeza-Ezcurra/87220bc324f5b2c90d504700480c7212bf2d0434#:~:text=It%20is%20shown%20that%2C%20in%20the%20Gulf%20of,nursery%20and%2For%20feeding%20grounds%20by%20many%20commercial%20species.
166 Anneboina, L.R. and K.S.K. Kumar. 2017. "Economic analysis of mangrove and marine fishery linkages in India." *Emsystem Services* 24: 114-123. https://www.sciencedirect.com/science/article/pii/S2212041616302868.

impact, many shrimp ponds become unproductive after years of operation.[167,168] When this occurs, the areas are abandoned with damage to the naturally productive mangrove fisheries system. For example, a study in Thailand showed that mangrove destruction led to economic losses of USD 253 per hectare, which was much less than the short-term gains from aquaculture conversion. However, when discounted over time and factoring in timber values, intact mangroves showed 10 times the discounted returns compared with shrimp farming.[169]

Socioeconomic interactions between wild-caught fishing and aquaculture also exist and must be taken into consideration. In Bangladesh, a USAID-funded project focused on helping women develop fish ponds. However, this empowerment of women and flow of economic benefits to them led to resentment and tension with men.[170]

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167 Kauffman, J.B., R.F. Hughes, and C. Heider. 2009. "Carbon pool and biomass dynamics associated with deforestation, land use, and agricultural abandonment in the neotropics." *Ecological Applications* 19: 1211-1222. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/08-1696.1.

168 Kauffman, J.B., V.B. Arifanti, H.H. Trejo, M.C.J. Garcia, J. Norfolk, M. Cifuentes, D. Hadriyanto, and D. Mudiyarso. 2017. "The jumbo carbon footprint of a shrimp: carbon losses from deforestation." *Frontiers in Ecology and the Environment* 15: 183-188. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.1482.

169 Barbier, E.B. 2003. "Habitat-Fishery Linkages and Mangrove Loss in Thailand." *Contemporary Economic Policy* 21 (1): 59-77. https://www.researchgate.net/publication/247674981_Habitat-fishery_linkages_and_mangrove_loss_in_Thailand.

170 USAID. 2017. "Final Performance Evaluation: Aquaculture for Income and Nutrition (AIN)." https://pdf.usaid.gov/pdf_docs/pa00mv3p.pdf.

5. CLIMATE CHANGE CONSIDERATIONS

As described previously, climate change will continue to affect both wild-caught and farmed saltwater and freshwater fisheries, threatening marine and freshwater ecosystems and putting livelihoods at risk.

Climate impacts on marine and freshwater ecosystems include increases in water temperature, increases in ocean acidity, decreases in oxygen content, and changes in water cycle variability. According to the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, "the ocean has warmed unabated since 2005, continuing the clear multidecadal ocean warming trends."[171] Increasing water temperatures alter the optimal temperature range for certain cultured organisms, making it increasingly difficult to maintain farming operations as changes in the immediate environment can affect some farmed species of fish. The broad impacts of warming waters on coral reefs, which has led to mass coral bleaching and die-offs, for example, can significantly affect important breeding grounds for a wide range of fisheries.[172] The potential for eutrophication as a result of increased temperatures is another monitored impact in relation to fish farming operations. Eutrophication is the process by which excess nutrients enter a body of water, increasing the amount of plant and algae growth, producing carbon dioxide, and leading to ocean acidification.[173] Changes in the level of dissolved oxygen can result in fish death, as well as create conditions for virulent pathogen outbreaks.[174] Additionally, "warming-induced changes in spatial distribution and the abundance of fish stocks have already challenged the management of some important fisheries and their economic benefits."[175] The risk of increased storm intensity and frequency is another threat to fish farming operations. Storm surges, inland flooding, and saltwater intrusion can damage the structural integrity of aquaculture farms. Such impacts can result in a loss of fish stock, damage to facilities and equipment, and a high risk to employees, which ultimately affects the strength of farming operations and surrounding communities that rely on farmed fish.[176] These impacts have grave implications for fisheries, whose catches and composition have already been affected by the impact of warming and changing primary production on growth, reproduction, and the survival of fish stocks.

There is significant confidence that marine heat waves and higher than average ocean temperatures are already exposing species and ecosystems to environmental conditions beyond their tolerance limits, and ecosystem models project a decline in marine animal biomass with warming under shared socioeconomic pathways (SSPs) 1 through 2.6 and SSPs 5 through 8.5 by 2100, with regional variation.[177] By 2100, the percentage of marine and freshwater fish

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[171] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[172] Hamilton, M., Robinson, J.P.W., Benkwitt, C.E. et al. 2022. "Climate impacts alter fisheries productivity and turnover on coral reefs." *Coral Reefs* 41: 921–935. https://doi.org/10.1007/s00338-022-02265-4.

[173] NOAA. 2023. "What is Eutrophication?" https://oceanservice.noaa.gov/facts/eutrophication.html.

[174] Soto, D., Brugere, C. n.d. "The Challenges of Climate Change for Aquaculture." *FAO Aquaculture Newsletter*. https://www.fao.org/3/i0305e/i0305e16.pdf.

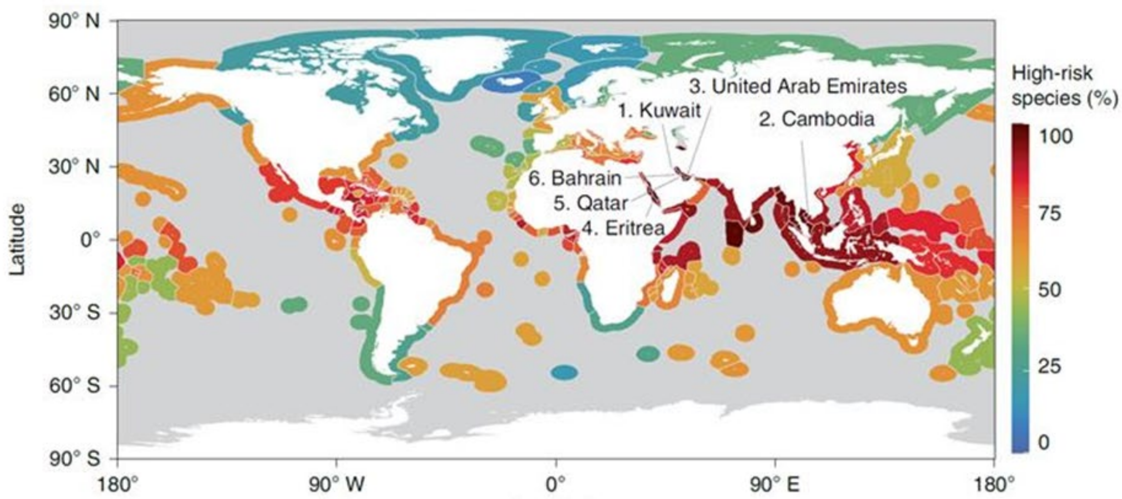
[175] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[176] The WorldFish Center. 2007. *The Threat to Fisheries and Aquaculture from Climate Change*. The WorldFish Center. https://www.worldfishcenter.org/publication/threat-fisheries-and-aquaculture-climate-change.

[177] IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, doi:10.1017/9781009157896.

species that could be affected by water temperatures exceeding their tolerance limit for reproduction ranges from about 10% to about 60% under the sustainability-focused (SSPs 1–1.9) and the fossil fuel development-focused (SSPs 5–8.5) climate projection scenarios.[178] For inland standing waters, the speed at which they are warming is increasing faster than the ability of some aquatic species to disperse to cooler habitats.[179] Studies also have found that nearly half of the current freshwater fish species could become extinct in the coming decades under moderate (RCP 4.5) and high (RCP 6.0) emissions scenarios, and that these declines are especially pronounced in tropical regions and in river basins with greater precipitation and warming.[180] Furthermore, under a fossil fuel development-focused climate projection scenario (SSPs 5–8.5), 9 percent of the ocean could contain at least 50 percent of their constituent species at high or critical climate risk, and 1 percent could contain ecosystems where almost all (greater than 95 percent) species are at high or critical risk,[181] as shown in Figure 12 below. Climate risk encapsulates current sensitivity, future exposure, and innate adaptivity. This study also found that climate change disproportionately affects top predators, which could fundamentally alter the structure of marine ecosystems, with consequences for energy transfer, ecosystem stability, and ecosystem functioning.

FIGURE 12. THE PROPORTION OF FISHED SPECIES AT RISK (HIGH OR CRITICAL) UNDER A HIGH EMISSIONS SCENARIO TO THE YEAR 2100[182]



https://www.cambridge.org/core/books/climate-change-2021-the-physical-science-basis/415F29233B8BD19FB55F65E3DC67272B.

[178] Dahlke, F. T., Wohlrab, S., Butzin, M., & Pörtner, H. O. 2020. "Thermal bottlenecks in the life cycle define climate vulnerability of fish." *Science* 369 (6499): 65-70. https://www.science.org/doi/10.1126/science.aaz3658.

[179] Woolway, R.I., Maberly, S.C. 2020. "Climate velocity in inland standing waters." *National Climate Change* 10: 1124-1129. https://doi.org/10.1038/s41558-020-0889-7.

[180] Manjarrés Hernández, A., Guisande, C. y García Roselló, E. 2021. "Predicting the effects of climate change on future freshwater fish diversity at global scale." *Nature Conservation* 43: 1-24. https://doi.org/10.3897/NATURECONSERVATION.43.58997.

[181] Boyce, Daniel & Tittensor, Derek & Garilao, Cristina & Henson, Stephanie & Kaschner, Kristin & Kesner-Reyes, Kathleen & Pigot, Alex & Reyes, Rodolfo & Reygondeau, Gabriel & Schleit, Kathryn & Shackell, Nancy & Sorongon-Yap, Patricia & Worm, Boris. 2022. "A climate risk index for marine life." *Nature Climate Change* 12: 1-9. https://www.researchgate.net/publication/362854169_A_climate_risk_index_for_marine_life.

[182] Ibid.

Farmed fish also are at greater risk of pathogens due to the existing structures of farming practices, which include keeping fish in close proximity and at high densities to increase productivity.[183] These risks are further exacerbated by the impacts of climate change, which can shift or create the conditions for disease spread. Increased storm intensity and frequency can damage and flood existing farming infrastructure, which includes post-harvest facilities, farm sites, and transportation routes.[184] There is significant confidence that climate change has already increased observed precipitation, winds, and extreme sea level events, which increases the intensity of multiple extreme events and the associated cascading impacts. As global temperatures continue to rise, the average intensity of tropical cyclones and the intensity and magnitude of storm surge and precipitation rates are projected to increase,[185] further threatening farming infrastructure.

Mitigating emissions reduces the climate risks posed to marine and freshwater species, enhances ecosystem stability, and benefits food-insecure populations in low-income countries. However, past GHG emissions have already committed the global ocean to future warming, ocean acidification, and ocean deoxygenation; however, it is important to realize that the rates of these changes are dependent on future emissions.[186] Climate-induced changes to biophysical and biochemical conditions will require significant changes in aquaculture and farming practices, such as adapting species and strains to changing conditions, as well as restructuring training and educational support. Climate models project decreases in marine animal biomass and fish catch potential, which elevate the risk of the impacts on income, livelihood, and food security of dependent human communities.[187]

As the climate continues to change due to rising GHG emissions, USAID has direct opportunities to reduce or avoid emissions in wild-caught fisheries and aquaculture practices, as well as to consider measures to build resilience and introduce adaptation measures in wild-caught fishery and aquaculture projects.

When planning wild-caught fishery and aquaculture projects, the design process should include consideration of the potential near- and long-term changes to climate conditions and local weather patterns. Evolving and shifting climate change impacts, for example, the increased frequency of extreme weather events, changing rainfall and wind patterns, and other hazards, can result in unexpected and significant risks to wild-caught fishery and aquaculture activities. USAID's required process for climate risk management (CRM) enables relevant climate risks to be considered and addressed for each wild-caught fishery and aquaculture program activity.

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[183] Walker, PJ, Mohan CV. 2009. "Viral disease emergence in shrimp aquaculture: origins, impact and the effectiveness of health management strategies." *Reviews in Aquaculture* 125-154. https://pubmed.ncbi.nlm.nih.gov/32328167/.

[184] Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., eds. 2018. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome: FAO, 628. https://openknowledge.fao.org/server/api/core/bitstreams/5fed4a8a-2ed4-4b46-8e8b-a30608163e06/content.

[185] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

[186] IPCC, 2021: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, In press, https://www.cambridge.org/core/books/climate-change-2021-the-physical-science-basis/415F29233B8BD19FB55F65E3DC67272B.

[187] IPCC. 2019. *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

When seeking to address climate change challenges, it also is useful to take a broad perspective in considering options for reducing emissions and building resilience at the same time, especially given the potential co-benefits of actions that utilize nature-based approaches. CRM and GHG emissions reduction actions can be supplemented and supported by measures to mobilize financing for climate-related investments; efforts to strengthen enabling conditions, governance, and shifts to market signals; and engagement with Indigenous Peoples, local communities, and women, youth, and marginalized and underrepresented groups and/or people in vulnerable situations to foster buy-in and direct engagement in the wild-caught fisheries and aquaculture operations.

Consistent with proven approaches for sustainable, effective development assistance, climate-focused activities should, where applicable, also seek to reflect the principles of locally led development, equity and inclusion, private sector engagement, nature-based solutions, innovation, and the use of evidence.

5.1 REDUCING GREENHOUSE GAS EMISSIONS

Food production is responsible for approximately a quarter of anthropogenic GHG emissions globally; however, marine fisheries are typically excluded from global assessments or are generalized due to a limited number of case studies. Studies that have quantified GHG emissions from aquaculture have found that aquaculture has low emissions intensity compared with terrestrial livestock, which is largely due to the absence of enteric methane, high fertility, low feed conversion ratios, and less land use change.[188] Within fisheries and aquaculture, there are varying levels of associated GHG emissions and nutritional benefits. One study found that across all fish and other aquatic foods, farmed bivalves and seaweeds generate the lowest emissions, while capture fisheries predominantly generate the highest level of GHG emissions.[189] Figure 13 below illustrates the relative nutritional value and production-related GHG emissions (excluding post-harvest emissions) per edible weight of certain aquatic food groups from fisheries and aquaculture. Of note, crustaceans tend to have lower relative nutritional value but higher relative GHG emissions.[190]

[188] MacLeod, M.J., Hasan, M.R., Robb, D.H.F. et al. 2020. "Quantifying greenhouse gas emissions from global aquaculture." *Scientific Reports* 10: 11679. https://doi.org/10.1038/s41598-020-68231-8.
[189] Gephart, J.A., E. Rovenskaya, U. Dieckmann, M.L. Pace, and Å. Brännström. 2016. "Vulnerability to shocks in the global seafood trade network." *Environmental Research Letters* 11. doi:10.1088/1748-9326/11/3/035008. https://iopscience.iop.org/article/10.1088/1748-9326/11/3/035008.
[190] Bianchi, M., Hallström, E., Parker, R.W.R. et al. 2022. "Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice." *Communications Earth & Environment* 3. https://doi.org/10.1038/s43247-022-00516-4.

FIGURE 13. NUTRIENT DENSITY AND GHG EMISSIONS OF GLOBALLY IMPORTANT AQUATIC FOOD GROUPS FROM FISHERIES (SOLID COLORS), AQUACULTURE (STRIPED), BEEF (B), CHICKEN (C), AND PORK (P). THE RELATIVE SIZE OF THE AQUATIC FOOD GROUP BUBBLES IS PROPORTIONATE TO 2015 GLOBAL EDIBLE WEIGHT PRODUCTION VOLUMES, AND GHG AND NUTRIENT DENSITY VALUES ARE WEIGHTED BY SPECIES.[191]

Blue carbon represents the amount of carbon that is captured by the world's oceans and coastal ecosystems.[192] Blue carbon ecosystems, which are some of the most significant biological carbon sinks in the world, are typically vegetated coastal marine habitats (e.g., seagrasses, mangroves, tidal marshes) that contain up to 50 percent of all organic carbon buried in ocean sediments and can accumulate and store greater carbon volumes at faster rates than terrestrial forests.[193] Habitat loss due to coastal marine aquaculture and the nutrient enrichment associated with fed finfish marine aquaculture decrease blue carbon and its ongoing sequestration potential, leading to increased GHG emissions from these ecosystems. Blue carbon emissions can be reduced by shifting net pens and operations into deeper water; however, this shift also could result in increased operational GHG emissions from fuel use, maintenance, and additional infrastructure needs offshore.[194]

GHG emissions from the global fishing industry grew by 28 percent between 1990 and 2011, with little coinciding increase in production.[195] Emissions during this period were primarily driven by increased harvests from fuel-intensive crustacean fisheries. At the same time, wild-caught fishing has begun to plateau and there has been a greater reliance on aquaculture to feed the

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[191] Ibid.
[192] Brodeur, Jean et al. 2022. NOAA Blue Carbon White Paper. NOAA. https://repository.library.noaa.gov/view/noaa/40456.
[193] Jones, AR, Alleway HK, McAfee D, Reis-Santos P, Theuerkauf SJ, Jones RC. 2022. "Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture." *Bioscience* 72 (2): 123-143. doi:10.1093/biosci/biab126. https://academic.oup.com/bioscience/article/72/2/123/6485038.
[194] Ibid.
[195] Parker et al. 2018. "Fuel use and greenhouse gas emissions of world fisheries." *Nature Climate Change* 8: 333-337. https://doi.org/10.1038/s41558-018-0117-x.

world's growing population.[196] For all wild-caught aquatic food, the primary emissions result from energy use from boat fuel and other transportation of feed and materials, cold storage of caught organisms, infrastructure equipment, energy used for food conversion from raw materials to final products, and the energy used for refrigeration and cooking. For all farmed aquatic food, emissions primarily result from energy use from boat fuel and transportation, cold storage of caught organisms, electricity for infrastructure and maintenance of commercial and feed organisms, and energy for the conversion from raw materials to final products, refrigeration, and cooking. Emissions also can result from land use change, management, and water stratification of ponds.[197,198] When looking at which stage of aquaculture had the largest impact on GHG emissions, Bohnes et al (2018) found that fishmeal production resulted in largest impacts. In their literature review of LCAs of farmed shrimp and prawns Pazmiño et al (2024), also found that feed production was the largest source of GHG emissions, mostly from production of ingredients in feed and the energy required for processing and transporting the feed.[199]

As mentioned above, one research study estimates that 11 percent of all GHG emissions from food waste come from fish and aquatic foods.[200] Another study estimates that emissions from food loss and waste are 39 percent of fish landed globally.[201] In particular, one of the main sources of emissions from fed finfish is the decomposition of waste food.[202] Few countries, however, currently account for food loss and waste as part of their nationally determined contribution (NDC) toward reducing emissions. At each stage of production (i.e., upstream, on farm, and downstream), there are both direct and indirect emissions associated with fisheries and aquaculture. However, there are several emissions mitigation options throughout the value chain of fisheries and aquaculture. For example, nature-based solutions, such as protecting or fostering the growth of kelp forests, seagrass vegetation, and oyster beds, can simultaneously

[196] Yuan, J., Xiang, J., Liu, D. et al. 2019. "Rapid growth in greenhouse gas emissions from the adoption of industrial-scale aquaculture." *National Climate Change* 9: 318-322. https://doi.org/10.1038/s41558-019-0425-9.
[197] Fan, M., Zhang, W., Wu, J., & Zhou, J. 2022. "Agricultural land use and pond management influence spatial-temporal variation of CH4 and N2O emission fluxes in ponds in a subtropical agricultural headstream watershed." *Frontiers in Environmental Science* 10. https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2022.1029334/full.
[198] Malerba, M.E., de Kluyver, T., Wright, N. et al. 2022. "Methane emissions from agricultural ponds are underestimated in national greenhouse gas inventories." *Communications Earth & Environment* 3. https://doi.org/10.1038/s43247-022-00638-9.
[199] Pazmiño, M. L., Chico-Santamarta, L., Boero, A., & Ramirez, A. D. (2024). Environmental life cycle assessment and potential improvement measures in the shrimp and prawn aquaculture sector: A literature review. *Aquaculture and Fisheries*. https://www.sciencedirect.com/science/article/pii/S2468550X24000856.
[200] Guo, Xuezhen, Jan Broeze, Jim J. Groot, Heike Axmann, and Martijntje Vollebregt. 2020. "A worldwide hotspot analysis on food loss and waste, associated greenhouse gas emissions, and protein losses." *Sustainability*. https://www.researchgate.net/publication/344856881_A_Worldwide_Hotspot_Analysis_on_Food_Loss_and_Waste_Associated_Greenhouse_Gas_Emissions_and_Protein_Losses.
[201] FAO. 2017. "Strengthening sector policies for better food security and nutrition results (Fisheries and aquaculture policy guidance note 1." Rome. https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/885757/.
[202] Jones, AR, Alleway HK, McAfee D, Reis-Santos P, Theuerkauf SJ, Jones RC. 2022. "Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture." *Bioscience* 72 (2): 123-143. doi:10.1093/biosci/biab126. https://academic.oup.com/bioscience/article/72/2/123/6485038.

reduce GHG emissions by sequestering carbon; these also create a buffer against climate impacts such as storm surge and ocean acidification.[203,204,205]

GHG emissions sources and emissions mitigation options are provided in more detail for different fishery and aquaculture activities in Table 2.

TABLE 2. MITIGATING GHG EMISSIONS FROM FISHERIES AND AQUACULTURE

GHG EMISSIONS SOURCES	EMISSIONS MITIGATION OPTIONS	ESTIMATION TOOLS
WILD-CAUGHT AQUATIC FOOD (FRESH AND SALTWATER)		
Combustion of boat fuel and other fuel use Electricity used for infrastructure (processing and storage facilities) Electricity used for equipment Energy used for cold storage of caught organisms Disrupting blue carbon ecosystems through overfishing and/or trawling Emissions from food loss and waste Refrigerant leakage from cold storage	Use fuel-efficient boats in a manner that maximizes fuel efficiency (e.g., maintaining lower speeds) to reduce emissions from transportation. Maintain boat motors. Shift to low- or no-emission energy sources and biofuels to reduce emissions from transportation and infrastructure. Ensure that cold storage is efficient and does not leak refrigerants or coolants. Take care not to disrupt or damage ecosystems, in particular, blue carbon ecosystems, which sequester carbon.	The GHG Protocol's GHG Emissions Calculation Tool can be used to estimate possible significant emissions (and emissions reductions) resulting from the use of transportation, refrigeration, and other equipment.[206]
AQUACULTURE		
Combustion of boat fuel and other energy used for the transportation of feed and materials Fuel used for transportation to facilities Energy used for feed production and processing Land use change for terrestrial	Use closed-system technology (e.g., recirculating aquaculture systems), which has shown efficient control of emissions while keeping low energy demand. Avoid cage farming, which results in larger nutrient emissions than pond farming. Use aerated systems specifically	USAID's Clean Energy Emission Reduction (CLEER) Tool can be used to estimate emissions that would be avoided as a result of renewable energy use.[208] The GHG Protocol's GHG Emissions Calculation Tool can be used to estimate possible significant emissions (and

[203] Hori, Masakazu, et al. 2021. "Oyster aquaculture using seagrass beds as a climate change countermeasure." *Bulletin of Japan Fisheries Research and Education Agency* 50: 123-133. https://www.researchgate.net/publication/351991923_Oyster_aquaculture_using_seagrass_beds_as_a_climate_change_countermeasure.
[204] Froehlich, H. E., et al. 2019. "Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting." *Current Biology* 29: 3087-3093. https://doi.org/10.1016/j.cub.2019.07.041.
[205] Chung, Ik Kyo, Jin Ae Lee, Jong Ahm Shin, Jong Gyu Kim, Kwang-Seok Park Jung Hyun Oak. 2013. "Installing kelp forests/seaweed beds for mitigation and adaptation against global warming: Korean Project Overview." *ICES Journal of Marine Science* 70 (5): 1038–1044. https://doi.org/10.1093/icesjms/fss206.
[206] For more information on GHG Protocol's GHG Emissions Calculation Tool, see GHG Protocol's website, accessible at https://ghgprotocol.org/calculation-tools-and-guidance.
[208] For more information on USAID's CLEER Tool, see the CLEER TOOL website, accessible at https://www.cleertool.org/.

GHG EMISSIONS SOURCES	EMISSIONS MITIGATION OPTIONS	ESTIMATION TOOLS
feed production (e.g., soybeans) On-farm emissions for terrestrial feed production Emissions from wild-caught aquatic feed Electricity used for infrastructure and maintenance Energy used for cold storage of caught organisms for feed Coastal and subtidal land use change and/or degradation from poor aquaculture farm siting Refrigerant leakage from cold storage Emissions from ponds: land use change from creating them, management activities, and water stratification Emissions from food loss and waste	to address methane emissions from the conversion of paddy fields to aquaculture. Utilize areas that can be converted to carbon-neutral seaweed farms, which can offset some emissions and provide other benefits to coastlines affected by eutrophic, hypoxic, and/or acidic conditions.[207] Shift to low- or zero-emission energy sources to reduce emissions, such as biofuels. Co-locate offshore marine aquaculture farms with energy generation to reduce emissions. Adopt farming practices, such as fallowing, or regularly shift the location of infrastructure within the broader farm area to reduce emissions. Improve the feed conversion ratio of aquatic food through genetics and innovating feed composition to reduce emissions. Commit to using feed from deforestation-free soy/crops or more sustainable sources of feed. Repurpose shell waste from bivalve aquaculture as construction aggregate or for mortar mixes, which can lead to long-term carbon storage while offsetting emissions from energy intensive, nonrenewable resources. Ensure that cold storage is efficient and does not leak refrigerant.	emissions reductions) resulting from the use of transportation, refrigeration, and other equipment.[209]
POST-HARVEST		
Energy used for transportation, storage, and processing	Shift to low- or zero-emission energy sources and biofuels to reduce emissions from both	The GHG Protocol's GHG Emissions Calculation Tool can be used to estimate possible

[207] Froehlich, H. E., et al. 2019. "Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting." *Current Biology* 29: 3087-3093. https://doi.org/10.1016/j.cub.2019.07.041.
[209] For more information on GHG Protocol's GHG Emissions Calculation Tool, see GHG Protocol's website, accessible at https://ghgprotocol.org/calculation-tools-and-guidance.

GHG EMISSIONS SOURCES	EMISSIONS MITIGATION OPTIONS	ESTIMATION TOOLS
Electricity used for infrastructure and maintenance Energy used for refrigeration and cooking Refrigerant leakage from cold storage Emissions from food loss and waste	transportation and infrastructure. Use efficient equipment and machinery to reduce energy usage for food processing. Ensure that cold storage is efficient and does not leak refrigerant.	significant emissions (and emissions reductions) resulting from the use of vehicles and other equipment.[210]

5.2 BUILDING RESILIENCE AND ADAPTING TO CLIMATE CHANGE

IPCC states that climate change is impacting food security globally, with the most prominent impacts on small-scale producers, including fisheries.[211] A global analysis of fishery revenues suggest that developing countries with high fishing dependency will be most negatively affected by the impacts of climate change.[212] Aquatic food makes critical contributions to food and nutrition security for low-income countries in particular, and is often a more sustainable and nutrient-rich source of animal-sourced food than terrestrial meat production.[213] Blasiak et al. (2017) assessed 147 countries on the vulnerability of their national economies to climate change impacts on fisheries using a vulnerability index and found that 87 percent of the least developed countries are within the top half of that index, attributing this to lower levels of adaptive capacity in these countries.[214] The impacts of climate change also may threaten the non-marine livelihood sources of households for whom fisheries or aquaculture are one part of a balanced livelihood portfolio. If another livelihood source declines (e.g., if an extreme drought causes a crop failure), this can place pressure on marine and freshwater resources.

Changes in climate are anticipated to increase inland wild-caught freshwater fisheries' vulnerability due to changes in water quality by decreasing dissolved oxygen, changing water chemistry, and potentially increasing heavy metal concentrations.[215] Increasing sea surface temperatures and sea level are expected to continue to affect fish stock and prey species composition, distribution, and populations. This will likely reduce fish yields, catch rates, and fish quality. More frequent and intense extreme rainfall events endanger those employed in wild-caught fishery and aquaculture activities and threaten coastal infrastructure. Such storms also can decrease fisheries' habitats and damage aquaculture operations, including through

[210] Ibid.
[211] Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, et al. 2019. *Changing Ocean, Marine Ecosystems, and Dependent Communities*. Cambridge, UK and New York, NY, USA: Cambridge University Press, 447–587. https://doi.org/10.1017/9781009157964.007.
[212] Lam, Vicky W. Y., William W. L. Cheung, Gabriel Reygondeau, and U. Rashid Sumaila. 2016. "Projected change in global fisheries revenues under climate change." *Scientific Reports*. https://doi.org/10.1038/srep32607.
[213] Tlusty et al. 2019. "Reframing the sustainable seafood narrative." *Global Environmental Change* 59. https://doi.org/10.1016/j.gloenvcha.2019.101991.
[214] Blasiak, R., J. Spijkers, K. Tokunaga, J. Pittman, N. Yagi, and H. Osterblom. 2017. "Climate Change and Marine Fisheries: Least Developed Countries Top Global Index of Vulnerability." *PLoS ONE* 12 (6). http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179632.
[215] Chen, Y., A.S. Todd, M.H. Murphy and G. Lomnicky. 2016. "Anticipated Water Quality Changes in Response to Climate Change and Potential Consequences for Inland Fisheries." *Fisheries* 41 (7): 413-416. doi:10.1080/03632415.2016.1182509. https://afspubs.onlinelibrary.wiley.com/doi/10.1080/03632415.2016.1182509.

increased surface runoff from nearby agrochemicals affecting water bodies that are essential for fisheries and aquaculture.

USAID requires consideration and management of the full range of climate risks to nearly all projects and activities as part of the CRM process. CRM offers a method through which project designers and implementers can screen activities for climate risks and develop responses to address those risks and build resilience. Automated Directives System (ADS) Reference 201mal can help guide project planners through the CRM process. As part of the CRM process, USAID requires the identification of climate-related risks during project or activity design, as well as the development of CRM options to help reduce the impact that climate change can have on wild-caught fishery and aquaculture activities. For a detailed description of how to assess and address climate-related risks, see the USAID Climate Risk Screening and Management Tools. This resource guides project developers in defining the scope of the project; assesses climate risks that could affect project activities; assesses adaptive capacity; assigns risk ratings for each climate risk; explores potential opportunities that could arise from addressing these risks; and describes management options that address the positive and negative aspects of the climate risks.

Managing climate risks and building resilience helps project planners increase the likelihood of long-term success of their projects and contributes to climate adaptation. Embedding climate resilience in design enables projects to minimize future loss and damage (and the associated costs) and resume operations swiftly following extreme climate events, resulting in a sounder investment.

One must exercise caution in considering CRM measures because they potentially could inadvertently result in increased vulnerability to climate impacts for certain individuals or communities, particularly marginalized and underrepresented groups and/or people in vulnerable situations. This is sometimes called maladaptation. For example, a waterway that is dammed to improve water resource access during drought conditions could disrupt fish migration and reduce their survival. Consideration of a range of possible scenarios and potential maladaptation risks is important to maximize the benefits of adaptation and resilience-building measures.

Equity is a critical element of climate-resilient activity design because activities that lack resilience or address risks without considering equity concerns can create or reinforce vulnerabilities for people. Activity planners must seek to both improve climate resilience and work with local communities and Indigenous Peoples to ensure that local knowledge and voices, including around potential climate risks and adaptation measures, are incorporated into design and implementation.

TABLE 3. CLIMATE STRESSORS AND IMPACTS ON FISHERIES AND AQUACULTURE

CLIMATE STRESSORS	DIRECT AND INDIRECT IMPACTS ON FISHERIES AND AQUACULTURE
Ocean acidification due to increased dissolution of carbon into seawater	● Crustaceans and mollusks may have more difficulty forming their exoskeletons (i.e., exterior shell), especially during juvenile life stages, which may cause the following impacts: ○ Increased mortality rates. ○ Reduced reproductive success of bivalves. ○ Acidic seawater impacts the ability of coral to deposit calcium carbonate and build its skeleton. In addition, it may affect the ability of coral to grow through increased reef erosion. ○ Reduced structural integrity of reefs.

CLIMATE STRESSORS	DIRECT AND INDIRECT IMPACTS ON FISHERIES AND AQUACULTURE
	○ Decreased ability to provide habitat for fisheries.
Increasing sea surface and pond temperature due to increased absorbed heat from air	● Fish stock and prey species composition, distribution, and population changes due to fish migration to colder or warmer water, which can cause the following impacts: ○ Decreased catch rates for targeted species in the original location. ○ A need to revise fishing regulations and management as fishers migrate with the fish. ○ Increased potential for interaction between targeted and bycatch species. ○ Changed location and period of spawning could affect fish stock growth and survival. ○ Decreased recruitment (i.e., transitioning between life stages) of fish species. ○ Additional challenges for fishery management related to transboundary stocks, decreased accuracy of scientific advice based on historical data, and decreased effectiveness of existing strategies. ● Changes in primary productivity can cause changes in fish yields. ● Environmental conditions may exceed species' biological requirements, resulting in decreased abundance. ● Increased incidence and spread of pathogens due to increased temperature and salinity, which may have the following impacts: ○ Decreased catch rates and fish quality. ○ Increased risk of fish loss in aquaculture operations due to decreased dissolved oxygen and increased disease risks. ○ Loss of coral reefs from bleaching. ○ Increased vulnerability to disease. ○ Reduced growth and reproduction. ○ Decreased biodiversity and habitats for fish.
Sea level rise and coastal erosion	● Coastal erosion can cause indirect impacts, such as the following: ○ Increased vulnerability of coastal infrastructure. ○ Inland migration of coastal fishery habitat. ○ Decreased coastal fishery habitat, such as mangrove forests and seagrass meadows. ○ Decreased carbon sequestration by wetlands, seagrasses, and mangroves, or alternately the release of emissions by affected areas. ● Saltwater intrusion into coastal aquifers can cause the following impacts: ○ Increased salinity, which may decrease aquaculture capabilities for freshwater operations. ○ Reduced freshwater supplies at fish landing and processing sites.
Changing frequency and intensity of storms	● Changing storm patterns can increase the vulnerability of social and natural systems, resulting in the following: ○ Increased risk for fishers at sea. ○ Increased risk of damage to aquaculture operations from more intense storms, including the potential for penned fish to escape. ○ Increased vulnerability of coastal infrastructure and the risk of damage.

CLIMATE STRESSORS	DIRECT AND INDIRECT IMPACTS ON FISHERIES AND AQUACULTURE
Changes in the patterns and seasonality of precipitation	● Seasonal water bodies could dry up and streamflow could be reduced, which can lead to the following: ○ Decreased habitat for fisheries. ○ Reduced availability of water bodies for seasonal aquaculture. ● Increased intensity and the amount of rainfall can cause the following: ○ Flooding. ○ Pulse inputs of freshwater into nearshore marine systems, which may negatively affect juveniles of targeted species. ○ Increased sedimentation.

Table 8 contains more specific information on the climate risks across fishery and aquaculture activities, as well as measures to manage these risks.

6. SOCIAL IMPACTS

The potential exists for adverse and unintended negative social impacts as a result of wild-caught fisheries and aquaculture projects. USAID is committed to integrating stakeholders' voices, concerns, perspectives, and values as a form of acquiring feedback and input on a proposed project to identify potential social impacts early on and make sound decisions during the design and planning phase. As indicated in the adjacent textbox, per ADS 201, USAID requires an initial screen of potential social impacts.

USAID's visions, policies, and strategies call for a participatory process that safeguards against doing harm to its beneficiaries. This process includes ensuring meaningful stakeholder engagement from government, communities, and individuals to assure that USAID's international development efforts benefit all members of society, particularly marginalized and underrepresented groups and/or people in vulnerable situations.

Social Impact Risk Initial Screening (SIRS) Tool

Per the June 2024 update to ADS Chapter 201 Program Cycle Operational Policy, USAID design teams must conduct an initial screening of the social impact of their Activities and Programs using the Social Impact Risk Initial Screening and Diagnostic Tools (ADS 201mbf).216 The Social Impact Risk Initial Screening (SIRS)217 Tool is intended to help USAID design teams plan for, mitigate, and monitor potential adverse social impacts from USAID Activities and Programs. The Tool consists of 10 questions designed to kickstart mandatory analytical thinking about a variety of different potential adverse social impacts and help identify when additional social safeguarding is needed. Additional social safeguarding may include redesigning Activity/Program components or concepts, identifying social impact mitigation measures, or conducting additional analyses, such as a Social Impact Assessment. When filling out the Tool, design teams should only check "no" when they are highly certain that there is no potential for an adverse impact. The complexity of the process for completing the Tool will vary based on the severity of social impacts posed by the Activity/Program.

Stakeholder engagement is critical for ensuring that USAID maintains accountability to program participants by ensuring the active participation of local communities, developing mitigation measures that include participants' voices, as well as ensuring that affected individuals and communities can communicate their concerns through USAID's Accountability Mechanism.[218] Given the importance of stakeholder engagement for fostering a successful project, the project may benefit from sustaining this engagement throughout the entire project life.

Just as environmental compliance measures under 22 Code of Federal Regulations (CFR) 216[219] seeks to avoid, minimize, and mitigate impacts, including in the case of wild-caught fisheries and aquaculture projects, social impacts should be assessed to determine whether there has been a change from baseline conditions for individuals and communities resulting from a USAID project. Furthermore, there may be pre-existing adverse conditions in a local community prior to a USAID-funded activity, which should be taken into consideration to maximize benefit sharing so that proposed USAID-funded activities minimize unintended social

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[216] USAID. 2024. A Mandatory Reference for ADS Chapter 201. https://www.usaid.gov/about-us/agency-policy/series-200/references-chapter/201mbf.

[217] ibid.

[218] The USAID Social, Economic, and Environmental Accountability Mechanism (SEE-AM) is expected to be formally launched in summer 2024. The SEE-AM offers communities and project participants to report adverse social, economic, or environmental impacts caused by USAID-funded activities. Complaints and questions can be submitted to disclosures@usaid.gov.

[219] USAID. 1980. Reg. 216 (22 CFR 216). https://www.usaid.gov/environmental-procedures/laws-regulations-policies/22-cfr-216.

consequences, such as impacts on a person's livelihood, economic activities, traditional vocations, land or property rights, access to natural resources, culture and customs, and health and well-being.

In the case of the fisheries sector, more than 3 billion people worldwide depend on fisheries for their food security and jobs. USAID invested more than USD 60 million in fiscal year 2021 to more than 20 countries to promote sustainable fisheries and conserve marine biodiversity.[220] The Agency's work to identify and counter illegal fishing focuses on strengthening resource governance and management and promoting aquatic food traceability.[221] As part of this important work, it is critical to assess the social impacts of fisheries or aquaculture projects. In addition, the sector relies on a value chain and, therefore, the impacts must be evaluated in this context while assessing direct and indirect impacts. NOAA's document entitled 'A Practitioner's Handbook for Fisheries Social Impact Assessment' provides additional details on conducting social impact assessments regarding fisheries.[222]

6.1 KEY SOCIAL IMPACTS

This section is organized according to the principles presented in USAID's Voluntary Social Impacts Principles Framework.[223] The Voluntary Social Impact Principles Framework encompasses nine principles for considering and assessing potential social risks and social impacts across USAID programs, projects, and activities. Table 4 summarizes the nine principles. For additional information on the nine Principles see the USAID Voluntary Social Impact Principles Framework. The subsequent sections present an illustrative list of potential social impacts pertaining to wild-caught fisheries and aquaculture projects that Missions and/or Implementing Partners (IPs) should consider.

TABLE 4: USAID SOCIAL IMPACT PRINCIPLES

PRINCIPLE		DESCRIPTION
1	Indigenous Peoples	Indigenous Peoples are a distinct cultural, linguistic, and social group with historical continuity, collective attachment to surrounding natural resources, and/or commitment to maintaining ancestral systems. Specific actions are required of USAID programs involving Indigenous Peoples.
2	Cultural Heritage	Cultural heritage is part of every culture and is found all over the world. It includes archaeological sites, historic buildings, artifacts, and natural environments inherited from past generations as well as intangible knowledge and practices. Working in areas with cultural heritage or on cultural heritage projects can have consequences beyond just destruction of an important resource and can also offer potential means of positively engaging with communities.
3	Land Tenure, Displacement, and Resettlement	Land tenure is associated with acquiring and managing rights to land. Land use change may lead to compulsory displacement and resettlement (CDR), and/or the loss of access and/or use of land and natural resources, which should be avoided and minimized to reduce social impacts on affected landholders, tenants, community members, and pastoralists, among other groups. Failure to account for, and respect, the land and resource rights of local community

[220] USAID. n.d.(a). Marine and Fisheries. https://biodiversitylinks.org/what-we-do/marine-and-fisheries.
[221] USAID. n.d.(b). Illegal, Unreported, and Unregulated Fishing. https://www.usaid.gov/biodiversity/illegal-unreported-and-unregulated-fishing.
[222] Clay, Patricia M., and Lisa L. Colburn. 2020. A Practitioner's Handbook for Fisheries Social Impact Assessment. NOAA Tech. https://spo.nmfs.noaa.gov/sites/default/files/TM212_0.pdf.
[223] USAID. 2024. "Voluntary Social Impact Principles Framework." https://www.usaid.gov/environmental-procedures/environmental-compliance-esdm-program-cycle/social-impact-assessment.

PRINCIPLE		DESCRIPTION
		members can cause costly delays, work stoppages, protests, and, in some cases, violence. USAID may face legal actions and suffer financial, brand, or reputational harm.
4	Health, Well-being, and Safety	Health, Well-being, and Safety is safeguarding against potential physical, psycho-social, and health impacts among project staff, program participants, and communities where AID actions are implemented. Individual USAID actions must account for potential occupational health and safety risks, as well as potential uneven socio-economic gains across affected communities/program participants, to avoid unintended consequences.
5	Working with Security Personnel	Cognizance of the unique challenges involved in engaging security personnel, working with security personnel prioritizes a rights-based approach to ensure respect for, and safety of, individuals and local communities. Without transparent and accountable oversight of rule of law, the risks of potential human rights violations increase.
6	Conflict Dynamics	Attentiveness to the operational context in relation to past and present conflicts as well as sensitivity around the role that a USAID action has in shaping the conflict landscape. Poor understanding of conflict dynamics increases the possibility of contributing to or exacerbating conflict.
7	Inclusive Development	Inclusive development is an equitable development approach built on the understanding that every individual and community, of all diverse identities and experiences, is instrumental in the transformation of their own societies, which means providing them with the opportunity to be included, express their voices, and exercise their rights in activities and public decisions that impact their lives. Inclusion is key to aid effectiveness. Nondiscrimination is the basic foundation of USAID's inclusive development approach.
8	Environmental Justice	Environmental Justice (EJ) is the fair treatment and meaningful engagement throughout the project life cycle of marginalized and underrepresented groups and/or people in vulnerable situations, with respect to environmental and/or health impacts and implementation and enforcement of environmental laws. It includes the protection of marginalized and underrepresented groups that may face enhanced vulnerability due to environmental harms caused by any action or activity. Marginalized and underrepresented groups and/or people in vulnerable situations may include (but are not limited to): Indigenous Peoples, LGBTQI+ persons, persons with disabilities, children and other youth, older persons, women, low-income populations, and all disadvantaged and marginalized communities across race, color, gender, or national origin.
9	Labor	The Labor principle focuses on advancing worker empowerment, rights, and labor standards through programming, policies, and partnerships to advance sustainable development outcomes. USAID recognizes the high risk of labor abuses that may result from programming, and, thus, USAID works to establish and strengthen labor protections (including social protections) that align with internationally recognized worker rights. This principle includes the promotion of safe and healthy work environments; respecting the principles of freedom of association and collective bargaining; the elimination of forced labor and the worst forms of child labor; and the protection from discrimination at work.

6.1.1 LAND TENURE, DISPLACEMENT, AND RESETTLEMENT

The value chain that is involved in the processing and distribution of fishing resources may cause land use change, which, in turn, may have imminent changes or impacts on land tenure. While fishery and aquaculture projects will not likely need large portions of land to undertake a project unless, for example, land clearance is needed for the establishment of aquaculture ponds, it is important to be cognizant of the social implications that may come about due to land use change. This may have serious repercussions regarding land use access; access to resources; implications for land tenure and resource claims, including access to fisheries and resource rights, due to the siting or placement of a project; and other attributes that will come to light at the project level.[224, 225] Therefore, these important aspects (land tenure and/or resource claims, including access to fisheries) should be assessed early on during the design phase when a project is being proposed.

Land tenure is the relationship that individuals and groups of people have with regard to land, access to land, and related resources (e.g., access to fisheries) and is associated with acquiring and managing the rights to land. Land tenure rules define the ways in which property rights to land are allocated, transferred, used, or managed in a particular society. Land tenure issues can be complicated in areas that may not have a formal system of land ownership or of documentation of land ownership. For example, traditional rights to use land for hunting and/or gathering may be allocated at the local level without a legal registration system. These alternate forms of land tenure and land use must be considered when assessing impacts, designing mitigation measures, and determining compensation. Failure to account for the land and resource rights of local people can cause costly delays, work stoppages, protests, and, in some cases, violent conflict.

Furthermore, in the context of wild-caught fisheries and aquaculture projects, tenure rights for marine and/or freshwater systems also will have to be carefully evaluated for social impacts, including the implications for marine tenure.226

Loss of access to land and/or resources (such as fisheries) or impacts on land and/or marine tenure may lead to economic displacement. For example, an individual may lose access to freshwater or marine ecosystems that provide them with the resources that are essential to their economic or subsistence survival. Consequently, this may lead to the disruption of local or traditional livelihoods, which is discussed in the Other Social Considerations section.

6.1.2 HEALTH, WELL-BEING AND SAFETY

Specific choices around project design and implementation invariably have the potential to influence health, well-being, and safety. Assessing and managing the potential social impacts related to health, well-being, and safety requires a careful and sustained effort. Wild-caught fisheries and aquaculture projects may lead to unintended social impacts. For example, the introduction of a particular species may pose a health risk to a nearby local community or in an aquaculture project there may be the accumulation of stagnant water in which mosquitoes may propagate and contribute to an increase in vector-borne diseases, such as dengue and malaria, which may have negative community health impacts. Furthermore, road construction that may be an ancillary project as part of the supply chain to take fish resources to market or to a port for exportation may lead to unintended impacts to the local community's health, well-being, and safety due to changes to local road traffic patterns causing an increase in pedestrian-related accidents and noise pollution, and therefore should be planned for ahead of time. Public safety

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[224] Zhang, W., Belton, B., Edwards, P., Henriksson, P.J.G., Little, D.C., Newton, R. & Troell, M. 2022. Aquaculture will continue to depend more on land than sea. Nature, 603: E2–E4. Cited 25 March 2022. https://www.nature.com/articles/s41586-021- 04331-3.
[225] FAO. 2022. The State of World Fisheries and Aquaculture 2022. Rome: Towards Blue Transformation. https://doi.org/10.4060/cc0461en.
[226] For additional information on marine tenure and coastal resource management, see Landlinks' "Marine Tenure and Coastal Resource Management" webpage, accessible at https://www.land-links.org/issue/marine-tenure/#:~:text=Marine%20tenure%20involves%20establishing%20a,any)%20to%20others%20and%20how.

risks also may arise, depending on the wild-caught fishery and aquaculture projects being proposed, which should be taken into consideration. For example, if women from a local community depend on a certain water resource for sustenance yet will have to travel a greater distance, possibly to a remote and unfamiliar location, because access may have been impeded due to an aquaculture project, this may lead to an increase in gender-based violence.

Meaningful stakeholder engagement entails:

- People from diverse social groups are provided with an opportunity to participate in decisions about activities that may affect their environment, livelihoods, well-being, and/or health;
- The public's contribution can influence the agency's decision;
- Community views, perspectives, and concerns will be considered in the decision-making process; and
- Decision makers will seek out and facilitate the stakeholder engagement process with potentially affected people[227]

6.1.3 CONFLICT DYNAMICS

USAID's projects are often implemented in fragile or conflict-affected environments. USAID's work encompasses investments in conflict prevention and mitigation, stabilization, and peace building, parallel to investments in other sectors. Understanding conflict dynamics and how a project in the wild-caught fisheries and aquaculture sectors, affects or is being affected by these dynamics is an essential component of being conflict aware and conflict sensitive.[228] For example, local communities may have a heightened awareness of the distribution of resources, as well as the roles and responsibilities of the people involved in the distribution of those resources, and proposed wild-caught fishery and aquaculture projects may exacerbate the underlying conflict dynamics. Historical grievances may become known due to the proposal of wild-caught fishery and aquaculture projects that benefit one group of people over another, which may exacerbate local tensions that spur other impacts, such as violent conflict. In addition, fisheries (and other natural resources) can create conflict as different users compete for rights to access. Moreover, boats on the high seas have few mechanisms for grievance redress if another actor uses violence against them in the pursuit of fish. Implementers should consider the extent to which fisheries' resources are a driver of conflict and plan accordingly. Therefore, conflict dynamics at the site level should be understood during the planning and design phase by means of engaging stakeholders in a participatory approach and assessing the conflict dynamics. Additional resources and guidance on conflict dynamics may be found in footnote 229.

6.1.4 LABOR

Specific choices around project design and implementation invariably have the potential to influence labor.[230] Assessing and managing potential social impacts related to labor practices

[227] USAID. 2024. "Voluntary Social Impact Principles Framework." https://www.usaid.gov/environmental-procedures/environmental-compliance-esdm-program-cycle/social-impact-assessment.
[228] Ibid.
[229] USAID. n.d. Technical Publications on Conflict Management and Mitigation. https://www.usaid.gov/conflict-violence-prevention/technical-publications; USAID. 2024. "Voluntary Social Impact Principles Framework." https://www.usaid.gov/environmental-procedures/environmental-compliance-esdm-program-cycle/social-impact-assessment.
[230] IFC Performance Standard 2 recognizes that "the pursuit of economic growth through employment creation and income generation should be accompanied by the protection of the fundamental rights of workers and must respect several International Labor Organization (ILO) Conventions, including ILO Convention 87 on Freedom of Association and Protection of the Right to Organize; ILO Convention 98 on the Right to Organize and Collective Bargaining; ILO Convention 29 on Forced Labor; ILO Convention 105 on the Abolition of Forced Labor; ILO Convention 138 on

and working conditions is a multilayered process that necessitates a careful and sustained effort. USAID staff and Implementing Partners should consider labor practices and working conditions in individual projects to avoid, minimize, and/or mitigate potential impacts. See footnote [231] for additional resources.

Working in the Fisheries sector may pose an array of risks to workers. Please follow guidance from the document entitled "Convention 188: Work in Fishing Convention".[232] Furthermore, USAID does not support fishery improvements or aquaculture projects that utilize or benefit from the worst forms of child labor, forced labor[233], and/or human trafficking g.[234] Where these practices do occur, projects should consider the addition of components that identify and counter the worst forms of child labor and human trafficking in the harvesting, processing, and other aspects of the supply chain[235]. USAID guidance on child labor,[236] forced labor, and human trafficking, and all projects in this sector should be assessed for these human rights violations[237],[238]. For example, with regards to the worst forms of child labor, projects can include traceability schemes, which help buyers avoid purchasing from supply chains known to engage in these practices and promote corporate social responsibility audits by large-scale buyers. In other instances, projects could involve community-based behavior change communication interventions to make the practices of the worst forms of child labor socially unacceptable.

6.2 OTHER SOCIAL CONSIDERATIONS

6.2.1 THE ROLE OF STAKEHOLDER ENGAGEMENT

Stakeholder engagement provides a systematic approach to Missions and Implementing Partners to acquire stakeholders' input, information, feedback, local and traditional knowledge, local perspectives, and concerns early on, during the design and planning phase, well before the assessment of the social impacts phase, as well as should be sustained throughout the

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Minimum Age (of Employment); ILO Convention 182 on the Worst Forms of Child Labor; ILO Convention 100 on Equal Remuneration; ILO Convention 111 on Discrimination (Employment and Occupation); UN Convention on the Rights of the Child, Article 32.1; and the UN Convention on the Protection of the Rights of All Migrant Workers and Members of Their Families" United Nations. 1990. "Chapter IV. Human Rights." https://treaties.un.org/doc/Treaties/1990/12/19901218%2008-12%20AM/Ch_IV_13p.pdf.

[231] External resources pertaining to labor practices and working conditions are accessible at the following: https://documents1.worldbank.org/curated/en/149761530216793411/pdf/ESF-Guidance-Note-2-Labor-and-Working-Conditions-English.pdf; https://www.ifc.org/content/dam/ifc/doc/2010/2012-ifc-performance-standard-4-en.pdf; https://www.ilo.org/global/standards/introduction-to-international-labour-standards/lang--en/index.htm.

[232] ILO. 2007. "Convention 188: Work in Fishing Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C188.

[233] Responsible Sourcing Tool. n.d. "Is Forced Labor Hidden in Your Global Supply Chain." https://www.responsiblesourcingtool.org/.

[234] USAID. n.d. Counter Trafficking in Persons https://www.usaid.gov/trafficking

[235] Responsible Sourcing Tool. n.d. "Is Forced Labor Hidden in Your Global Supply Chain." https://www.responsiblesourcingtool.org/.

[236] USAID. n.d. USAID's Guidance on Child Safeguarding for Implementing Partners https://www.usaid.gov/PreventingSexualMisconduct/Partners/Child-Safeguarding/FAQ#r57lup3rgd18; UN Global Compact. n.d. The Ten Principles of the UN Global Compact. https://www.unglobalcompact.org/what-is-gc/mission/principles/principle-5.

[237] U.S. Department of Labor. 2022. "Findings on the Worst Forms of Child Labor." https://www.dol.gov/agencies/ilab/resources/reports/child-labor/findings.
U.S. Department of Labor. 2022. "List of Good Produced By Child Labor or Forced Labor." https://www.dol.gov/sites/dolgov/files/ilab/child_labor_reports/tda2021/2022-tvpra-list-of-goods-v3.pdf.

[238] U.S. State Department. 2024. "Trafficking in Persons Report." https://www.state.gov/trafficking-in-persons-report/.

entire project life cycle.[239] Stakeholders may be groups or individuals from the private or public sector, as well as individuals who may be considered an affected party along with those who may have interests in a project or the ability to influence its outcome, either positively or negatively. Members of civil society organizations may also be considered such as women's groups, local fishers' groups, and small-scale subsistence fishing cooperatives. Special attention should be paid to marginalized and underrepresented groups and/or people in vulnerable situations because they may be inequitably affected by a project.

Stakeholder mapping, engagement, and consultation are key steps in the planning process of wild-caught fisheries and aquaculture projects and will also be crucial in identifying opportunities for the inclusion of marginalized and underrepresented groups and/or people in vulnerable situations.[240] Stakeholder engagement should be a broad, inclusive, and continuous process. The benefit of beginning the stakeholder engagement process early on and sustaining it throughout the entire project life cycle is that it may allow for the co-creation[241] of positive benefits, for example identifying mitigation measures regarding the social impacts based on traditional knowledge from local community members, through adaptive management. Information on best practices for stakeholder engagement is available in the USAID document entitled Environmental Compliance Factsheet: Stakeholder Engagement in the Environmental and Social Impact Assessment (ESIA) Process.[242]

6.2.2 THE LOCAL COMMUNITY

When planning and designing wild-caught fisheries and aquaculture projects, the local community in which the project will be embedded should be assessed. This assessment may be addressed prior to assessing potential social impacts by means of undertaking a desktop review of the characteristics of the community, such as demographics; socioeconomic composition; and political, institutional, and legal frameworks, as well as through field visits and stakeholder engagement. Although the particulars of identifying social impacts for wild caught fisheries and aquaculture projects depend on the site location, and local context, undertaking stakeholder engagement early on is necessary to improve the understanding of how the proposed project may affect the local community. If stakeholders in a local community voice concerns regarding potential negative social impacts due to a proposed project, the social impacts may be assessed, and mitigation and monitoring measures designed. Management measures should be commensurate with the degree of the identified adverse social impacts. In cases where social impacts from project activities are deemed to adversely affect the lands, rights, and livelihoods of individuals and communities, implementation of the project should be reconsidered (i.e., potentially ended). If/when the project is under implementation, the local community is adversely impacted, implementation of the project may need to be curtailed until

[239] USAID. 2022. "Community Engagement Guide." https://www.climatelinks.org/sites/default/files/asset/document/2022-04/5a.%201_Community%20Engagement%20Reference%20Guide_30Mar22_508.pdf.

[240] USAID. 2016. "Environmental Compliance Factsheet: Stakeholder Engagement in the Environmental and Social Impact Assessment (ESIA) Process." https://www.usaid.gov/sites/default/files/2022-05/Stakeholder_Engagement_052016.pdf.

[241] USAID defines co-creation as a process that "brings people together to collectively design solutions to specific development challenges. Time limited and participatory, partners, potential implementers, and end-users define a problem collaboratively, identify new and existing solutions, build consensus around action, and refine plans to move forward with program and projects." For additional information see https://www.usaid.gov/co-creation-usaid.

[242] USAID. 2016. "Environmental Compliance Factsheet: Stakeholder Engagement in the Environmental and Social Impact Assessment (ESIA) Process." https://www.usaid.gov/sites/default/files/2022-05/Stakeholder_Engagement_052016.pdf.

adequate management measures have been designed and implemented to mitigate the identified impacts.

6.2.3 GENDER EQUALITY

Many social impacts are gender differentiated and can affect men and women in different ways. USAID seeks to support gender equality with the following goals: (1) improve the lives of people by advancing gender equality; (2) empower women and girls to participate fully in, and equally benefit from, the development of their societies on the same basis as men; and (3) secure equal economic, social, cultural, civil, and political rights regardless of gender. USAID policy requires that a Gender Analysis "be integrated in strategic planning, project design and approval, procurement processes, and measurement and evaluation" as part of ADS 205: Integrating Gender Equality and Women's Empowerment in USAID's Program Cycle, which seeks to integrate gender and equality into the program cycle.[243]

Special attention must be paid to how wild-caught fisheries and aquaculture projects may affect women and girls. Gender Analysis[244] "is a systematic analytical process used to identify, understand, and describe gender differences and the relevance of gender roles and power dynamics in a specific context." Such analysis[245] typically involves examining the differential impact of development policies and programs on women and men and may include the collection of sex-disaggregated or gender-sensitive data. Gender Analysis examines the "different roles, rights, and opportunities of men and women and relations between them. It also identifies disparities, examines why such disparities exist, determines whether they are a potential impediment to achieving results, and looks at how they can be addressed."[246] Furthermore, there may be gender divisions in the decision-making process that may influence how the placement of the project may be proposed.

Disparate gender impacts on wild-caught fisheries and aquaculture projects may involve imbalances in stakeholder input, decision making, employment opportunities, and monetary compensation for project impacts. A Gender Analysis helps to identify gender disparities in the community early on. Because USAID projects require stakeholder engagement and consultation as part of the process of identifying, avoiding, and mitigating adverse social impacts, it is increasingly important to be aware of gender-based barriers to public participation. In these cases, stakeholder engagement and consultations may need to occur in a gender sensitive manner, for instance by having separate venues for men and women. To acquire input and feedback from women, a combination of methods may be undertaken (such as interviews and focus groups). For, instance semi-structured interviews or women-only focus groups may be conducted with women in a safe space such as an individuals' home or place of worship. Providing a space in which to obtain women's perspectives may shed light on a potential gender division in decision making and consultation, and in turn could impact siting and benefit sharing.

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[243] USAID. 2023. "ADS Chapter 205: Integrating Gender Equality and Women's Empowerment in USAID's Program Cycle." https://www.usaid.gov/about-us/agency-policy/series-200/205#:~:text=USAID%20has%20adopted%20several%20comprehensive,fully%20exercise%20their%20rights%2C%20determine.

[244] USAID. 2023. "2023 Gender Equality and Women's Empowerment Policy." https://www.usaid.gov/document/2023-gender-equality-and-womens-empowerment-policy.

[245] USAID. 2011. "Tips for Conducting a Gender Analysis at the Activity or Project Level." https://pdf.usaid.gov/pdf_docs/PDACX964.pdf.

[246] USAID. 2023. "2023 Gender Equality and Women's Empowerment Policy." https://www.usaid.gov/document/2023-gender-equality-and-womens-empowerment-policy.

6.2.4 DISRUPTION OF LOCAL OR TRADITIONAL LIVELIHOODS

The siting and placement of a proposed project may affect local or traditional livelihoods. Even though a project may be on a small scale, it may entail land use change to some degree, which may affect local community members. For example, a moratorium period[247] may be introduced as part of a project in order to allow declining fish stocks to replenish over time; however, this may lead to direct negative socioeconomic impacts on the local community, such as the loss of jobs, because the local fishers rely on fishing as their primary or sole economic activity and it may be their only source of income. A moratorium would be considered a direct negative economic impact. Furthermore, a moratorium may **lead to indirect social impacts as well because people may be forced to look for work in illicit sectors, such as prostitution or organized crime.**

The nature and range of social impacts may not be immediately apparent during the planning phase for wild-caught fisheries and aquaculture projects; hence, the need to start engaging stakeholders as early as possible in the project life cycle (i.e., at the program design stage and throughout project implementation). Particular attention should be paid to marginalized and underrepresented groups and/or people in vulnerable situations in order to not put them in a position of increased socioeconomic vulnerability. The potential for adverse impacts on community members' livelihoods needs to be addressed at the local level and often on an individual basis.

A Livelihood Action Plan that entails a "Sustainable Livelihoods Approach" may be useful when completing a Social Impact Assessment for a project that may affect the economic conditions of rural communities that are particularly disadvantaged and poor. A Livelihoods Restoration Strategy may also be necessary where comparable economic opportunities are not readily available to the affected populations.[248]

In Tables 5 and 6 below, potential social impacts, mitigation, and monitoring measures for wild-caught fisheries and aquaculture projects are presented. The tables are for illustrative purposes only and do not provide an exhaustive list.

TABLE 5. POTENTIAL SOCIAL IMPACTS REGARDING WILD-CAUGHT FISHERIES PROJECTS

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING MEASURES
Labor: Worst forms of Child Labor **Causes:** Poverty-stricken communities where children are forced to work, either in family-run operations or otherwise, which compromises their ability to attend school or enjoy their childhood to its fullest potential.	• Set up a stakeholder engagement plan (SEP) and undertake stakeholder engagement. • Follow guidance as per International Labor Organization (ILO) conventions. See Footnote[249]	• Periodically review and update the SEP according to stakeholder feedback and input. • Record the number of community meetings and the number of participants at each meeting that has been held to keep awareness-building

[247] A moratorium period is the temporary suspension of an activity that takes place within a specific time frame.
[248] Asian Development Bank. 2017. "Proposition 5: The Sustainable Livelihoods Approach." https://link.springer.com/content/pdf/10.1007/978-981-10-0983-9_5.pdf?pdf=inline%20link.
[249] ILO. 2007. "Convention 188: Work in Fishing Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C188.
ILO. 2011. "Convention 189: Domestic Workers Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C189.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING MEASURES
● A source of cheap (and exploitable) labor ● Cultural traditions and customs ● Lack of legislation, enforcement, and oversight ● Lack of education or awareness **Impact:** Worst forms of child labor puts minors in very dangerous positions, such as diving for tangled fishing nets, and causes a loss of educational opportunities and deprives children of their childhood, which may have lasting negative effects on the child's mental, physical, and emotional well-being. Children also are at greater risk for health impacts, as well as the potential for sexual harassment or exploitation.	● Hold community meetings, workshops, and focus groups that are culturally appropriate to build awareness about child labor. ● Refer to guidance documents, such as USAID's Guidance on Child Safeguarding for Implementing Partners, Basic Page.[250] ● Develop partnerships with local schools in order to define strategies to incentivize high rates of attendance for children. ● Community "watch dog" groups may be set up to ensure that an activity is not engaging in child labor. ● Set up a Grievance Redress Mechanism (GRM).	efforts sustained throughout the project life cycle. ● Review the Grievance Redress Mechanism on a regular basis and ensure that the complaints have been addressed in a timely manner. ● Projects can include traceability schemes, which help buyers avoid purchasing from supply chains known to engage in child labor practices, and support projects that promote corporate social responsibility audits by large-scale buyers. ● Projects also can involve community-based behavior change communication interventions to make the child labor practices socially unacceptable.
Disruption to Local or Traditional Livelihoods **Impact:** Increased incidence of poverty and food insecurity among poor and vulnerable households due to a fishing moratorium that may have been introduced because of a proposed project to replenish declining fish stocks. This may lead to a loss of jobs, food insecurity for groups, and social issues, especially for those who depend on wild-caught fisheries.	● Establish a Stakeholder Engagement Plan (SEP). ● Avoid the impact, if possible, through design approaches that may, for example, instead of banning the fishing activity completely, control it to minimize the effects on dwindling fish stocks. ● Support the establishment of a community council to ensure that a greater voice is given to a diverse range of stakeholders in the design and implementation of the project. ● Grant secure access to fishing grounds and resources, such as tenure and exclusive use zoning, to a number of small-scale fishers. ● Develop interdisciplinary partnerships that include fisheries, aquaculture, ecosystem managers,	● Review the SEP periodically with stakeholder feedback and input. ● Obtain stakeholder's feedback on mitigation measures through conducting fisherfolk village meetings and community surveys. ● To help diversify the local economy, record the number of community members who are receiving vocational training in other sectors. ● Review the Grievance Redress Mechanism on a periodic basis and ensure that complaints have been addressed.

[250] USAID. n.d. "USAID's Guidance on Child Safeguarding for Implementing Partners." https://www.usaid.gov/safeguarding-and-compliance/partners/child-safeguarding/FAQs#:~:text=USAID%20requirements%20on%20child%20safeguarding,to%20whom%20to%20report%20under.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING MEASURES
	nutritionists, economists, and policymakers to address nutrition and food insecurity. ● Establish partnerships with local educational institutions that may offer vocational training in order to develop alternative livelihoods. ● Establish a Grievance Redress Mechanism.	
Gender Equality Women may not be involved at all points of the value chain in wild-caught fishery projects. A large percentage of women are "engaged in the informal, lowest paid, least stable, and least skilled segments of the workforce."[251] Women may have to travel farther and to unfamiliar locations to retrieve fisheries' resources, increasing their risk of gender-based violence. Women who may have been disproportionately affected due to this proposed activity may turn to other types of work out of need, such as sex work.	● Establish a Stakeholder Engagement Plan (SEP). ● Understand gender-based barriers to public participation. ● Conduct semi-structured interviews with women in a safe space, such as the individual's home or place of worship, for example, or by conducting a women-only focus group. ● Mainstream gender throughout the fisheries value chain. ● Undertake a Gender Analysis and follow the guidance per the Gender Equality and Women's Empowerment Policy.[252]	● Conduct monthly reviews to monitor gender equality in fisheries. ● Continue stakeholder engagement on an ongoing basis. ● Facilitate discussions with workers to determine whether everyone is given an opportunity to consider roles in which they are interested. ● Report on the women-led community protection groups on a periodic basis to ensure that women have access to natural resources in a manner that does not pose a safety risk. ● Review and address any grievances and complaints in a timely manner. ● Follow guidance as set out in the Foundational Elements for GBV Programming in Development [253] for additional information on gender-based violence (GBV).
Conflict Dynamics "Elite capture" of fishery benefits, which may lead to conflicts from the disproportionate capture of fishery benefits.	● Establish a Stakeholder Engagement Plan (SEP) to acquire information at the local level on the possibility of elite capture of fishery benefits and	● Review and update the SEP periodically. ● Conduct ongoing site visits to the fishing communities and sustain stakeholder

[251] FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en.
[252] For more information on gender programming, see the *Gender Equality and Women's Empowerment Policy*, accessible at https://www.usaid.gov/document/2023-gender-equality-and-womens-empowerment-policy. For more information, see Tips for Conducting a Gender Analysis at the Activity or Project Level, accessible at https://pdf.usaid.gov/pdf_docs/PDACX964.PDF.
[253] For more information on GBV, see the *Foundational Elements for GBV Programming in Development,* accessible at https://www.usaid.gov/foundational-elements.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING MEASURES
	undertake stakeholder engagement. ● Engage in participatory planning approaches, including conducting site visits, public community meetings, semi-structured interviews with stakeholders, and focus groups. Facilitate “Fisher to Fisher” dialogues at the local level, which is a type of ongoing stakeholder engagement that will help ascertain that benefits are equally distributed in the community. ● Provide access to best practices in extension services ● Develop governance capacity to reduce elite capture. See footnote [254].	engagement throughout the project life cycle. ● Keep a record of the facilitated “Fisher to Fisher” dialogues to continue monitoring that benefits are being equitably distributed.
Labor Fishers may be forced to work under intense, hazardous, and difficult working conditions.	● Establish a Stakeholder Engagement Plan (SEP). ● Follow guidance as per International Labor Organization (ILO) conventions. See Footnote[255] ● Address occupational safety during the pre-implementation Environmental and Social Impact Assessment (ESIA) Process (e.g., USAID IEEs and EAs). The process should specifically address labor safety and the health risks presented by activities at wild-caught fisheries. ● Ensure that beneficiaries have proper Personal Protective Equipment (PPE) ● Engage the private sector in developing incentives to improve labor conditions.	● Continue to sustain stakeholder engagement on an ongoing basis and integrate stakeholder feedback and input. ● Institute procedures for documenting and reporting unsafe working conditions. ● Keep a record of all trainings on labor safety. ● Keep records on accidents ● Keep records on PPE.

[254] USAID. 2023. “Feed the Future and Conflict Integration: A Toolkit for Programming.” https://www.resiliencelinks.org/system/files/documents/2023-05/USAID_Feed%20the%20Future%20and%20Conflict%20Integration%20Toolkit_Final_508_May2023%20%281%29.pdf.

[255] ILO. 2007. "Convention 188: Work in Fishing Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C188.
ILO. 2011. "Convention 189: Domestic Workers Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C189.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING MEASURES
	● Institute a “Zero Accidents” code of conduct. ● National and local governments should enforce labor regulations for the wild-caught fisheries sector. ● Provide access to extension services for fishers. ● Conduct SEPs to understand the types of working conditions for fishers. ● Develop local fishery management and representatives to support and enforce safe working conditions among fishers. ● Conduct safety trainings.	

TABLE 6. POTENTIAL SOCIAL IMPACTS REGARDING AQUACULTURE PROJECTS

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING CONSIDERATIONS
Labor There may be safety and health risks for fish processors who smoke dry fish. They can experience exposure to carbon monoxide, particulate matter, and carcinogens from the smoke.[256, 257] Health impacts include headaches, respiratory distress, and burns. Fish processing may generate odor pollution that can affect workers and the local community. There may be poor labor conditions.	● Establish a Stakeholder Engagement Plan (SEP). ● Follow guidance as per International Labor Organization (ILO) conventions. See Footnote[258] ● Address occupational safety during the pre-implementation Environmental and Social Impact Assessment (ESIA) Process (e.g., USAID IEEs and EAs). The process should specifically address labor safety and the health risks presented by aquaculture activities, particularly the smoking of fish. ● Create an Emergency Preparedness Plan for the fish	● Review the SEP periodically. ● Conduct stakeholder engagement on a continuous basis. ● Institute procedures for documenting and reporting on health and safety labor practices and working conditions. ● Keep a record of all trainings on labor safety. ● Keep a record of all trainings on emissions exposure and burn prevention and treatment. ● Appoint safety representatives or form health and safety committees.

[256] Weyant, Cheryl L., Antwi-Boasiako Amoah, Ashley Bittner, Joe Pedit, Samuel Nii Ardey Codjoe, and Pamela Jagger. 2022. "Occupational Exposure and Health in the Informal Sector: Fish Smoking in Coastal Ghana." *Environmental Health Perspectives* 130 (1). https://ehp.niehs.nih.gov/doi/10.1289/EHP9873.
[257] Tongo, I., O. Ogbeide, and L. Ezemonye. (2017). Human health risk assessment of polycyclic aromatic hydrocarbons (PAHs) in smoked fish species from markets in Southern Nigeria. *Toxicology Reports* 4:55-61. https://www.sciencedirect.com/science/article/pii/S221475001630110X.
[258] ILO. 2007. "Convention 188: Work in Fishing Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C188.
ILO. 2011. "Convention 189: Domestic Workers Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C189.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING CONSIDERATIONS
	smoking plant and train workers to adhere to the plan. ● Choose technologies that minimize smoke-related safety and health risks. ● Conduct safety trainings for workers on how to safely smoke fish. ● Institute a “Zero Accidents” code of conduct and train workers to achieve this goal. ● Establish first aid procedures for accidents and train workers on how to perform them. ● Workers should smoke fish in well-ventilated spaces. ● Establish a testing procedure to regularly monitor emissions from fish smoking and keep a record of the results.	● Keep records on all accidents and always strive for a “Zero Accidents” environment.
Health, Well-Being, and Safety Aquaculture projects may create a breeding habitat for mosquitoes and other disease vectors from standing water. This may cause an increase in cases of malaria and other vector-borne diseases in local communities.	● Establish a Stakeholder Engagement Plan (SEP) early on during the project and conduct stakeholder engagement. ● Educate community members and aquaculture project workers on vector-borne diseases from stagnant water. ● Conduct awareness-building and educational workshops that communicate the risks from vector-borne diseases, such as malaria. ● Build the capacity for community health services and health education. ● Promote better aquaculture practices. ● Train workers on methods to prevent stagnant water.	● Review and update the SEP on a periodic basis. ● Monitor areas that are prone to stagnant water regularly. This may be based on community monitoring practices where community members monitor and regularly update the data. This practice also will add value to the sustainability of the project in the long run. ● Institute procedures for documenting and reporting cases of vector-borne diseases, such as malaria or dengue fever. ● Appoint safety representatives or form health and safety committees.
Gender Equality Women may not be fully participating in the value chain and/or in key aspects of sustainable fishery management and extension, which can result in poor processing practices and weaker fishery management	● Establish a Stakeholder Engagement Plan (SEP). ● Undertake a Gender Analysis and follow the guidance per the Gender Equality and	● Review and update the SEP periodically. ● Conduct monthly reviews to monitor gender equality in the workplace. ● Facilitate focus groups with women workers to determine whether everyone is given an equal opportunity regarding

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING CONSIDERATIONS
having an impact on the local community. There may be a lack of natural resources, such as wood, due to wood procurement for fish smoking. With the lack of resources nearby, women may find themselves traveling farther/to unfamiliar areas to have access to those natural resources. This may increase the risk of gender-based violence.	Women's Empowerment Policy.[259] ● Strengthen the role of women in the fisheries value chain through management training and support the creation of women-led fish processing associations. ● Solicit female workers' input to fully understand the range of their skills and assess where capacity building and training should be focused in order to increase their participation in the labor force. ● Ensure that there are safe spaces for workers to discuss what tasks they are comfortable performing and what tasks they are not comfortable performing. ● Offer roles to all potential workers in a gender-equal manner. ● Regarding the lack of natural resources, which may become burdensome to women and may increase gender-based violence, co-create a community map that allows women stakeholders to participate in the identification of geographical areas in which the natural resources that they depend on for sustenance are located and avoid the areas on which they depend. ● Establish women-led community protection groups to ensure that individuals feel safe traveling to areas on which they depend. ● Establish a Grievance Redress Mechanism.	the various roles in the workplace. ● Regarding the natural resources example, reporting on the women-led community protection groups should be undertaken on a periodic basis to ensure that women have access to natural resources in a manner that does not pose a safety risk. ● Review the Grievance Redress Mechanism and address grievances and complaints in a timely manner.
Land Use Change and Tenure Rights	● Consider alternatives during the design phase, which include stakeholders'	● Keep a log on all potential land use changes.

[259] USAID. 2023. "2023 Gender Equality and Women's Empowerment Policy." https://www.usaid.gov/document/2023-gender-equality-and-womens-empowerment-policy.

SOCIAL IMPACT	MITIGATION MEASURES	MONITORING CONSIDERATIONS
The land use changes required for the establishment of large ponds for aquaculture may have implications for land tenure, as well as resource rights and claims.	perspectives and views, to avoid impacts on marginalized and underrepresented groups and/or people in vulnerable situations. ● Establish a Stakeholder Engagement Plan (SEP). Speak with stakeholders who may be negatively affected by the project and seek compensation strategies at the household level. ● Create a log on the tenure rights of project-affected people and seek guidance from footnote [260].	● Keep a log on tenure rights of project-affected people or community members and seek guidance from footnote [261]. ● Periodically review the reports on land use changes and the affected stakeholders. ● Undertake ongoing stakeholder engagement and periodically update the SEP with stakeholder feedback and input. ● Keep a log on compensation strategies at the household level and report on which stakeholders have been compensated to ensure that compensation is on track.
Conflict Dynamics The local procurement of construction materials (e.g., timber, fill, sand, gravel) needed to execute aquaculture projects has caused an increase in the competition for natural resources, which may increase social conflict among different groups of people who depend on the resources for different activities and/or are competing for the construction jobs at the local level.	● Establish a Stakeholder Engagement Plan (SEP). ● Ensure social inclusion, especially marginalized and underrepresented groups and/or people in vulnerable situations through ongoing stakeholder engagement. ● Consult with community leaders and stakeholders to understand existing conflicts and tensions. ● Undertake a Conflict Dynamics Analysis. ● Establish clear guidelines on the procurement of construction materials and guidelines on the employment process for construction jobs.	● Review the SEP periodically. ● Obtain feedback on an ongoing basis using a combination of approaches, such as facilitating village meetings or conducting community surveys. ● Keep a log on the results of the Conflict Dynamics Analysis.[262]

[260] For more information on land tenure, see Landlinks' "Land Tenure and Disasters" webpage, accessible at https://www.land-links.org/issue-brief/land-tenure-and-disasters/.
[261] Ibid.
[262] For more information on the Conflict Dynamics Analysis, see the Construction SEG, accessible at *https://www.usaid.gov/document/sector-environmental-guideline-construction-2017*.

7. SECTOR PROJECT AND ACTIVITY DESIGN – SPECIFIC ENVIRONMENTAL GUIDANCE

Most USAID wild-caught fishery projects and activities, especially those funded with biodiversity funds, are designed to improve sustainable fishery management, livelihoods, and food security, and minimize harm to the environment by improving and conserving biodiversity and their ecosystem services. Likewise, aquaculture projects and activities are designed with the intent of promoting sustainable aquaculture practices, increasing food security, and generating income for local smallholders. However, there may be situations where activities could have unintended adverse environmental and socioeconomic impacts. USAID published a number of guidance documents, including a guide on Sustainable Fisheries and Responsible Aquaculture (2013), which provides detailed guidance for staff and partners on how to design fishery and aquaculture projects. This section builds on that guidance document, focusing on the good management practices and design criteria that can help prevent damaging environmental impacts.

7.1 BEST PRACTICES APPLICABLE TO FISHERIES AND AQUACULTURE

Developing a fishery or aquaculture development project is a stepwise process that begins with identifying the key issues—the socioeconomic and biophysical drivers that threaten sustainability—and thereafter setting the goal and developing a plan of action. The project objectives should be clear and accommodate short-term outputs, as well as longer term changes in social and environmental indicators, such as policy gaps, management capacity, food production, and fish populations. Monitoring, evaluation, and learning need to be designed into the project at the outset to track environmental outcomes and impacts. These aspects of the design should include identifying environmental and social baselines, and conducting environmental and socioeconomic assessments, and assessments of current and applied science to create evidence-based analyses that help identify environmental changes, impacts, and mitigation strategies. The assessment should include the status of and gaps in policies, regulations, management capacity, and extension services. Mapping is useful during the assessment phase because it can pinpoint areas that are suitable and unsuitable for aquaculture and establish georeferenced points. Validating local knowledge with scientific, evidence-based data and analysis is important in order to discern the effects of fisheries and aquaculture from other environmental and human threats and stressors.

Participatory resource assessments, including community-based mapping and other tools, can be used to identify critical habitats and fishing grounds, who is using the fisheries and aquaculture-related resources, who benefits from resource exploitation, and who would be affected by either fishery management or aquaculture development. These assessments are important from an environmental impact perspective because it identifies the pressures that different resource user groups have on the environment. It also can help identify shifts in environmental pressures, economic benefits, or power arrangements as a result of fisheries and aquaculture development. It is important to empower marginalized and underrepresented groups and/or people in vulnerable situations to participate in the management of fisheries and aquaculture. As mentioned previously in the Social Impacts section, it is important to take into account the differences between men and women because, in many coastal fishing communities, there are clear roles for men; women; and the old, young, rich, and poor. Gender relationships may be determined by social structures and shaped by social relations. Men and women have different perspectives, interests, needs, and priorities, which must be clearly understood before successfully engaging them in fishery management. For example, there are instances where women fish traders have boycotted fish caught with small mesh nets and dynamite—in essence becoming advocates for conservation. However, when not engaged, women could unintentionally also support environmentally harmful fishing practices.

Factors that influence the ability of women and men to engage in fishery management

- Women and men tend to do different work in the fisheries sector.
- Women tend to have less access than men to formal decision-making authorities and are less involved in local decision-making structures.
- Women and men have different access to and control over fishery resources.
- Women and men have different spheres of traditional knowledge and leadership.
- Women and men have different domestic responsibilities, including financial expenditures.

Approaches should be designed to strengthen the resilience of the ecosystem and reduce climate risks. “No regrets” approaches (i.e., approaches that are beneficial even in the absence of climate change) make sense. These approaches may include large-scale landscape and seascape planning and zoning for specific uses and user groups. It is important to see the full picture of resource use and user groups in an area to understand the cascading effects that aquaculture and fisheries development can have. Spatial planning and zoning can lessen conflicts over resource use and ensure that aquaculture operations and fisheries stay within the surrounding ecosystem’s carrying capacity. Precautionary approaches should be followed. For example, if a stock’s status is unknown or if anecdotal evidence (e.g., local knowledge) suggests that a fishery is fully exploited, then avoid supporting activities that increase fishing effort. Donor coordination can create synergies at the same time as it can help avoid unintentional environmental, social, and climate impacts. For example, although well intended, a donor-funded project to replace fishing vessels after a tsunami or hurricane may contradict a different donor project working on reducing fishing effort.

7.2 FISHERIES

Unsustainable and improperly managed fishing can lead to unwanted environmental, economic, and social impacts. The first step toward preventing environmental and social impacts in fisheries is to support sound fishery management and good governance. This means including environmental objectives (e.g., prevent overexploitation and degradation of ecosystem health) in the broader capture fishery’s vision or goal. Best management practices that support environmentally sound fisheries include the following:

- **Design projects and activities to prevent or reduce overfishing for all fish populations**. Any project or activity that promotes increased fishing capacity and fishing effort should be avoided for stocks that are considered to be fully fished or overfished and for any populations without adequate management systems in place.

The Government of The Gambia has granted exclusive use rights to the cockle and oyster fishery in the Tanbi Wetlands National Park to the TRY Oyster Women's Association. This is the first instance of a women's group being granted exclusive use rights to a fishery in Sub-Saharan Africa. More than 6,300 hectares of oysters and mangroves have been protected. Through concrete short-term value chain benefits and initiatives to strengthen social cohesion, solidarity, and conflict resolution, TRY has reduced fishing pressure and made visible progress toward medium- and long-term environmental benefits.

- **Understand the current status of the fish stocks.** This step is an important part of the fisheries project design. FAO and national bodies are tasked with conducting fish stock assessments. Stocks that have not been assessed are referred to as data-poor fisheries. Where the stock status is unknown, the precautionary principle suggests that no capacity or fishing effort increases should be contemplated.[263, 264, 265]

- **Use co-management approaches and strengthen fishing associations.** Inclusive, participatory processes that engage fishery stakeholders and fishing associations in management plans and best practices create local engagement and ownership. They allow local stakeholders to generate place-based fishery management rules that aim to reduce, mitigate, or eliminate activities that degrade resources or ecosystem services, while promoting those that support natural processes and help "grow" fish populations. For large countries or small-scale stocks, it may make sense to decentralize management to the village, district, or regional level. Local fishery management established without a strong constituency of fishers will likely face high levels of non-compliance, which, in turn, may have negative environmental impacts.

- **Move from open access to managed or restricted access systems and promote secure tenure and use rights.** Restricted access and use rights over fishing grounds and resources tend to provide long-term economic incentives for those in the fishery to engage in sustainable conservation practices, thus avoiding the overexploitation. Output controls such as quotas can prevent stocks from becoming overfished and/or allow them

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[263] Garcia, S.M. 1994. "The precautionary principle: Its implications in capture fisheries management." Ocean and Coastal Management 22: 99-125. https://www.sciencedirect.com/science/article/abs/pii/0964569194900140.

[264] Costanza, R., F. Andrade, P. Antunes, M. van den Belt, D. Boersma, D.F. Boesch, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, J.G. Pereira, S. Rayner, R. Santos, J. Wilson, and M. Young. 1998. "Principles for Sustainable Governance of the Oceans." Science 281 (5374): 198-199. https://www.semanticscholar.org/paper/Principles-for-Sustainable-Governance-of-the-Oceans-Costanza-Andrade/892f91938746e5718ef8e4bd7ba85a894c6a067b#:~:text=Six%20core%20principles%20are%20proposed%20to%20guide%20governance,pollution%2C%20and%20environmental%20and%20climate%20change%20are%20increasing.

[265] Weiss, C. 2006. "Can there be science-based precaution?" Environmental Research Letters 1 (1). https://ui.adsabs.harvard.edu/abs/2006ERL.....1a4003W/abstract#:~:text=%27Science-based%20precaution%27%20is%20possible%20in%20logic%20if%20not,one%20is%20willing%20to%20pay%20to%20avoid%20risk.

to rebuild.[266, 267] However, managed access alone will not prevent overfishing or avoid ecosystem degradation unless fishing effort and catch controls among those who have access are agreed upon and fully enforced. By managing access in combination with restricting fishing effort among those with access rights, it is possible to keep fishing effort within the maximum biological yield, which allows the biological systems to be productive, healthy, and even grow over time. Design strategies to create managed use rights that provide incentives for stewardship for improved fishery management and that give fishers the legal authority to manage resources. Protected areas, sanctuaries, and no-take areas are forms of managed or restricted access that make sense for some fisheries. Although they displace rather than reduce fishing effort, they are commonly established to enhance the natural productivity of fisheries and biological diversity by providing a safe haven for fish populations to feed, breed, and grow.

- **Manage fishing efforts through input controls, such as closed seasons and areas and banning certain highly efficient gear or sizes and lengths of net**. It is important to consider environmental objectives when deciding between input and output controls. Developed countries, including the United States, are putting more emphasis on quota- or catch-based management, which limits the number and size of fish harvested (i.e., "the output") regardless of the inputs used. However, small-scale fisheries in developing countries still rely primarily on input controls, which control the fishing effort used to harvest fish. Regardless of the type of control used, it is important to consider direct and indirect environmental impacts. For example, a focus on output controls may retain a fishery within the maximum sustainable yield, but it also may allow the use of gear that destroys habitats for other species. Applying ecosystem-based fishery management (EBM) strategies will avoid these types of issues because it focuses on conserving the underlying health and resilience of the fisheries ecosystem upon which productive and profitable fisheries depend. EBM considers the linkages between species and habitats and ensures that fishery management minimizes the impact on habitats and the ecosystem.

- **Managing at the scale of the fish stock and conserve critical fish habitats thereby enhancing fish productivity and sustainability**. Fish migrate across geographic boundaries, and, consequently, fishery management will only be effective if it involves the full range of communities, regions, and/or countries that host the fish stock. If management does not cover the entire population, it may miss critical life cycle stages and habitats, or it could displace fishing pressure from one area to another.

- **Design fishery management and outreach/extension to fit local capacity, as well as the complexity of the fishery**. For example, ensure that fishers use the most suitable types of gear for a fishery to avoid unnecessary bycatch. Build and leverage champions and constituency strategies that encourage stewardship, fair trade, and long-term productivity. Build the capacity of government institutions and universities to serve as extension services to disseminate best practices and strengthen fishing associations and co-management.

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[266] Shepherd, J. G. 1981. "Matching fishing capacity to the catches available: a problem in resource allocation." Journal of Agricultural Economics 43: 331-340. https://www.researchgate.net/publication/229486613_Matching_Fishing_Capacity_to_the_Catches_Available_A_Problem_in_Resource_Allocation.

[267] Castillo, C., and J. Dresdner. 2013. "Effort optimisation in artisanal fisheries with multiple management objectives, collective quotas and heterogeneous fleets." Australian Journal of Agricultural and Resource Economics 57 (1): 104–122. https://onlinelibrary.wiley.com/doi/10.1111/j.1467-8489.2012.00609.x

- **Avoid promoting destructive gear for the project and support policy and regulations that limit or ban their use.** Projects also can promote and pilot-test technological innovations that reduce environmental impact. Depending on the nature and ecological complexity of the bottom, many experts believe that lower impact gear, such as hand lines and fish pots, is better because it exerts less environmental damage on bottom substrates than trawling nets in sensitive areas.[268, 269, 270]

- **Implement common fishery management measures to avoid capturing endangered, threatened, and protected species and ban some gear entirely or require devices that reduce the incidence of bycatch**. For example, by law, the United States requires that turtle excluder devices be used on all trawlers targeting wild-caught shrimp products destined for U.S. importation. Fishery projects should avoid promoting gear that may increase the incidence of capture of endangered, threatened, and protected (ETP) species and should consider supporting activities to reduce ETP bycatch.[271]

- **Adhere to relevant international agreements and commitments to environmental and social sustainability and good practices in fishery projects and activity design**. One means to combat illegal fishing, in addition to strengthening fishery management and enforcement, is to support traceability strategies for export commodities (e.g., U.S. importation requirements for catch documentation and traceability, Convention on International Trade in Endangered Species of Wild Fauna and Flora).[272] Traceability is the ability to track the movement of fishing resources from the source to the end consumer. The traceability of fish and other aquatic food products caught or traded by legal and illegal means remains a significant challenge, particularly in developing countries and for fish in domestic supply chains. Data on government landings reports and data found in vessel catch records exist but are generally not readily available, and illegal catch hotspots are poorly documented over time. For more information on illegal, unreported, and unregulated fishing and traceability, see footnote 273.

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268 Kaiser, M.J., and B.E. Spencer. 1996. "The effects of beam trawl disturbance on infaunal communities in different habitats." Journal of Animal Ecology 65: 348–358. https://www.jstor.org/stable/5881.

269 DeAlteris, J., L. Skrobe, and C. Lipsky. 1999. "The Significance of Seabed Disturbance by Mobile Fishing Gear Relative to Natural Processes: A Case Study in Narragansett Bay, Rhode Island." American Fisheries Society Symposium 22: 224–237. https://www.researchgate.net/publication/236963096_The_significance_of_seabed_disturbance_by_mobile_fishing_gear_relative_to_natural_processes_A_case_study_in_Narragansett_Bay_Rhode_Island.

270 Pitcher, C.R., N. Ellis, W.N. Venables, T.J. Wassenberg, C.Y. Burridge, G.P. Smith, M. Browne, F. Pantus, I.R. Poiner, P.J. Doherty, J.N.A. Hooper, and N. Gribble. 2016. "Effects of trawling on sessile megabenthos in the Great Barrier Reef and evaluation of the efficacy of management strategies." ICES Journal of Marine Science 73 (Supplement 1): S115-S126. https://academic.oup.com/icesjms/article/73/suppl_1/i115/2573860.

271 Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. "Understanding impacts of fisheries bycatch on marine megafauna." Trends in Ecology and Evolution 19 (11): 598-604. https://www.sciencedirect.com/science/article/abs/pii/S0169534704002642#:~:text=Understanding%20impacts%20of%20fisheries%20bycatch%20on%20marine%20megafauna,Solutions%20...%205%20Conclusions%20and%20future%20directions%20.

272 For more information see the Convention on International Trade in Endangered Species of Wild Fauna and Flora NOAA webpage, accessible at https://www.fisheries.noaa.gov/national/international-affairs/convention-international-trade-endangered-species-wild-fauna-and.

273 USAID. n.d. “Illegal, Unreported, and Unregulated Fishing.” https://www.usaid.gov/biodiversity/illegal-unreported-and-unregulated-fishing.

- **Avoid polluting the environment**. There are a number of practical steps that people working onboard fishing vessels and in the post-harvest sector can take to prevent direct environmental impacts. These steps include avoiding the discharge of polluted water, oil, and non-decomposable trash, such as plastics, into coastal and sensitive waters and excluding motorized vessels from areas that contain important shallow water habitats or small enclosed ecosystems.

7.3 AQUACULTURE

Uncontrolled aquaculture growth can lead to unwanted environmental, economic, and social impacts. To avoid adverse environmental impacts, aquaculture development endeavors must consider a number of issues, such as governance, policy, and management frameworks; proper siting, permitting, and zoning; culture technologies and production oversight; extension capacity; processing; and transportation. Aquaculture-specific guidance includes the following:

- **Support strengthened governance and management systems for aquaculture, such as environmental rules and regulations and zoning/siting approval procedures for small, medium, and large production systems.** Good governance, policies, and regulations, along with training, technical assistance, extension services, and monitoring at all levels of production, are essential to minimize threats to the environment. This involves strengthening institutional extension capacity to promote best aquaculture management practices that address critical issues, such as how to avoid the transmission of disease and parasites to the wild population and how to reduce and mitigate water pollution.

- **Create synergies and collaboration among producers**. Consider public policy and private sector agreements and commitments that can create opportunities and incentives for improved management. Spatial planning and zoning help mitigate environmental impacts by ensuring that producers are not too concentrated in one area, which, in turn, reduces the risk of disease.

- **Invest in technological innovation and transfer**. Extension support and trainings in breeding and hatchery technology, disease control, feed and nutrition, water supply, and wastewater treatment can help prevent environmental degradation. Providing incentives for sustainability can be beneficial. For example, low-interest loans and tax exemptions for small-scale farmers can help farmers adopt technologies that increase productivity and reduce the pressure to clear new land.

- **Use an ecosystem approach to aquaculture management (EAAM) that integrates aquaculture ventures within the broader ecosystem to ensure that the activities do not threaten the sustained delivery of ecosystem services**. Taking an EAAM approach includes capacity modeling, watershed considerations (upstream and downstream), and understanding the accumulative impacts of aquaculture—all of which are important when employing a precautionary and adaptive approach.

- **Site aquaculture operations in an appropriate manner to ensure efficient farm operations, minimize environmental impacts, and reduce threats to biodiversity**. Proper siting of production systems can help avoid the loss of critical habitats, such as mangroves, coral reefs, wetlands, lagoons, river inlets, bays, estuaries, swamps, marshes, or high wildlife use areas. Many factors must be considered when siting and building earthen pond systems, including soil type, grade, and elevation; distance from water sources; the type of water source; and other physical factors. Farmers must be able to drain the ponds completely for harvesting and disinfecting.[274] Situate ponds away from tidal areas that are subject to flooding to avoid the spread of disease and the contamination of freshwater.

General rules of thumb for siting aquaculture operations include (1) maintaining adequate distance from other aquaculture enterprises, natural spawning runs, restricted areas, and sensitive ecosystems; (2) choosing sites with adequate wave, current, and tidal patterns; (3) avoiding sites that are close to polluting industries; (4) avoiding sites that are near wild stock populations; and (5) avoiding lakes and ponds that are sources of drinking water. Other aquaculture design considerations include consideration of upstream and downstream water flows. For example, construct wetlands to treat the settling pond water from freshwater ponds before it is released downstream.

- **Promote closed systems or terrestrial ponds with safeguards to reduce escapees, diseases, parasites, and pollution.** Net pens should be sited in highly flushed, deepwater sites with no tidal reversals.

- **Promote low-impact species (low on the food chain) and use non-native species only where escape is impossible or where survival and reproduction under local conditions are impossible**. Non-native species, such as tilapia, can be cultured in places where it has been cultured for a long time and is already well established.

- **Use best management practices for monitoring and controlling ponds**. Best management practices include using aquaculture feed that results in efficient feed conversion rates and low waste (e.g., use appropriate feed management and distribute feed evenly). Other practices include:

  - Use of approved drugs or pesticides only during disease outbreak and only if recommended.
  - Limiting the use of fertilizer and monitoring and control effluents before discharging to meet water quality standards for turbidity, suspended solids, pH, dissolved oxygen, and so forth.
  - Collection and safe disposal of unmarketable fish, blood, and guts.
  - Avoiding discharges near or upstream of recreational areas, marine parks, fishing grounds, shellfish beds used for commercial or recreational harvest, or other sensitive areas.

- **Consider polyculture and integrated multitrophic aquaculture**. Rice-fish polycultures have been shown to reduce the need for both pesticides and soil nutrients. The fish will consume algae and weeds, fertilize the water, and improve soil texture. Aquaculture in irrigation channels can potentially control algae and weeds if well managed.

- **Avoid the culture, transport, and trade of live ornamentals**. Ornamental fish for the aquarium trade are frequently captured illegally by using destructive fishing methods, such as cyanide. Aquaculture of ornamentals is not advisable for the following reasons: (1) collecting wild seedlings will reduce the wild population; (2) without adequate traceability protocols, it is difficult to discern and certify the ornamentals that have been

[274] USAID. 2013. "Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners." https://www.usaid.gov/sites/default/files/2022-05/FishAquaGuide14Jun13Final.pdf.

cultured sustainably and distinguish cultured from wild-caught specimens; and (3) the transport and escape of wild species from the ornamental trade have caused serious harm in destination countries.

- Apply **biosecurity measures to prevent diseases** from occurring and spreading. This includes controlling inputs (e.g., eggs, larvae, juveniles), supplies (e.g., food, veterinary products), water quality, and farm employee hygiene. However, an emerging issue is implementing biosecurity measures during transportation. For example, it is important to disinfect vehicles and maintain good hygiene during transport to avoid the spreading of disease among farms. Biosecurity measures also are critical during the importation and regional transport of brood stock to avoid the spread of disease and the introduction of aquatic invasive species. Biosecurity measures also are important for disease prevention and to avoid illegal importation of species and strains not duly approved.

7.4 POST-HARVEST HANDLING AND PROCESSING

There are environmental risks associated with post-harvest handling and processing of cultured and wild-caught fish. Post-harvest activities should be coupled with fishery and aquaculture management that aims to achieve sustainable harvesting, prevent overfishing, or focus on fish varieties that are already sustainably harvested. Similarly, the post-harvest activities should be coupled with policy and management activities that promote sound permitting and licensing of processing facilities. Some best practices to avoid environmental impacts during post-harvest handling and processing include the following:

- **Invest in environmentally sound processing, packaging, and transportation methods**. Develop best practices processing compacts that explain handling and food safety, including the use of best practices in the disposal of fish processing waste and discarded fish guts (also called gurry). Use fuel-efficient technologies to avoid contributing to deforestation and the overuse of fuelwood. Choose technologies that minimize smoke-related safety and health risks. Evaluate the sources for procuring construction materials in order to avoid adverse local impact. For post-harvest processing of wild-caught fish, it is important to couple efforts to increase the value of fish products with measures to manage fishing effort. Otherwise, it is possible that the increased value will promote overfishing.

- **Improve landing sites and processing facilities to limit the effluents and solid waste that may produce adverse effects on coastal and aquatic habitats**. When rehabilitating landing and processing sites, minimize the impact on sensitive ecosystems and avoid contaminating groundwater and surface water. Standing water should be avoided as it attracts mosquitoes and other disease vectors.

- **Strengthen the role of women in the fisheries value chain through management training and support for women's fish processing associations**. This is important because including women in participatory processes may strengthen fishery management and extension, resulting in better fishery management.

- **Avoid processing wild-caught fish for fish meal.** This use may decrease the fish available locally for protein, disrupt livelihoods, and increase the demand for and price of fish, spurring additional pressure on fish stocks.

8. MITIGATION OF IMPACTS AND MONITORING

The previous sections have described how fishery and aquaculture activities may directly and indirectly affect the aquatic resources and ecosystems that they depend on. This document also has provided best practices regarding how to avoid negative environmental impacts. This section will provide guidance on how to monitor and mitigate negative environmental impacts.

Monitoring, evaluation, and learning are crucial for providing feedback about what works, what does not work, and why, allowing projects to adapt to and adjust implementation. To fully understand the potential effects, it is critical to hypothesize how fishery and aquaculture activities will interact with the environment and socioeconomic systems and determine what the positive and negative effects will be. Then, if an action does not have the intended effect, project managers should determine whether the problem is due to poor implementation or whether the theory behind the implementation strategy is flawed.

To measure outputs, outcomes, and impacts, fishery and aquaculture projects need to establish a clear understanding of the key issues and the relationships among the activity objectives, the environment, and socioeconomic systems; a clear theory of change, which is required for all USAID activities; and baselines, which will be the starting point for routine monitoring. Key questions are “What is the system or context in which the activity will be implemented?” “What is the theory of change for the activity?,” and “What needs to be monitored?”

A series of tools or How-to Guides, created for use in USAID biodiversity programming but applicable to many fields and endorsed by the Bureau for Planning, Learning and Resource Management, are available to USAID staff and implementers to help with each of the following:

- The How-to Guide on Developing Situation Models in USAID Biodiversity Programming allows an activity to map out the problem context to be addressed.[275]
- The second How-to Guide on Using Results Chains to Depict Theories of Change builds off of the situation model guide to help design teams develop results chains that clearly state the expected results and assumptions behind the proposed strategic approaches that make up the program’s theory of change.[276]
- The third How-to Guide on Defining Outcomes and Indicators for Monitoring, Evaluation, and Learning uses the results chains developed in the second guide and provides help with identifying key results for developing outcome statements and performance indicators.[277]

Fishery and aquaculture projects will likely have a mix of indicators measuring biophysical conditions, socioeconomic benefits, governance capacity, and management frameworks. Recommended monitoring and mitigation measures that can be taken to prevent the categories of environmental impacts identified above (in Section 4) are summarized in Table 7 below.

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[275] USAID’s How-to Guide on Developing Situation Models in USAID Biodiversity Programming is accessible at http://pdf.usaid.gov/pdf_docs/PA00M8MV.pdf.
[276] USAID’s How-to Guide on Using Results Chains to Depict Theories of Change is accessible at http://pdf.usaid.gov/pdf_docs/PA00M8MW.pdf.
[277] USAID’s How-to Guide on Defining Outcomes and Indicators for Monitoring, Evaluation, and Learning is accessible at https://usaidlearninglab.org/sites/default/files/resource/files/biodiversity_howtoguide3_508.pdf.

TABLE 7. MITIGATION AND MONITORING OF ENVIRONMENTAL AND SOCIOECONOMIC IMPACTS IN PROJECT AND ACTIVITY IMPLEMENTATION

POTENTIAL ADVERSE ENVIRONMENTAL IMPACTS	INDICATORS	MITIGATION MEASURES
WILD-CAUGHT FISHERIES		
Impacts related to overfishing: • Loss of species diversity, abundance, and biomass • Reduction in natural productivity and resilience • Changes in trophic structure and food web cascades	• Percentage of stock overfished • Degree of overfishing • Stock declining, stable, or rebuilding • Landings data • Excess capacity • Governance capacity and responsiveness • Season length • Level of subsidies • Data availability • Changes in net income • Local and export market prices	• Strengthen fishery management and governance, including co-management and use rights. • Enhance training in fishery best practices. • Develop managed access and move away from open access. • Develop systems for action and participatory research. • Ensure that monitoring results are factored into the revision of fishery management plans. • Enhance record-keeping (e.g., using tablets for data collection). • Control illegal fishing in small-scale and industrial fisheries. • Set minimum size limits for harvested fish. • Select appropriate fishing gear based on the targeted species. • Select fishing nets with the appropriate mesh size. • Close seasons during critical stages in the fish life cycle to increase natural productivity. • Improve boat and fisher registration and licensing programs and cap the number of boats allowed in the fishery, as appropriate. • Establish reserves/permanent closed areas or temporary area closures during critical life stages (spawning aggregations). • Promote the aquaculture of species lower on the food chain to reduce dependence on wild-caught fish meal.
Impacts related to fuel consumption: • Emission of carbon dioxide and other GHGs	• Fuel intensity per gear type • Number of fishing vessels with motors • Average number of hours that vessel engines are used per week	• Develop and adopt fuel efficiency standards. • Cap the number of boats allowed in a geographical area. • Control illegal fishing. • Promote policies and implement practical measures that reduce GHG emissions.
Impacts of the capture of endangered, threatened, and protected (ETP) species: • Decrease in the populations of species,	• Number of vessels using turtle-excluding devices • Number of ETP species caught as	• Use bycatch reduction devices to allow large animals and ETP species to escape from the nets. • Ban small mesh nets and other gear that are prone to catching ETP species. • Implement information, education, and communications campaigns to raise awareness of the importance of ETP species.

such as turtles and dolphins	bycatch • Population sizes of ETP species	
Impacts related to destructive fishing practices: • Decrease in the non-targeted fish population and juvenile fish stocks • Decrease in sustainability and profitability • Degradation of coral reefs, seagrasses, and other aquatic habitats (from bottom trawling) • Fish kills and habitat degradation/poisoning (from dynamite and cyanide fishing)	• Number of vessels/fishers using destructive gear • Number of policies, regulations, and management actions implemented to reduce destructive practices • Illegal, unregulated, or unreported landings • Enforcement capability • Governance responsiveness • Management jurisdiction	• Use appropriate gear for the different habitats and species to avoid harming the environment and its productivity. • Promote the prohibition of destructive practices. • Use mesh sizes that allow small and juvenile fish to escape. • Use a square mesh or a mesh with square windows instead of a diamond-shaped mesh (diamond-shaped mesh constricts during towing). • Educate fishers about the long-term environmental and economic damage to ecosystems from using cyanide or dynamite. • Implement bans on destructive gear and species that are in danger of commercial extirpation or that have very low abundance. • Engage with the private sector to develop fishery improvement and certification initiatives.
Impacts related to the loss of ecosystem services: • Reduction of anadromous fisheries, leading to upstream impacts and reduced population sustainability • Reduction of seabed ecosystems, leading to reductions in demersal fisheries • Increases in bycatch and a reduction in ecosystem integrity • Lost nets (ghost fishing), depleting resources and damaging non-targeted species	• Ecosystem performance index • Status of critical habitats (e.g., coral reefs, mangroves, submerged aquatic vegetation) • Proportion of critical habitats under protection • Ensure the availability of fish for local consumption	• Protect critical habitats that are important in critical life stages (breeding areas or nursery areas such as mangrove forests, coral reefs, or submerged aquatic vegetation. • Develop plans for rehabilitating damaged ecosystems (e.g., reforestation). • Improve integrated planning. • Include climate information in land use and project planning. • Educate and build awareness about ecosystem services. • Register nets and gear to discourage indiscriminate discarding. • Promote the recycling of plastic and old nets; create financial incentives for recycling and/or proper waste management.

• Plastic pollution		
AQUACULTURE SITE SELECTION AND CONSTRUCTION		
Habitat loss and degradation: • Habitat clearing for the construction of ponds or other forms of aquaculture (e.g., seaweed) • Erosion from aquaculture construction • Seepage into groundwater and surface water	• Environmental performance index • Status of critical habitats (e.g., coral reefs, mangroves, submerged aquatic vegetation) • Proportion of critical habitats under protection • Hectares of healthy mangrove forest, wetlands, and coral reef area • Number of policies, regulations, and management actions implemented for proper siting	**Site selection:** • Avoid siting ponds in locations that would have negative effects on mangrove forests, seagrass beds, or coral reefs. • Use already cleared land whenever possible; reuse existing ponds before creating new ones to minimize the disturbance of soil and vegetation. • Site ponds on the landward side of mangrove forests; leave the seaward side undisturbed and ensure the adequate flow of fresh water for the mangroves. **Construction of aquaculture operations:** • Consider floating and submerged cages rather than earthen ponds. • Use off-bottom culture techniques for seaweed. • Build smaller ponds that are easier to manage and may have fewer environmental impacts. • Build ponds on soils with adequate clay content. • Space ponds well apart. • Support the establishment or strengthening of policies and management that promote the proper siting of aquaculture ponds, the appropriate selection of species, and proper water management to reduce the cumulative impacts on the environment.

Rerouting of water flows through pond enclosures:
• Disease outbreaks
• Changes in hydrologic patterns
	• Water flow
	• Water quality (input and output)
		• Evaluate how much water can be taken from a given water body or how much effluent it can receive without important alterations to its ecological equilibrium.
		• Construct adequate water inlet and outlet systems, taking into account water flow and water quality impacts:
		  ○ Use lower stocking densities and less intensive production systems.
		  ○ Establish or strengthen the management of water and flows at the larger watershed level.

AQUACULTURE OPERATIONS		

Water contamination and sedimentation:
• Solid waste pollution
• Sediment discharge
• Effluent discharges into the ecosystem and open waters, which may include aquaculture feed, waste,
	• Sediment discharge
	• Water quality
	• Pollution shocks and accidents
	• Level of chronic pollution
	• Pollutant concentrations in the
		• Develop national guidelines for the use of chemicals, pesticides, feed, and waste.
		• Reduce, recycle, and buy back plastic waste (e.g., lines, containers, netting) used in aquaculture.
		• **Control effluent discharge:**
		  ○ Implement measures to control site drainage, surface runoff, and sewage discharge during construction and operations.
		  ○ Promote closed culture systems and the establishment of policies

and chemicals used for pesticide control, disinfection, and growth promotion	environment and inside ponds: loadings of nitrogen, phosphorous, organic matter, suspended solids, and 5-day biochemical oxygen demand	that prohibit cage or net culture in open water. ○ Build ponds on soil with adequate clay content to avoid seepage into groundwater and surface water. ○ Use settling ponds or other control structures. ○ Maintain vegetated buffer zones. ○ Do not discharge nutrient-enriched water into freshwater bodies. ○ Use polyculture (e.g., raising several species, including at least one herbivorous species) to consume excess nutrients. ○ Implement integrated multitrophic aquaculture to recuperate carbon, nitrogen, and phosphorous supplied to the system and diminish the environmental impacts caused by the effluents. ○ Promote the culture of filter feeders—organisms that strain their food out of the water—to reduce waste and improve water quality by consuming plankton and preventing eutrophication. ○ Consider growing mollusks, macroalgae, and microalgae by themselves or in conjunction with other species to reduce nutrient loading and eutrophication. • **Reduce overcrowding and overfeeding, which create excess effluents:** ○ Use lower stocking densities. ○ Use high-quality feed and increase the frequency of feedings to diminish the pollution potential of effluents. ○ Feed the right amounts at the right times; use feed pellets designed to float longer in the water column. • **Reduce the adverse effects from the use of chemicals:** ○ Use integrated pest management or polyculture to control weeds. ○ Construct deeper ponds. ○ Consider the use of less toxic alternatives to hazardous products. ○ Designate areas for storage and refueling. ○ Apply chemicals with proper containment and away from watercourse or wetlands. ○ Prepare an Emergency Spill Response Plan ○ Contains spills and treat contaminated soil and water as required. • **Prevent the spreading of disease through water contamination:** ○ Filter or ozonate the effluent from ponds and recirculating tank systems. ○ Promptly remove diseased and dying fish. ○ During disease outbreaks, retain aquaculture effluent to prevent disease from spreading to wild populations. ○ Promote the establishment of policies and regulations that prohibit

		fish cages to prevent the buildup of fish waste and sediment. ○ Avoid the frequent draining of shrimp ponds in order to allow microbial processes and deposition to remove nutrients and organic matter from within, which also will conserve fresh water. • **Control effluents:** ○ Use aeration and water circulation to break down organic matter and minimize anaerobic sediment accumulation at the bottom of shrimp ponds. Aeration also may remove ammonia. ○ Use settling ponds to treat suspended solids. ○ Always settle effluents released at the time of harvest. ○ Consider the use of less toxic alternatives to hazardous products. ○ Improve the training of technicians
Impacts on the aquaculture pond and immediate area: • Salinization/Acidification of soils • Erosion • Impacts on the pond floor	• Degree of soil salinity/acidity	• Implement sustainable aquaculture technologies that limit the salinization and acidification of soils, allowing aquaculture operations to remain productive over time. • Use off-bottom systems, such as rafts and lines, for mollusk culture. • Use settling ponds or other control structures. • Plan for seasonal weather patterns and other constraints that influence erosion. • Predetermine the shutdown criteria for bad weather conditions. • Maintain a vegetated buffer zone.
Trapping and collection of wild eggs, larvae, juveniles, and adults for aquaculture production, which may lead to overharvesting	• Prevalence of the use of wild organisms in aquaculture	• Use hatcheries to provide eggs, larvae, and so forth for aquaculture operations.
Introduction of non-native and invasive species, along with pathogens, predators, parasites, and diseases, into the ecosystem, with adverse effects on fisheries	• Prevalence of non-native and invasive species • Prevalence of pathogens • Prevalence of predators • Prevalence of parasites • Prevalence of disease • Proportion of sick animals; number of	**Species selection:** • Select native rather than exotic species. • Gather information about the biology and ecology of the organism to be farmed (e.g., life cycle, nutritional requirements, tolerance to environmental change) to ensure that the species will survive in the planned aquaculture environment. **Disease prevention:** • Stock certified pathogen-free fish. • Use lower stocking densities. • Vaccinate fish. • Apply integrated pest management. • Filter or ozonate the effluent from ponds and recirculating tank systems. • Promptly remove diseased and dying fish.

	diseased animals/total animals and incidences of disease outbreaks	• During disease outbreaks, retain aquaculture effluent to prevent diseases from spreading to wild populations. • Consider treating the influent water supply (e.g., with chlorine) to eliminate pathogens and the associated use of chemicals. • Set up multiple safeguards to reduce escapes.
POST-HARVEST HANDLING AND PROCESSING OF WILD-CAUGHT FISHERIES AND AQUACULTURE		

Post-harvest handling: Landing site infrastructure/activities that affect sensitive coastal habitats and human health	• Prevalence of low-cost fish handling technologies
	• Prevalence of good road and infrastructure quality
	• Degree of landing site sanitation and hygiene
	• Landing site management capacity
	• Degree of landing site security
	• Reliability of utilities and electricity
	• Degree of access to ice and refrigeration
		• Follow USAID small-scale construction guidelines:
		  ○ Construction SEG[278]
		  ○ Visual Field Guide: Construction[279]

Post-harvest processing: • Disturbances to existing landscapes, habitats, water resources, and sensitive ecosystems due to facility renovation and construction • Increased fishing pressure and overfishing due to increased profitability from	• Number of buyers • Degree of vertical integration • Prevalence of low-cost fish drying technologies • Access to extension services • Degree of post-harvest site safety	• Establish a technical monitoring construction committee to monitor construction and evaluate its compliance, ensuring that building permits and licenses are obtained, as necessary. • Establish or strengthen fishing associations that will be responsible for maintaining landing sites and processing facilities. • Do not allow activities within 30 meters of a permanent or seasonal stream or water body. • Follow proper health and sanitation procedures, including in the disposal of fish processing waste and fish gurry. • Develop best practices that include an agreement to not purchase or process

[278] For more information see the Construction SEG, available on USAID's Environmental Guidelines & Resources webpage, accessible at https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources#ho
[279] For more information see the Visual Field Guide: Construction on USAID's Visual Field Guides webpage, accessible at https://www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/visual-field-guides.

post-harvest processing • Adverse effects on the receiving coastal and marine environment from fish processing effluents and solid waste • Disturbances in habitat and local hydrology from land use changes arising from construction	• Degree of post-harvest site sanitation and hygiene • Post-harvest management capacity • Reliability of utilities and electricity • Degree of access to ice and refrigeration • Capacity among post-harvest processors	juvenile fish or illegally caught fish. • Ensure that construction materials and wood for smoke drying are sustainably and responsibly sourced. • Support the establishment of policies that limit the number and capacity of processing facilities based on the sustainability of the fish populations and the type (small-scale or large-scale) of processing facilities based on equity for small-scale fishers and processors. • Follow USAID food processing guidance.[280]

TABLE 8. CLIMATE RISK MANAGEMENT FOR WILD-CAUGHT FISHERY AND AQUACULTURE PROJECTS

CLIMATE STRESSORS	CLIMATE RISKS	RISK MITIGATION MEASURES
Ocean acidification due to increased dissolution of carbon into seawater	• Impacts on crustaceans and mollusks, which may have more difficulty forming their exoskeleton (i.e., exterior shell), especially for juvenile life stages. This may cause increased mortality rates and reduced reproductive success for bivalves. • Impact on the ability of coral to deposit calcium carbonate and build its skeleton. This may affect the ability of coral to grow, which can contribute to increased reef erosion.	• Monitor and predict changes to ocean chemistry and their biological impacts. • Conduct risk assessments for local/commercial fisheries and aquaculture farms. • Develop conservation strategies for marine organisms and ecosystems. • Build capacity and support long-term adaptation planning with communities and government agencies.
Increasing sea surface and pond temperature due to an increase in absorbed heat from air	• Changes in sea surface temperatures can result in decreased catch rates for targeted species in the original location. This can result in decreased fish stock growth and survival due to changes in fish stock location and a period of spawning.	• Revise fishing regulations and management as fishers migrate with the fish. • Provide design support for aquaculture ponds to mitigate temperature increases. • Increase the resilience of local fishing communities. • Encourage fishing communities to take advantage of

[280] USAID. 2013. “Food Processing. Resource Efficient And Cleaner Production Briefing And Resource Guide For Micro & Small Enterprises.” https://www.usaid.gov/sites/default/files/202205/USAID_MSE_Sector_Guideline_Food_Processing_2013.pdf.

CLIMATE STRESSORS	CLIMATE RISKS	RISK MITIGATION MEASURES
	● Increasing temperatures and salinity can lead to the incidence and spread of pathogens and changes in dissolved oxygen levels in aquaculture operations. ● Changes in environmental conditions may exceed species' biological requirements, resulting in decreased abundance.	fish species that are becoming more abundant due to climate change. ● Promote management approaches and policies that maximize the resilience of vulnerable fish species (e.g., no-take zones).
Increased average temperatures, along with the increased frequency and intensity of heat waves	● Increasing temperatures and extreme climate-related events, such as heat waves, may increase the prevalence of heat-related diseases, or otherwise negatively affect the health of fishers and the communities involved in fishery and aquaculture activities.	● Require that employees receive proper hydration and are not exposed to dangerously high heat levels in accordance with local and national health and safety requirements. ● Ensure that emergency plans are in place (and are well communicated to crews) to respond to climate-related extreme events.
Sea level rise due to melting glacial waters and expansion of ocean waters resulting from increased temperatures	● Coastal erosion as a result of sea level rise can cause indirect impacts, such as the increased vulnerability of coastal infrastructure, as well as inland migration of coastal fisheries' habitat. ● Changes in coastal integrity can decrease coastal fisheries' habitat, such as mangrove forests and seagrass meadows. ● Destruction of coastal areas can result in decreased/the loss of carbon sequestration by wetlands, seagrasses, and mangroves. ● Saltwater intrusion into coastal aquifers can affect salinity levels, which may decrease the aquaculture capabilities for freshwater operations and reduce freshwater supplies at fish landing and processing sites.	● Conduct capacity building and long-term adaptation planning with communities and government agencies. ● Promote the restoration and conservation of mangrove forests and seagrass meadows. ● Reinforce existing or implement new infrastructure to protect against coastal flooding. ● Conduct risk assessments for local and commercial fisheries and aquaculture farms. ● Manage aquaculture farm discharges from ponds to comply with in-country discharge standards, applicable international best practices, and USAID Sector Environmental Guidelines for small-scale aquaculture. ● Strengthen the institutions that are responsible for the conservation and management of ecosystems and natural resources, including their ability to incorporate climate change into their activities.
Increasing frequency and severity of storms (intense rainfall and high wind events) and flooding	● Storms and flooding can result in increased risk for coastal communities and fishers at sea. ● Storms can increase the risk of damage to inland fisheries, as well as aquaculture operations, including the potential for penned fish to escape. ● Storms and flooding can increase the threat of damage to coastal infrastructure, as well	● Conduct capacity building and long-term adaptation planning with communities and government agencies. ● Reinforce existing or construct new infrastructure to protect against flooding and storm intensity. ● Conduct risk assessments for local and commercial fisheries and aquaculture operations. ● Implement health and safety measures for fishers at sea. ● Develop emergency response plans for coastal communities and fishers at sea.

CLIMATE STRESSORS	CLIMATE RISKS	RISK MITIGATION MEASURES
	as infrastructure along rivers and lakes. ● Flooding can increase sedimentation and pulse inputs of freshwater into nearshore marine systems, which may negatively affect the juveniles of targeted species in fisheries.	
Changing precipitation patterns and seasonality	● Changes in seasonality can result in decreased habitat for fisheries and reduced availability of waterbodies for seasonal aquaculture and inland fisheries.	● Conduct capacity building and long-term adaptation planning with communities and government agencies. ● Provide design support for aquaculture ponds to mitigate the effects of changes in seasonality. ● Support the optimization of aquaculture management practices conditioned by climate (for early and late onset of rainfall, good, average, and bad seasons).

9. REFERENCES AND RESOURCES

9.1 REFERENCES

Aburto-Oropeza, O., E. Ezcurrat, G. Danemann, V. Valdez, J. Murray, and E. Sala. 2001. "Mangroves in the Gulf of California increase fishery yields." PNAS 105 (30). https://www.semanticscholar.org/paper/Mangroves-in-the-Gulf-of-California-increase-yields-Aburto%E2%80%90Oropeza-Ezcurra/87220bc324f5b2c90d504700480c7212bf2d0434#:~:text=It%20is%20shown%20that%2C%20in%20the%20Gulf%20of,nursery%20and%2For%20feeding%20grounds%20by%20many%20commercial%20species.

Ahmed, N., J.D. Ward, and C.P. Saint. 2014. "Can integrated aquaculture-agriculture (IAA) produce "more crop per drop"?" Food Security 6 (6): 767-779. https://www.researchgate.net/publication/267335842_Can_integrated_aquaculture-agriculture_IAA_produce_more_crop_per_drop#:~:text=The%20practice%20of%20pond-based%20IAA%20and%20rice-fish%20farming,recognized%20that%20IAA%20produces%20%E2%80%9Cmore%20crop%20per%20drop%E2%80%9D.

Alongi, D.M. 2002. "Present state and future of the world's mangrove forests." Environmental Conservation 29 (3): 331-349. https://www.researchgate.net/publication/231955066_Present_State_and_Future_of_the_World%27s_Mangrove_Forests.

Anneboina, L.R. and K.S.K. Kumar. 2017. "Economic analysis of mangrove and marine fishery linkages in India." Emsystem Services 24: 114-123. https://www.sciencedirect.com/science/article/pii/S2212041616302868.

Anthony, K. R. N., D. I. Kline, G. Diaz-Pulido, S. Dove, and O. Hoegh-Guldberg. 2008. "Ocean Acidification Causes Bleaching and Productivity Loss in Coral Reef Builders." PNAS. https://www.pnas.org/doi/full/10.1073/pnas.0804478105.

Anyusheva, M., M. Lamers, Ng. La, V.V. Vien Nguyen and T. Strek. 2012. "Fate of Pesticides in Combined Paddy Rice–Fish Pond Farming Systems in Northern Vietnam." Journal of Environmental Quality 41 (2): 515-525. https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/jeq2011.0066.

Asian Development Bank. 2017. "Proposition 5: The Sustainable Livelihoods Approach." https://link.springer.com/content/pdf/10.1007/978-981-10-0983-9_5.pdf?pdf=inline%20link.

Awuor, F. J. 2012. "The role of women in freshwater aquaculture development in Kenya." Aquatic Ecosystem Health & Management 24(1): 73-81. https://scholarlypublishingcollective.org/msup/aehm/article-abstract/24/1/73/173879/The-role-of-women-in-freshwater-aquaculture.

Ayilu, R.K., T.O. Antwi-Asare, P. Anoh, A. Tall, N. Aboya, S. Chimatiro, and S. Dedi. 2016.

Informal artisanal fish trade in West Africa: Improving cross-border trade. Program Brief, Penang, Malaysia: WorldFish. https://digitalarchive.worldfishcenter.org/handle/20.500.12348/3864.

Badjeck, Marie-Caroline, Edward H. Allison, Ashley S. Halls, and Nicholas K. Dulvy. 2010. "Impacts of Climate Variability and Change on Fishery-Based Livelihoods." Marine Policy 34 (3): 375–383. https://www.sciencedirect.com/science/article/abs/pii/S0308597X09001237?via%3Dihub

Banas, D., G. Masson, L. Leglize, and J-C Pihan. 2002. "Discharge of sediments, nitrogen (N) and phosphorus (P) during the emptying of extensive fishponds: effect of rain-fall and management practices." Hydrobiologia 472: 29–38. https://link.springer.com/article/10.1023/A:1016360915185.

Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F. 2018. Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. FAO Fisheries and Aquaculture Technical Paper No. 627, Rome: FAO, 628. https://openknowledge.fao.org/server/api/core/bitstreams/9aeb8ade-a623-4954-8adf-204daae3b5de/content.

Barbier, E.B. 2003. "Habitat-Fishery Linkages and Mangrove Loss in Thailand." Contemporary Economic Policy 21 (1): 59-77. https://www.researchgate.net/publication/247674981_Habitat-fishery_linkages_and_mangrove_loss_in_Thailand.

Berkes, Fikret, and Mina Kislalioglu. 1989. "A comparative study of yield, investment and energy use in small-scale fisheries: Some considerations for resource planning." Fisheries Research. https://www.sciencedirect.com/science/article/abs/pii/0165783689900556.

Berlanga-Robles, C.A., A. Ruiz-Luna, G. Bocco and Z. Vekerdy. 2011. "Spatial analysis of the impact of shrimp culture on the coastal wetlands on the Northern coast of Sinaloa, Mexico." Ocean & Coastal Management 54: 535-543. https://www.sciencedirect.com/science/article/abs/pii/S0964569111000494.

Beveridge, M.C.M. 1984. "Cage and pen fish farming: Carrying capacity models and environmental impact." FAO Fisheries Technical Paper (255): 131. https://www.fao.org/4/AD021E/AD021E00.htm.

Bianchi, M., Hallström, E., Parker, R.W.R. et al. 2022. "Assessing seafood nutritional diversity together with climate impacts informs more comprehensive dietary advice." Communications Earth & Environment 3. https://doi.org/10.1038/s43247-022-00516-4.

Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, et al. 2019. Changing Ocean, Marine Ecosystems, and Dependent Communities. Cambridge, UK and New York, NY, USA: Cambridge University Press, 447–587. https://doi.org/10.1017/9781009157964.007.

Bindu, M.S. and I.A. Levine. 2011. "The commercial red seaweed Kappaphycus alvarezii—an overview on farming and environment." Journal of Applied Phycology 23: 789–796. https://link.springer.com/article/10.1007/s10811-010-9570-2.

Blasiak, R., J. Spijkers, K. Tokunaga, J. Pittman, N. Yagi, and H. Osterblom. 2017. "Climate Change and Marine Fisheries: Least Developed Countries Top Global Index of Vulnerability." PLoS ONE 12 (6). http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179632.

Bohnes F.A., Hauschild M.Z., Schlundt J. and Laurent A., 2018. Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development. Reviews in aquaculture, 1-19. DOI: 10.1111/raq.12280. https://onlinelibrary.wiley.com/doi/10.1111/raq.12280?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Boyce, Daniel & Tittensor, Derek & Garilao, Cristina & Henson, Stephanie & Kaschner, Kristin & Kesner-Reyes, Kathleen & Pigot, Alex & Reyes, Rodolfo & Reygondeau, Gabriel & Schleit, Kathryn & Shackell, Nancy & Sorongon-Yap, Patricia & Worm, Boris. 2022. "A climate risk index for marine life." Nature Climate Change 12: 1-9. https://www.researchgate.net/publication/362854169_A_climate_risk_index_for_marine_life.

Boyd, C.E., C. Lim, J. Queiroz, K. Salie, L. De Wet, and A. McNevin. 2008. Best management practices for responsible aquaculture. USAID/Aquaculture Collaborative Research Support Program, Corvallis, Oregon: Oregon State University, 47. https://pdf.usaid.gov/pdf_docs/PNADM906.pdf.

Brodeur, Jean et al. 2022. NOAA Blue Carbon White Paper. NOAA. https://repository.library.noaa.gov/view/noaa/40456.

Brugere, C. and M. Williams. 2017. “Women in aquaculture profile.” GAF. https://www.genderaquafish.org/women-in-aquaculture.htm.

Brush, C.G., A. deBruin, and F. Welter. 2009. "A gender-aware framework for women's entrepreneurship." International Journal of Gender and Entrepreneurship 1 (1): 8-24. https://www.researchgate.net/publication/235302742_A_Gender-Aware_Framework_for_Women's_Entrepreneurship.

Castillo, C., and J. Dresdner. 2013. "Effort optimisation in artisanal fisheries with multiple management objectives, collective quotas and heterogeneous fleets." Australian Journal of Agricultural and Resource Economics 57 (1): 104–122. https://onlinelibrary.wiley.com/doi/10.1111/j.1467-8489.2012.00609.x.

Chen, Y., A.S. Todd, M.H. Murphy and G. Lomnicky. 2016. "Anticipated Water Quality Changes in Response to Climate Change and Potential Consequences for Inland Fisheries." Fisheries 41 (7): 413-416. doi:10.1080/03632415.2016.1182509. https://afspubs.onlinelibrary.wiley.com/doi/10.1080/03632415.2016.1182509.

Cho et al. 1994. "Development of high nutrient- dense, low pollution diets and prediction of aquaculture wastes using biological approaches." Aquaculture 124: 293-305. https://www.sciencedirect.com/science/article/abs/pii/0044848694904030.

Chung, Ik Kyo, and Jin Ae Lee, Jong Ahm Shin, Jong Gyu Kim, Kwang-Seok Park Jung Hyun Oak. 2013. "Installing kelp forests/seaweed beds for mitigation and adaptation against global warming: Korean Project Overview." ICES Journal of Marine Science 70 (5): 1038–1044. https://doi.org/10.1093/icesjms/fss206.

Clay, Patricia M., and Lisa L. Colburn. 2020. A Practitioner's Handbook for Fisheries Social Impact Assessment. NOAA Tech. https://spo.nmfs.noaa.gov/sites/default/files/TM212_0.pdf.

Costanza, R., F. Andrade, P. Antunes, M. van den Belt, D. Boersma, D.F. Boesch, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, J.G. Pereira, S. Rayner, R. Santos, J. Wilson, and M. Young. 1998. "Principles for Sustainable Governance of the Oceans." Science 281 (5374): 198-199. https://www.semanticscholar.org/paper/Principles-for-Sustainable-Governance-of-the-Oceans-Costanza-Andrade/892f91938746e5718ef8e4bd7ba85a894c6a067b#:~:text=Six%20core%20principles%20are%20proposed%20to%20guide%20governance,pollution%2C%20and%20environmental%20and%20climate%20change%20are%20increasing.

Costello, C. D. Ovando, T. Clavelle, C.K. Straus, R. Hilborn, M.C. Melnychuk, T.A. Branch, S.D. Gaines, C.S. Szuwalski, R.B. Cabral, D.N. Rader, and A. Leland. 2016. "Global fishery prospects under contrasting management regimes." PNAS 113 (18): 5125-5129. doi:10.1073/pnas.1520420113. https://www.pnas.org/doi/full/10.1073/pnas.1520420113.

Cox, A. and U.R. Sumaila. 2010. "A Review of Fisheries Subsidies: Quantification, Impacts, and Reform." Oxford University Press 99-112.

Cromey, C.J., T.D. Nickell, and K.D. Black. 2002. "DEPOMOD modelling the deposition and biological effects of waste solids from marine cage farms." Aquaculture 214: 211-239. https://www.sciencedirect.com/science/article/abs/pii/S004484860200368X.

Dahlke, F. T., Wohlrab, S., Butzin, M., & Pörtner, H. O. 2020. "Thermal bottlenecks in the life cycle define climate vulnerability of fish." Science 369 (6499): 65-70. https://www.science.org/doi/10.1126/science.aaz3658.

Daskalov, G.M., A.N. Grishin, S. Rodionov, and V. Mihneva. 2007. "Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts." Proceedings of the National Academy of Sciences 104 (25): 10518–10523. https://www.pnas.org/doi/full/10.1073/pnas.0701100104.

Davis, D.L., C.L. Miller and R.P. Phelps. 2005. "Replacement of fish meal with soybean meal in the production diets of juvenile red snapper, Lutjanus campechanus." Journal of the World Aquaculture Society 36: 114-119. https://www.researchgate.net/publication/227636454_Replacement_of_Fish_Meal_with_

Soybean_Meal_in_the_Production_Diets_of_Juvenile_Red_Snapper_Lutjanus_campechanus.

DeAlteris, J., L. Skrobe, and C. Lipsky. 1999. "The Significance of Seabed Disturbance by Mobile Fishing Gear Relative to Natural Processes: A Case Study in Narragansett Bay, Rhode Island." American Fisheries Society Symposium 22: 224–237. https://www.researchgate.net/publication/236963096_The_significance_of_seabed_disturbance_by_mobile_fishing_gear_relative_to_natural_processes_A_case_study_in_Narragansett_Bay_Rhode_Island.

DeSilva, S.S., T.T.T. Nguyen, G.M. Turchini, U.S. Amarasinghe, and N.W. Abery. 2009. "Alien species in aquaculture and biodiversity: A paradox in food production." AMBIO 38: 24–28. https://pubmed.ncbi.nlm.nih.gov/19260343/#:~:text=However%2C%20voluntary%20and%20or%20accidental%20introduction%20of%20exotic,biodiversity%2C%20is%20an%20imperative%20for%20a%20sustainable%20future.

Di Cicco, E., Ferguson HW, Schulze AD, Kaukinen KH, Li S, Vanderstichel R, et al. 2017. "Heart and skeletal muscle inflammation (HSMI) disease diagnosed on a British Columbia salmon farm through a longitudinal farm study." PLoS ONE 12 (2). https://doi.org/10.1371/journal.pone.0171471.

Dwyer P.G., Knight J.M., Dale P.E.R. 2016. "Planning Development to Reduce Mosquito Hazard in Coastal Peri-Urban Areas: Case Studies in NSW, Australia." Water Science and Technology Library 72. https://link.springer.com/chapter/10.1007/978-3-319-28112-4_33

Fan, M., Zhang, W., Wu, J., & Zhou, J. 2022. "Agricultural land use and pond management influence spatial-temporal variation of CH4 and N2O emission fluxes in ponds in a subtropical agricultural headstream watershed." Frontiers in Environmental Science 10. https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2022.1029334/full.

FAO. 1988. Definition of aquaculture, Seventh Session of the IPFC Working Party of Expects on Aquaculture. Bangkok: IPFC/WPA/WPZ, 1-3. Definition taken from https://www.fao.org/3/X6941E/x6941e04.htm.

FAO. 2002. "Report of the Expert Consultation on Catalysing the Transition Away from Overcapacity in Marine Capture Fisheries." Rome. https://www.fao.org/3/y8169e/y8169e00.htm#Contents.

FAO. 2004. "Assessing Excess Fishing Capacity at World-Wide Level." https://www.fao.org/fishery/docs/DOCUMENT/news/assess/capa.htm.

FAO. 2014. Essential EAFM. Ecosystem Approach to Fisheries Management Training Course. Volume 1– For Trainees. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand, Bangkok, Thailand: RAP Publication 2014/13, 318. http://www.fao.org/3/a-i3778e.pdf.

FAO. 2015. "Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication." Rome, Italy, 34. http://www.fao.org/3/a-i4356e.pdf.

FAO. 2016. "The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all." Rome, Italy, 200. http://www.fao.org/3/a-i5555e.pdf.

FAO. 2016. Promoting gender equality and women's empowerment in fisheries and aquaculture. FAO Family Farm Knowledge Platform. https://www.fao.org/family-farming/detail/en/c/472871/.

FAO. 2017. "Strengthening sector policies for better food security and nutrition results (Fisheries and aquaculture policy guidance note 1." Rome. https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/885757/.

FAO. 2020. "FAO Policy on Gender Equality 2020–2030." Rome. http://www.fao.org/3/cb1583en/cb1583en.pdf.

FAO. 2021. "Trade in Fisheries and Aquaculture Products: A Major International Commodity." https://openknowledge.fao.org/server/api/core/bitstreams/9fb67a0f-c305-49d6-89d9-4499139ce341/content.

FAO. 2022. The State of World Fisheries and Aquaculture 2022. Rome: Towards Blue Transformation. https://doi.org/10.4060/cc0461en.

FAO. 2024. The State of World Fisheries and Aquaculture 2024. Blue Transformation in Action. Rome, Italy. https://doi.org/10.4060/cd0683en.

Froehlich, H. E., et al. 2019. "Blue Growth Potential to Mitigate Climate Change through Seaweed Offsetting." Current Biology 29: 3087-3093. https://doi.org/10.1016/j.cub.2019.07.041.

Fry, Jillian P., Nicholas A. Mailloux, David C. Love, Michael C. Milli, and Ling Cao. 2018. "Feed conversion efficiency in aquaculture: do we measure it correctly?" Environmental Research Letters. https://iopscience.iop.org/article/10.1088/1748-9326/aaa273#:~:text=The%20most%20widely%20used%20measurement%20is%20called%20the,are%20more%20efficient%20compared%20to%20pigs%20and%20cattle.

Garcia, S.M. 1994. "The precautionary principle: Its implications in capture fisheries management." Ocean and Coastal Management 22: 99-125. https://www.sciencedirect.com/science/article/abs/pii/0964569194900140.

Gentry, R., S.E. Lester, C.V. Kappel, T.W. Bell, J. Stevens, and S.D. Gaines. 2016. "Offshore aquaculture: Spatial planning principles for sustainable development." Ecology and Evolution 7 (2): 1- 11. https://onlinelibrary.wiley.com/doi/10.1002/ece3.2637.

Gephart, J.A., E. Rovenskaya, U. Dieckmann, M.L. Pace, and Å. Brannström. 2016. "Vulnerability to shocks in the global seafood trade network." Environmental Research Letters 11. doi:10.1088/1748-9326/11/3/035008. https://iopscience.iop.org/article/10.1088/1748-9326/11/3/035008.

Greer, Krista, Dirk Zeller, Jessika Woroniak, Angie Coulter, Maeve Winchester, M. L. Deng Palomares, and Daniel Pauly. 2019. "Global trends in carbon dioxide (CO2) emissions from fuel combustion in marine fisheries from 1950 to 2016." Marine Policy. https://www.sciencedirect.com/science/article/pii/S0308597X1730893X.

Guo, Xuezhen, Jan Broeze, Jim J. Groot, Heike Axmann, and Martijntje Vollebregt. 2020. "A worldwide hotspot analysis on food loss and waste, associated greenhouse gas emissions, and protein losses." Sustainability. https://www.researchgate.net/publication/344856881_A_Worldwide_Hotspot_Analysis_on_Food_Loss_and_Waste_Associated_Greenhouse_Gas_Emissions_and_Protein_Losses.

Hair, C.A., J.D. Bell, P.J. Doherty. 2002. "The use of wild-caught juveniles in coastal aquaculture and its application to coral reef fisheries." Responsible Marine Aquaculture (CABI Publishing) 327-254. https://www.cabidigitallibrary.org/doi/10.1079/9780851996042.0327.

Hamilton, M., Robinson, J.P.W., Benkwitt, C.E. et al. 2022. "Climate impacts alter fisheries productivity and turnover on coral reefs." Coral Reefs 41: 921–935. https://doi.org/10.1007/s00338-022-02265-4.

Hanley, N., R. Faichney, J. Shortle, and A. Monroe. 1998. "Economic and environmental modeling for pollution control in an estuary." Journal of Environmental Management 52: 211-225. https://www.sciencedirect.com/science/article/abs/pii/S0301479797901754?via%3Dihub.

Hansen, A.C., G. Rosenlund, O. Karlsen, W. Koppe and G.I. Hemrea. 2007. "Total replacement of fish meal with plant proteins in diets for Atlantic cod (Gadus morhua L.): Effects on growth and protein retention." Aquaculture 272: 599-611. https://www.sciencedirect.com/science/article/abs/pii/S0044848607008812#:~:text=No%20effects%20were%20seen%20when%20soybean%20meal%20%287%E2%80%9330%25,meal%20with%20plant%20protein%20in%20diets%20for%20cod.

Harborne, A.R., A. Rogers, Y-M. Bozec, and P.J. Mumby. 2017. "Multiple stressors and the functioning of coral reefs." Annual Reviews of Marine Science 9: 445-468. https://onlinelibrary.wiley.com/doi/10.1111/ddi.12814?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, J., Hofmann, E.E., Lipp, E., Osterhaus, A.D.M.E., Overstreet, R., Porter, J.W., Smith, G.W., & Vasta, G.R. 1999. "Emerging marine diseases - climate links and anthropogenic factors." Science 285: 1505– 1510.

https://www.researchgate.net/publication/345986294_Emerging_Marine_Diseases-Climate_Links_and_Anthropogenic_Factors.

Harvey, B. 2001. "A Primer for Planners: Biodiversity and Fisheries. Biodiversity Planning Support Programme." Global Environmental Facility. www.cbd.int/doc/nbsap/fisheries/Main-Report-Fish.pdf.

Hasimuna, O. J., S. Maulu, K. Nawanzi, B. Lundu, J. Mphande, C. J. Phiri, E. Kikamba, E. Siankwilimba, S. Siavwapa and M. Chibesa. 2023. "Integrated agriculture-aquaculture as an alternative to improving small-scale fish production in Zambia." *Frontiers in Sustainable Food Systems 7*:1161121. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2023.1161121/full.

Hattam, C., Atkins, J.P., Beaumont, N., Börger, T., Böhnke-Henrichs, A., Burdon, D., de Groot, R., Hoefnagel, E., Nunes, P.A., Piwowarczyk, J., Sastre, S., and M.C. Austen. 2015. "Marine ecosystem services: Linking indicators to their classification." Ecological Indicators 49: 61-75. http://dx.doi.org/10.1016/j.ecolind.2014.09.026.

Heck, Nadine, Michael W. Beck, Borja Reguero. 2021. "Storm Risk and Marine Fisheries: A Global Assessment." Marine Policy 132. https://www.sciencedirect.com/science/article/abs/pii/S0308597X21003092?via%3Dihub

Hlaváč, D., Z. Adámek, P. Hartman, and J. Másílko. 2014. "Effects of supplementary feeding in carp ponds on discharge water quality: a review." Aquaculture International 22 (1): 299-320. https://link.springer.com/article/10.1007/s10499-013-9718-6.

Hori, Masakazu, et al. 2021. "Oyster aquaculture using seagrass beds as a climate change countermeasure." Bulletin of Japan Fisheries Research and Education Agency 50: 123-133. https://www.researchgate.net/publication/351991923_Oyster_aquaculture_using_seagrass_beds_as_a_climate_change_countermeasure.

Huang, Minrui, Liuyong Ding, Jun Wang, Chengzhi Ding, & Juan Tao. 2021. "The impacts of climate change on fish growth: A summary of conducted studies and current knowledge." Ecological Indicators (121): 1470-1600. https://www.sciencedirect.com/science/article/pii/S1470160X20309158?via%3Dihub.

ILO. 2007. "Convention 188: Work in Fishing Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C188

ILO. 2011. "Convention 189: Domestic Workers Convention." https://normlex.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C189.

International Maritime Organization. 2023. "2023 IMO Strategy on Reduction of GHG Emissions from Ships." https://www.imo.org/en/OurWork/Environment/Pages/2023-IMO-Strategy-on-Reduction-of-GHG-Emissions-from-Ships.aspx.

IPBES. 2016. *The methodological assessment report on scenarios and models of biodiversity and ecosystem services*. Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 348. https://doi.org/10.5281/zenodo.3235428.

IPCC. 2019. IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. Cambridge, UK and New York, NY, USA: Cambridge University Press, 755. https://doi.org/10.1017/9781009157964.

IPCC. 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)], Cambridge, UK and New York, NY, USA: Cambridge University Press. https://www.cambridge.org/core/books/climate-change-2021-the-physical-science-basis/415F29233B8BD19FB55F65E3DC67272B.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan. 2001. "Historical overfishing and the recent collapse of coastal ecosystems." Science 293 (5530): 629-637. https://www.science.org/doi/10.1126/science.1059199.

Jacquet, J. and D. Pauly. 2008. "Funding Priorities: Big Barriers to Small-Scale Fisheries." Conservation Biology 22 (4): 832–835. doi:10.1111/j.1523-1739.2008.00978.x. https://conbio.onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2008.00978.x.

Johansen, L. H., Jensen, I., Mikkelsen, H., Bjørn, P. A., Jansen, P. A., & Bergh, Ø. 2011. "Disease interaction and pathogens exchange between wild and farmed fish populations with special reference to Norway." Aquaculture 315 (3-4): 167-186. https://doi.org/10.1016/j.aquaculture.2011.02.014.

Jones, AR, Alleway HK, McAfee D, Reis-Santos P, Theuerkauf SJ, Jones RC. 2022. "Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture." Bioscience 72 (2): 123-143. doi:10.1093/biosci/biab126. https://academic.oup.com/bioscience/article/72/2/123/6485038.

Kaiser, M.J., and B.E. Spencer. 1996. "The effects of beam trawl disturbance on infaunal communities in different habitats." Journal of Animal Ecology 65: 348–358. https://www.jstor.org/stable/5881.

Kaiser, M.J., I. Laing, S.D. Utting, and G.M. Burnell. 1998. "Environmental impacts of bivalve mariculture." Journal of Shellfish Research 17: 59-66. https://www.researchgate.net/publication/258998107_Environmental_impacts_of_bivalve_mariculture.

Kauffman, J.B., R.F. Hughes, and C. Heider. 2009. "Carbon pool and biomass dynamics associated with deforestation, land use, and agricultural abandonment in the neotropics." Ecological Applications 19: 1211-1222. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/08-1696.1.

Kauffman, J.B., V.B. Arifanti, H.H. Trejo, M.C.J. Garcia, J. Norfolk, M. Cifuentes, D. Hadriyanto, and D. Mudiyarso. 2017. "The jumbo carbon footprint of a shrimp: carbon losses from deforestation." Frontiers in Ecology and the Environment 15: 183-188. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.1482

Kawarazuka, N. and C. Béné. 2011. "The potential role of small fish species in improving micronutrient deficiencies in developing countries: building evidence." Public Health Nutrition 14 (11): 1927-38. doi:10.1017/S1368980011000814. https://www.cambridge.org/core/journals/public-health-nutrition/article/potential-role-of-small-fish-species-in-improving-micronutrient-deficiencies-in-developing-countries-building-evidence/C49790032DD4E921C33CD145402B7C3A.

Klassen, J. and D.M. Allen. 2017. "Assessing the risk of saltwater intrusion in coastal aquifers." Journal of Hydrology 551: 730-745. https://www.sciencedirect.com/science/article/abs/pii/S0022169417301233

Krkosek, M., Lewis MA, Morton A, Frazer LN, Volpe JP. 2006. "Epizootics of wild fish induced by farm fish." Proceedings of the National Academy of Science 103 (42). https://doi.org/10.1073/pnas.0603525103.

Kruijssen, F., I. Tedesco, A. Ward, L. Pincus, D. Love, and A.L. Thorne-Lyman. 2020. “Loss and Waste in Fish Value Chains: A Review of the Evidence from Low and Middle-Income Countries.” Global Food Security 26. https://www.sciencedirect.com/science/article/pii/S2211912420300882?via%3Dihub.

Lam, Vicky W. Y., William W. L. Cheung, Gabriel Reygondeau, and U. Rashid Sumaila. 2016. "Projected change in global fisheries revenues under climate change." Scientific Reports. https://doi.org/10.1038/srep32607.

Lewison, R.L., L.B. Crowder, A.J. Read and S.A. Freeman. 2004. "Understanding impacts of fisheries bycatch on marine megafauna." Trends in Ecology and Evolution 19 (11): 598-604. https://www.sciencedirect.com/science/article/abs/pii/S0169534704002642#:~:text=Understanding%20impacts%20of%20fisheries%20bycatch%20on%20marine%20megafauna,Solutions%20...%205%20Conclusions%20and%20future%20directions%20.

MacLeod, M.J., Hasan, M.R., Robb, D.H.F. et al. 2020. "Quantifying greenhouse gas emissions from global aquaculture." Scientific Reports 10: 11679. https://doi.org/10.1038/s41598-020-68231-8.

Malerba, M.E., de Kluyver, T., Wright, N. et al. 2022. "Methane emissions from agricultural ponds are underestimated in national greenhouse gas inventories." Communications Earth & Environment 306. https://doi.org/10.1038/s43247-022-00638-9.

Manjarrés Hernández, A., Guisande, C. y García Roselló, E. 2021. "Predicting the effects of climate change on future freshwater fish diversity at global scale." Nature Conservation 43: 1-24. https://doi.org/10.3897/NATURECONSERVATION.43.58997.

Marine Stewardship Council. 2016. Large vs small scale fishing – which is more sustainable? https://www.msc.org/media-centre/news-opinion/news/2020/02/21/large-vs-small-scale-fishing-which-is-more-sustainable.

Mason, Julia G., et al. 2022. "Attributes of climate resilience in fisheries: From theory to practice." Fish and Fisheries 23.3 522-544. https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12630?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Maulu, S. et al. 2021. "Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations." Frontiers in Sustainable Food Systems 5. https://doi.org/10.3389/fsufs.2021.609097.

McClenachan, L., S.T.M. Dissanayake and X. Chen. 2016. "Fair trade fish: consumer support for broader seafood sustainability." Fish and Fisheries 17: 825–838. https://onlinelibrary.wiley.com/doi/10.1111/faf.12148?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

McKindsey, C.W., H. Thetmeyer, T. Landry, and W. Silvert. 2006. "Review of current carrying capacity models for bivalve aquaculture and recommendations for research and management." Aquaculture 261 (2): 451-462. https://www.sciencedirect.com/science/article/abs/pii/S004484860600487X?via%3Dihub

McManus, J.W. 1997. "Tropical marine fisheries and the future of coral reefs: a brief review with emphasis on Southeast Asia." Coral Reefs 16 (Supplement 1): S121-S127. https://link.springer.com/article/10.1007/s002679900006.

Mora C., R.A. Myers, M. Coll, S. Libralato, T.J. Pitcher, R.U. Sumaila, D. Zeller, R. Watson, K.J. Gaston, and B. Worm. 2009. "Management Effectiveness of the World's Marine Fisheries." PLoS Biology 7 (6). https://doi.org/10.1371/journal.pbio.1000131.

Morley JW, Selden RL, Latour RJ, Frölicher TL, Seagraves RJ, Pinsky ML. 2018. "Projecting shifts in thermal habitat for 686 species on the North American continental shelf." PLOS ONE. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0196127.

Mormorunni, C. L. 2001. "The Spot Prawn Fishery: A Status Report." Asia Pacific Environmental Exchange, Earth Economics, Tacoma, WA. https://marinespecies.wildlife.ca.gov/spot-prawn/the-fishery/.

Moutinho, S., S. Martinez-Llorens, A. Tomas-Vidal, M. Jover-Cerda, A. Oliva-Teles, and H. Peres. 2017. "Meat and bone meal as partial replacement of fish meal in diets of gilthead seabream (Sparus aurata) juveniles: Growth, feed efficiency, amino acid utilization, and economic activity." Aquaculture 468 (1): 271-277. https://www.sciencedirect.com/science/article/abs/pii/S0044848616307293.

Muthukumaran, S. And K. Baskaran. 2013. "International Biodeterioration & Biodegradation Organic and nutrient reduction in a fish processing facility – A case study." International Biodeterioration & Biodegradation 85: 563-570. https://www.sciencedirect.com/science/article/abs/pii/S0964830513001194.

Myers, R.A., J.K. Baum, T.D. Shepherd, S.P. Powers, and C.H. Peterson. 2007. "Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean." Science 315: 1846-1850. https://www.science.org/doi/10.1126/science.1138657.

Naylor, R.L., R.J. Goldburg, J.H. Primavera, N. Kautsky, M.C.M. Beveridge, J. Clay, C. Folke, J. Lubchenko, H. Mooney and M. Troell. 2000. "Effect of aquaculture on world fish supplies." Nature 405: 1017-1024. https://www.nature.com/articles/35016500.

NOAA. 2019. "How Will Changing Ocean Chemistry Affect the Shellfish We Eat?" https://www.fisheries.noaa.gov/feature-story/how-will-changing-ocean-chemistry-affect-shellfish-we-eat.

NOAA. 2023. "What is Eutrophication?" https://oceanservice.noaa.gov/facts/eutrophication.html.

NOAA. n.d. Understanding Fisheries Management in the United States. Accessed 2024. https://www.fisheries.noaa.gov/insight/understanding-fisheries-management-united-states.

OECD/FAO. 2022. OECD-FAO Agricultural Outlook 2023-2032. https://www.oecd-ilibrary.org/agriculture-and-food/data/oecd-agriculture-statistics_agr-data-en.

Ojea, E., Pearlman, I., Gaines, S. D., & Lester, S. E. 2017. "Fisheries regulatory regimes and resilience to climate change." Ambio 46: 399-412. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5385667/.

Oken, E., M.L. Østerdal, M.W. Gillman, V.K. Knudsen, T.I. Halldorsson, M. Strøm, D.C. Bellinger, M. Hadders-Algra, K.F. Michaelsen, and S.F. Olsen. 2008. "Associations of maternal fish intake during pregnancy and breastfeeding duration with attainment of developmental milestones in early childhood: a study from the Danish National Birth Cohort." The American Journal of Clinical Nutrition 88 (3): 789-796. https://pubmed.ncbi.nlm.nih.gov/18779297/.

Parker et al. 2018. "Fuel use and greenhouse gas emissions of world fisheries." Nature Climate Change 8: 333-337. https://doi.org/10.1038/s41558-018-0117-x.

Parker, W.R. and P.H. Tyedmers. 2015. "Fuel consumption of global fishing fleets: current understanding and knowledge gaps." Fish and Fisheries 16: 684-696. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12087?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Pauly, D. and D. Zeller. 2016. "Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining." Nature Communications 7: 10244. doi:10.1038/ncomms10244. https://www.nature.com/articles/ncomms10244.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. "Fishing Down Marine Food Webs." Science 279 (5352): 860-863. https://www.science.org/doi/10.1126/science.279.5352.860.

Pazmiño, M. L., Chico-Santamarta, L., Boero, A., & Ramirez, A. D. (2024). Environmental life cycle assessment and potential improvement measures in the shrimp and prawn aquaculture sector: A literature review. *Aquaculture and Fisheries*. https://www.sciencedirect.com/science/article/pii/S2468550X24000856.

The Pew Charitable Trusts. 2017. "Port State Measures Agreement: Why Seafood Buyers Should Help." https://www.pewtrusts.org/~/media/assets/2017/11/eifp_port_state_measures_agreement_why_seafood_buyers_should_help.pdf.

Pikitch, E.K., K.J. Rountos, T.E. Essington, C. Santora, D. Pauly, R. Watson, U.R. Sumaila, P.D. Boersma, I.L. Boyd, D.O. Conover, P. Cury, S.S. Heppell, E.D. Houde, M. Mangel, E. Plaganyi, K. Sainsbury, R.S. Steneck, T.M. Geers, N. Gownaris, and Munch. 2012. "The global contribution of forage fish to marine fisheries and ecosystems." Fish and Fisheries 15 (1): 43-63. https://onlinelibrary.wiley.com/doi/10.1111/faf.12004.

Pitcher, C.R., N. Ellis, W.N. Venables, T.J. Wassenberg, C.Y. Burridge, G.P. Smith, M. Browne, F. Pantus, I.R. Poiner, P.J. Doherty, J.N.A. Hooper, and N. Gribble. 2016. "Effects of trawling on sessile megabenthos in the Great Barrier Reef and evaluation of the efficacy of management strategies." ICES Journal of Marine Science 73 (Supplement 1): S115-S126. https://academic.oup.com/icesjms/article/73/suppl_1/i115/2573860.

Porter, G. 1998. "Fisheries Subsidies, Overfishing and Trade." United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/8366/-Fisheries%20Subsidies%20and%20Overfishing_%20Towards%20a%20Structured%20Discussion-2002134.pdf.

Primavera, J.H. 2005. "Overcoming the impacts of aquaculture on the coastal zone." Ocean & Coastal Management 49: 531-545. https://www.sciencedirect.com/science/article/abs/pii/S0964569106000755.

Reeves, R.R., K. McClellan, and T.B. Werner. 2013. "Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011." Endangered Species Research 20: 13-97. https://www.int-res.com/articles/esr_oa/n020p071.pdf.

Responsible Sourcing Tool. n.d. "Is Forced Labor Hidden in Your Global Supply Chain." https://www.responsiblesourcingtool.org/.

Rice, M.A. and A.Z. DeVera. 1998. "Aquaculture in Dagupan City, Philippines." World Aquaculture 29 (1): 18-24. https://www.researchgate.net/publication/258767267_Aquaculture_in_Dagupan_City_Philippines.

Rice, M.A., P.D. Rawson, and A.D. Salinas and W.R. Rosario. 2016. "Identification and salinity tolerance of the western hemisphere mussel, Myrella charruana (D'Orbigny, 1842) in the Philippines." Journal of Shellfish Research 35 (4): 865-873. https://www.semanticscholar.org/paper/Identification-and-Salinity-Tolerance-of-the-Mussel-Rice-Rawson/046accf1b610dab3c14999ce2b78c035f7ec8a94.

Richardson, K., B. D. Hardesty and C. Wilcox. 2019. "Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis." *Fish and Fisheries*, 20(6):1218–1231. https://onlinelibrary.wiley.com/doi/10.1111/faf.12407?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Robinson, J.P.W., D.J. Mills, G.A. Asiedu, K. Byrd, M. del Mar Mancha Cisneros, P. J. Cohen, K. J. Fiorella, N. A. J. Graham, M. A. MacNeil, E. Maire, E. K. Mbaru, G. Nico, J. O. Omukoto, F. Simmance and C. C. Hicks. 2022. "Small pelagic fish supply abundant and affordable micronutrients to low- and middle-income countries." *Nature Food* 3:1075–1084. https://www.nature.com/articles/s43016-022-00643-3.

Román-Palacios, C., Moraga-López, D., & Wiens, J. J. 2022. "The origins of global biodiversity on land, sea and freshwater." Ecology Letters 25 (6): 1376-1386. https://onlinelibrary.wiley.com/doi/10.1111/ele.13999?af=R&msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Russ, G.R. and A.C. Alcala. 1989. "Effects of intense fishing pressure on an assemblage of coral reef fishes." Marine Ecology Progress Series 56 (1&2): 13-27. https://www.int-res.com/articles/meps/56/m056p013.pdf.

Sae-Lim, P., A. Kause, H. A. Mulder, I. Olesen. 2017. "Breeding and Genetics Symposium: Climate change and selective breeding in aquaculture." Journal of Animal Science 95 (4): 1801–1812. https://doi.org/10.2527/jas.2016.1066.

San Diego-McGlone, M.L., R.V. Azanza, C.L. Villanoy, and G.S. Jacinto. 2008. "Eutrophic waters, algal bloom and fish kill in fish farming areas of Bolinao, Pangasinan." Marine Pollution Bulletin 57: 295-301. https://www.sciencedirect.com/science/article/abs/pii/S0025326X08001811?via%3Dihub

Sanchez-Muros, M.J., F.G. Barroso, and F. Manzano-Agugliaro. 2014. "Insect meal as a renewable source of food for animal feeding." Journal of Cleaner Production 65: 6-27. https://www.sciencedirect.com/science/article/abs/pii/S095965261300841X.

Schuhbauer A., D. J. Skerritt, N. Ebrahi, F. Le Manach and U. R. Sumaila. 2020. " The Global Fisheries Subsidies Divide Between Small- and Large-Scale Fisheries." *Frontiers in Marine Science* 7:539214. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2020.539214/full.

Shepherd, J. G. 1981. "Matching fishing capacity to the catches available: a problem in resource allocation." *Journal of Agricultural Economics* 43: 331-340. https://www.researchgate.net/publication/229486613_Matching_Fishing_Capacity_to_th e_Catches_Available_A_Problem_in_Resource_Allocation.

Singh, G. G., Hilmi, N., Bernhardt, J. R., Montemayor, A. M. C., Cashion, M., Ota, Y., Acar, S., Brown, J. M., Cottrell, R., Djoundourian, S., González-Espinosa, P. C., Lam, V., Marshall, N., Neumann, B., Pascal, N., Reygondeau, G., Rocklöv, J., Safa, A.,. 2019. "Climate impacts on the ocean are making the Sustainable Development Goals a moving target travelling away from us." *People and Nature* 1 (3): 317–330. https://doi.org/10.1002/pan3.26.

Soto, D., Brugere, C. n.d. "The Challenges of Climate Change for Aquaculture." FAO Aquaculture Newsletter. https://www.fao.org/3/i0305e/i0305e16.pdf.

Stanford, Richard J., Budy Wiryawan, Dietriech G. Bengen, Rudi Febriamansyah, and John Haluan. 2017. "The Fisheries Livelihoods Resilience Check (FLIRES Check): A Tool for Evaluating Resilience in Fisher Communities." Fish and Fisheries 18 (6): 1011–25. https://onlinelibrary.wiley.com/doi/abs/10.1111/faf.12220?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Sumaila, U. R., N. Ebrahim, A. Schuhbauer, D. Skerritt, Y. Li, H. S. Kim, T. G. Mallory, V. W. L. Lam and D. Pauly. 2019. “Updated estimates and analysis of global fisheries subsidies.” Marine Policy 109:103695. https://www.sciencedirect.com/science/article/pii/S0308597X19303677?via%3Dihub.

Tacon, A. G. J., and M. Metian. 2009. "Fishing for Feed or Fishing for Food: Increasing Global Competition for Small Pelagic Forage Fish." Ambio. https://www.researchgate.net/publication/38039402_Fishing_for_Feed_or_Fishing_for_Food_Increasing_Global_Competition_for_Small_Pelagic_Forage_Fish.

Teh, L.C.L and Pauly, D. 2018. "Who Brings in the Fish? The Relative Contribution of Small-Scale and Industrial Fisheries to Food security in Southeast Asia." Frontiers in Marine Science 5: 44. doi:10.3389/fmars.2018.00044. https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2018.00044/full.

Teh, L.C.L. and Sumaila, U.R. 2013. "Contribution of marine fisheries to worldwide employment." Fish and Fisheries 14 (1): 77-88. doi:10.1111/j.1467-2979.2011.00450.x. https://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2011.00450.x?msockid=27f4aa84b15f6bab1516b947b04d6ac6.

Tekman, M. B., B. A. Walther, C. Peter, L. Gutow and M. Bergmann. 2022. “Impacts of plastic pollution in the oceans on marine species, biodiversity and ecosystems.” 1–221, WWF Germany, Berlin. doi: 10.5281/zenodo.5898684. https://www.wwf.de/fileadmin/fm-wwf/Publikationen-PDF/Plastik/WWF-Impacts_of_plastic_pollution_in_the_ocean_on_marine_species__biodiversity_and_ecosystems.pdf.

Temple, A. J., D. J. Skerritt, P. E. C. Howarth, J. Pearce and S. C. Mangi. 2022. “Illegal, unregulated and unreported fishing impacts: A systematic review of evidence and proposed future agenda." *Marine Policy*, 139:105033. https://www.sciencedirect.com/science/article/abs/pii/S0308597X2200080X?via%3Dihub

The WorldFish Center. 2007. The Threat to Fisheries and Aquaculture from Climate Change. *The WorldFish Center*. https://www.worldfishcenter.org/publication/threat-fisheries-and-aquaculture-climate-change.

Tlusty et al. 2019. "Reframing the sustainable seafood narrative." Global Environmental Change 59. https://doi.org/10.1016/j.gloenvcha.2019.101991.

Tongo, I., O. Ogbeide, and L. Ezemonye. 2017. "Human health risk assessment of polycyclic aromatic hydrocarbons (PAHs) in smoked fish species from markets in Southern Nigeria." Toxicology Reports 4: 55-61. https://www.sciencedirect.com/science/article/pii/S221475001630110X.

United Nations. 1990. "Chapter IV. Human Rights." https://treaties.un.org/doc/Treaties/1990/12/19901218%2008-12%20AM/Ch_IV_13p.pdf.

UN Global Compact. n.d. The Ten Principles of the UN Global Compact. https://www.unglobalcompact.org/what-is-gc/mission/principles/principle-5.

U.S. EPA. 2021. From Farm to Kitchen: The Environmental Impacts of U.S. Food Waste. U.S. Environmental Protection Agency Office of Research and Development. https://www.bing.com/search?q=131.+From+Farm+to+Kitchen%3A+The+Environmental+Impacts+of+U.S.+Food+Waste&cvid=6666285a1643438c9a85629a569054f5&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIHCAEQRRj8VdIBBzgxOWowajmoAgCwAgA&FORM=ANAB01&PC=U531.

USAID. 1980. Reg. 216 (22 CFR 216). https://www.usaid.gov/environmental-procedures/laws-regulations-policies/22-cfr-216.

USAID. 2011. "Tips for Conducting a Gender Analysis at the Activity or Project Level." https://pdf.usaid.gov/pdf_docs/PDACX964.pdf.

USAID. 2013. "Food Processing. Resource Efficient And Cleaner Production Briefing And Resource Guide For Micro & Small Enterprises." https://www.usaid.gov/sites/default/files/202205/USAID_MSE_Sector_Guideline_Food_Processing_2013.pdf.

USAID. 2013. "Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners." https://www.usaid.gov/sites/default/files/2022-05/FishAquaGuide14Jun13Final.pdf.

USAID. 2016. "Environmental Compliance Factsheet: Stakeholder Engagement in the Environmental and Social Impact Assessment (ESIA) Process." https://www.usaid.gov/sites/default/files/2022-05/Stakeholder_Engagement_052016.pdf.

USAID. 2017. "Ecosystems Improved for Sustainable Fisheries (ECOFISH) Project Completion Report." Washington, D.C., 140.

USAID. 2017. "Final Performance Evaluation: Aquaculture for Income and Nutrition (AIN)." https://pdf.usaid.gov/pdf_docs/pa00mv3p.pdf.

USAID. 2019. "Advancing Gender in the Environment: Gender in Fisheries - A Sea of Opportunities." https://biodiversitylinks.org/projects/current-global-projects/agent/resources/advancing-gender-in-the-environment-gender-in-fisheries2014a-sea-of-opportunities.

USAID. 2022. "Community Engagement Guide." https://www.climatelinks.org/sites/default/files/asset/document/2022-04/5a.%201_Community%20Engagement%20Reference%20Guide_30Mar22_508.pdf.

USAID. 2022. “Scoping Statement: Distribution of LLNs in Malawi.”

USAID. 2023. "2023 Gender Equality and Women's Empowerment Policy." https://www.usaid.gov/sites/default/files/2023-03/2023_Gender%20Policy_508.pdf.

USAID. 2023. "ADS Chapter 205: Integrating Gender Equality and Women's Empowerment in USAID’s Program Cycle." https://www.usaid.gov/about-us/agency-policy/series200/205#:~:text=USAID%20has%20adopted%20several%20comprehensive,fully%20exercise%20their%20rights%2C%20determine.

USAID. 2023. “Feed the Future and Conflict Integration: A Toolkit for Programming.” https://www.resiliencelinks.org/system/files/documents/2023-05/USAID_Feed%20the%20Future%20and%20Conflict%20Integration%20Toolkit_Final_508_May2023%20%281%29.pdf.

USAID. 2023. Guide to Encountering and Working with Cultural Heritage. https://www.usaid.gov/sites/default/files/2023-10/USAID-Cultural-Heritage-Guide-September-2023.pdf.

USAID. 2024. A Mandatory Reference for ADS Chapter 201. https://www.usaid.gov/about-us/agency-policy/series-200/references-chapter/201mbf.

USAID. 2024. "Social Impact Risk Initial Screening and Diagnostic Tools. A Mandatory Reference for ADS Chapter 201." https://www.usaid.gov/sites/default/files/2024-05/201mbf_051424.pdf.

USAID. 2024. "Voluntary Social Impact Principles Framework." https://www.usaid.gov/environmental-procedures/environmental-compliance-esdm-program-cycle/social-impact-assessment.

USAID. 2024. “Environmental Assessment for Broad Distribution of Long-Lasting Insecticide Nets in Malawi with Focus on the Impacts of Misuse for Fishing.” 379p.

USAID. n.d. Counter Trafficking in Persons. https://www.usaid.gov/trafficking

USAID. n.d. "Illegal, Unreported, and Unregulated Fishing." https://www.usaid.gov/biodiversity/illegal-unreported-and-unregulated-fishing.

USAID. n.d. "Marine and Fisheries." https://biodiversitylinks.org/what-we-do/marine-and-fisheries.

USAID. n.d. USAID's Guidance on Child Safeguarding for Implementing Partners https://www.usaid.gov/PreventingSexualMisconduct/Partners/Child-Safeguarding/FAQ#r57lup3rgd18.

USAID. n.d. Technical Publications on Conflict Management and Mitigation. https://www.usaid.gov/conflict-violence-prevention/technical-publications.

U.S. Department of Labor. 2022. "Findings on the Worst Forms of Child Labor." https://www.dol.gov/agencies/ilab/resources/reports/child-labor/findings.

U.S. Department of Labor. 2022. "List of Good Produced By Child Labor or Forced Labor." https://www.dol.gov/sites/dolgov/files/ilab/child_labor_reports/tda2021/2022-tvpra-list-of-goods-v3.pdf.

U.S. State Department. 2024. "Trafficking in Persons Report." https://www.state.gov/trafficking-in-persons-report/.

Waite, R., M. Beveridge, R. Brummett, S. Castine, N. Chaiyawannakarn, S. Kaushik, R. Mungking, S. Nawapakpilai, and M. Phillips. 2014. Creating a Sustainable Food Future, No. 5: Improving Productivity and Environmental Performance of Aquaculture. Working Paper. Washington, D.C.: World Resources Institute. http://www.wri.org/sites/default/files/wrr_installment_5_improving_productivity_environmental.

Walker, PJ, Mohan CV. 2009. "Viral disease emergence in shrimp aquaculture: origins, impact and the effectiveness of health management strategies." Reviews in Aquaculture 125-154. doi:10.1111/j.1753-5131.2009.01007.x. https://pubmed.ncbi.nlm.nih.gov/32328167/

Ward, GM, Faisan, JP, Cottier-Cook, EJ, et al. 2020. "A review of reported seaweed diseases and pests in aquaculture in Asia." Journal of the World Aquaculture Society 51: 815–828. https://doi.org/10.1111/jwas.12649.

Water Science School. 2019. How Much Water Is There on Earth? U.S. Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/how-much-water-there-earth.

Weiss, C. 2006. "Can there be science-based precaution?" Environmental Research Letters 1. https://ui.adsabs.harvard.edu/abs/2006ERL.....1a4003W/abstract#:~:text=%27Science-based%20precaution%27%20is%20possible%20in%20logic%20if%20not,one%20is%20willing%20to%20pay%20to%20avoid%20risk.

Weyant, Cheryl L., Antwi-Boasiako Amoah, Ashley Bittner, Joe Pedit, Samuel Nii Ardey Codjoe, and Pamela Jagger. 2022. "Occupational Exposure and Health in the Informal Sector: Fish Smoking in Coastal Ghana." Environmental Health Perspectives 130 (1). https://ehp.niehs.nih.gov/doi/10.1289/EHP9873.

Woolway, R.I., Maberly, S.C. 2020. "Climate velocity in inland standing waters." National Climate Change 10: 1124-1129. https://doi.org/10.1038/s41558-020-0889-7.

World Bank. 2016. Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs. Washington, D.C.: Wealth Accounting and the Valuation of Ecosystem Services Partnership (WAVES). http://documents.worldbank.org/curated/en/995341467995379786/Managing-coasts-with-natural-solutions-guidelines-for-measuring-and-valuing-the-coastal-protection-services-of-mangroves-and-coral-reefs.

World Bank. 2017. The Sunken Billions Revisited: Progress and Challenges in Global Marine Fisheries. Washington, D.C.: Environment and Sustainable Development series. https://openknowledge.worldbank.org/bitstream/handle/10986/24056/9781464809194.pdf?sequence=8.

World Fisheries Trust. 2008. "Industrial Fishery: Fishing Methods Fact Card." https://www.worldfish.org/GCI/gci_assets_moz/Fact%20Card%20%20Industrial%20Fishery.pdf.

Yousefi, Masoud, Arash Jouladeh-Roudbar, Anooshe Kafash. 2020. "Using endemic freshwater fishes as proxies of their ecosystems to identify high priority rivers for conservation under climate change." Ecological Indicators (112): 1470-1600. https://www.sciencedirect.com/science/article/abs/pii/S1470160X20300741?via%3Dihub

Yuan, J., Xiang, J., Liu, D. et al. 2019. "Rapid growth in greenhouse gas emissions from the adoption of industrial-scale aquaculture." National Climate Change 9: 318-322. https://doi.org/10.1038/s41558-019-0425-9.

Zhang, W., Belton, B., Edwards, P., Henriksson, P.J.G., Little, D.C., Newton, R. & Troell, M. 2022. "Aquaculture will continue to depend more on land than sea." Nature 603: E2-E4. https://www.nature.com/articles/s41586-021-04331-3.

9.2 RESOURCES

Aquaculture Certification Council. https://bapcertification.org/.

The Meloy Fund: A Fund for Sustainable Small-scale Fisheries in Southeast Asia. https://www.thegef.org/projects-operations/projects/9370.

USAID. Feed the Future Innovation Lab for Collaborative Research on Aquaculture and Fisheries Projects. https://aquafishcrsp.oregonstate.edu/projects.

USAID. Biodiversity Policy. https://www.usaid.gov/biodiversity/policy.

USAID. Biodiversity Conservation Gateway. https://rmportal.net/biodiversityconservation-gateway.

This resource is a clearinghouse for all documents produced by all USAID projects. This site can be used to search by project name for any past or present USAID project.

USAID. Biodiversity Conservation Gateway. Interactive Inventory of International Capacity Building Initiatives for Fisheries. https://rmportal.net/biodiversityconservation-gateway/legality-sustainability/fisheries-development/project-search.

USAID. Biodiversity How-to Guide 1: Developing Situation Models in USAID Biodiversity Programming. August 2016. http://pdf.usaid.gov/pdf_docs/PA00M8MV.pdf.

USAID. Biodiversity How-to Guide 2: Using Results Chains to Depict Theories of Change in USAID Biodiversity Programming. August 2016. http://pdf.usaid.gov/pdf_docs/PA00M8MW.pdf.

USAID. Biodiversity How-to Guide 3: Defining Outcomes & Indicators for Monitoring, Evaluation, and Learning in USAID Biodiversity Programming. August 2016. https://usaidlearninglab.org/sites/default/files/resource/files/biodiversity_howtoguide3_508.pdf.

USAID. Climate Risk Screening and Management Tool. https://www.climatelinks.org/resources/climate-risk-screening-management-tool.

USAID. Climate Risk Screening and Management Tool – Environment and Biodiversity Annex. https://www.climatelinks.org/sites/default/files/2017-05-24%20USAID%20CRM%20Tool%20Environment%20and%20Biodiversity%20Annex.pdf.

USAID. Sustainable Fisheries and Responsible Aquaculture: A Guide for USAID Staff and Partners. http://www.crc.uri.edu/download/FishAquaGuide14Jun13Final.pdf.

USAID. Sustainable Ocean Fund. https://rmportal.net/biodiversityconservation-gateway/legality-sustainability/fisheries-development/project-search/add-a-project-activity/sustainable-ocean-fund.

ANNEX 1. EXAMPLES OF RECENT AND ONGOING USAID FISHERY AND AQUACULTURE PROJECTS

TABLE 9. EXAMPLES OF RECENT AND ONGOING FISHERY PROJECTS

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
Global	Seafood Alliance for Legality and Traceability (SALT)	• Global alliance for knowledge exchange and action • Promote legal and sustainable fisheries • Improve transparency of aquatic food supply chains	Biodiversity	2017–2020
Global	Save Our Seas Initiative	• Combat ocean plastic pollution	Save Our Seas Act 2.0	2022-ongoing
AFRICA				
Malawi	Fisheries Integration of Society and Habitats (FISH)	• Biodiversity conservation for human well-being • Improved management of freshwater lakes and fisheries • Food security and livelihoods • Resilience to climate change • Sustainable fisheries co-management	Biodiversity, Global Climate Change Adaptation (Malawi Economic Growth Office)	2014–2019
Malawi	Restoring Fisheries for Sustainable Livelihoods in Lake Malawi (REFRESH)	• Improved ecosystem-based fisheries management • Improved fish stock assessments and data management • Strengthening decentralized fisheries co-management and governance • Gender empowerment	Biodiversity, Capture Fisheries Management	2019-2024

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
Ghana	Ghana Sustainable Fisheries Management Project	• Food security, nutrition, and livelihoods • Coastal fisheries governance and management • Rebuild target fish stocks (especially small-scale pelagic fisheries	Biodiversity Feed the Future (Ghana Economic Growth Office)	2014–2019
Ghana	Ghana Fisheries Recovery Activity (GFRA)	• Improve small-scale pelagic fisheries management • Reduce fishing overcapacity • Food security, socioeconomic well-being, and resilience of coastal communities	Feed the Future	2021-2026
Senegal	Collaborative Management for a Sustainable Fisheries Future in Senegal (COMFISH Plus)	• Food security and sustainable livelihoods • Improve governance and co-management of fisheries • Reduce illegal fishing • Gender empowerment	Biodiversity Feed the Future (Senegal Economic Growth Office)	2016–2018
Regional West Africa	West Africa Biodiversity and Integrated Climate Change	• Capacity building for law enforcement officials • Sustainable livelihoods • Coastal resilience	Biodiversity, Global Climate Change, Sustainable Landscapes (West Africa Economic Growth Office)	2015–2020
Somalia	Growth, Enterprise, Employment & Livelihoods	• Economic growth and jobs • Capacity building for sustainable fishery management • Combat illegal fishing	Biodiversity Economic Support Fund (USAID/East Africa, Somalia Unit)	2015–2020

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
		• Reduce reliance on inputs		
LATIN AMERICA AND CARIBBEAN (LAC)				
Regional	Central America Regional Biodiversity Coastal Project	• Improve management of biodiversity for secure livelihoods and national security • Increase resilience to climate change • Sustainable natural resources use	Biodiversity	2018–2023
Regional	Caribbean Marine Biodiversity Program	• Marine Protected Area management and governance • Fisheries governance and management • Reduce threats to biodiversity to maintain ecosystem services and improve human well-being	Biodiversity	2014–2019
Ecuador	Strengthening Natural Resource Governance in Ecuador (SNRGE)	• Combat illegal, unreported, and unregulated (IUU) fishing • Improved governance of fisheries resources	Biodiversity	2020-2024
Peru, Ecuador, and Colombia	Partnership for Sustainably Managed Fisheries	• Enforce domestic and international fisheries regulations and prevent IUU fishing • Sustainable fisheries management	Capture Fisheries Management	2022-2026
ASIA				
Indonesia	Sustainable Ecosystems Achieved	• Improve livelihoods, food security, and nutrition • Strengthen	Biodiversity Feed the Future	2015–2020

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
		fisheries and coastal governance • Maintain the productivity of fisheries • Marine protected area management • Combat illegal fishing		
Indonesia	Assistance to National Illegal, Unreported, and Unregulated Task Force	• Combat illegal and unreported fishing • Strengthen national capacity and security	USAID and Government of Indonesia partnership with INTERPOL	2016–2019
Philippines	Ecosystems Improved for Sustainable Fisheries (ECOFISH)	• Food security, nutrition, and livelihoods • Coastal fisheries and management • Improve governance and access • Ecosystem-based management • Improve the productivity and profitability of fisheries	Biodiversity (Philippines Economic Growth Office)	2012–2017
Philippines	Fish Right	• Sustainable use/resilience of critical coastal and marine resources • Sustainable fishery management	Biodiversity	2018–2023
Philippines	Sustainable Interventions for Biodiversity, Oceans, and Landscapes (SIBOL)	• Sustainable natural resource governance • Reduce environmental crimes and unsustainable practices	Biodiversity	2020-2025
Regional	Oceans and Fisheries Partnership (OCEANS)	• Sustainable fishery management • Catch documentation	Biodiversity (Regional Development Mission for Asia)	2015–2020

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
		and traceability • Reduce illegal fishing and trade in illegally caught products • Industry and market incentives • Governance and management • Fostering constituencies and political will • Transparency		
Bangladesh	Enhanced Coastal Fisheries (ECOFISH–Bangladesh)	• Community-based wild fishery management • Food security and nutrition • Fish sanctuaries • Livelihood development	Biodiversity	2014–2019
Bangladesh	Enhanced Coastal Fisheries in Bangladesh II (ECOFISH II)	• Combat illegal, unreported, and unregulated (IUU) fishing • Improved management and governance of natural resources • Food security, nutrition, and livelihoods	Biodiversity	2020-2025
Pacific Island Nations	OurFish OurFuture	• Combat illegal, unreported, and unregulated (IUU) fishing • Improved governance and increased stakeholder engagement	Feed the Future	2021-2026

TABLE 10. EXAMPLES OF RECENT AND ONGOING AQUACULTURE RESEARCH (AQUAFISH INNOVATION LAB) PROJECTS

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
AFRICA				
Kenya **Uganda**	Aquaculture Development in Kenya and Uganda: Advancing Cost-Effective Technology, Market Assessment, and End-User Engagement	• Livelihoods • Small-scale aquaculture • Supply/Value chain analysis • Gender capacity building	Feed the Future (USAID Bureau of Food Security)	2013–2018
Ghana **Tanzania**	Aquaculture Development and the Impact on Food Supply, Nutrition, and Health	• Human health and nutrition • Food quality and safety • Sustainable fish feed • Value chain analysis • Pond aquaculture	Feed the Future (USAID Bureau of Food Security)	2013–2018
ASIA				
Bangladesh	Enhancing Aquaculture Production Efficiency, Sustainability, and Adaptive Measures to Climate Change Impacts	• Food security • Sustainable aquaculture • Livelihoods • Climate change adaptation • Capacity building	Feed the Future (USAID Bureau of Food Security)	2013–2018
Burma	Sustainable Inland Fisheries for Burmese Food Security in an Era of Global Change	• U.S.-based desk study with existing data • Role of inland fisheries and aquaculture in nutrition and food security • Climate risk assessment	Feed the Future (USAID Bureau of Food Security)	2016–2018
Cambodia **Vietnam**	Improving Food Security, Household Nutrition, and Trade Through Sustainable Aquaculture and Aquatic Resource Management	• Food security • Sustainable freshwater aquaculture • Livelihoods • Climate change adaptation • Aquatic resource management • Snakehead aquaculture • Value-added processing	Feed the Future (USAID Bureau of Food Security)	2013–2018

COUNTRY	PROJECT NAME	FOCUS AREA(S)	FUNDING TYPE	TIME FRAME
		techniques • Gender		
Nepal	Advancing Aquaculture Systems in Nepal for More Social and Environmental Sustainability	• Food security • Small-scale aquaculture • Pond polyculture • Supply chain (seed source)	Feed the Future (USAID Bureau of Food Security)	2013–2018
Bangladesh, Kenya, Nigeria, and Zambia	Feed the Future Innovation Lab for Fish	• Improve nutrition, food security, and livelihoods • Increase the climate resilience of fisheries and other aquatic food systems	Feed the Future	2018-2022

ANNEX 2. AQUATIC ECOSYSTEM GOODS AND SERVICES, AND THE ASSOCIATED ADVERSE EFFECTS FROM CAPTURE FISHERIES AND AQUACULTURE

TABLE 11. EXAMPLES OF ECOSYSTEM SERVICES AND ASSOCIATED ADVERSE EFFECTS FROM FISHERIES AND AQUACULTURE

	FISHERIES		AQUACULTURE-MARICULTURE	
ECOSYSTEM GOODS AND SERVICES TYPES	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
Food	Fish, shellfish, and seaweed for human consumption as food	Overfishing and bycatch may degrade the ecological and economic viability of the fishery, reducing natural productivity and food security, and reducing genetic diversity, reproductive rates, or growth and maturation processes. All of which threaten ongoing food security. Abandoned fishing gear (e.g., ghost nets), collisions with sea life, and the use of toxic substances (e.g., cyanide) also may degrade food webs.	Fish, shellfish, and seaweed for human consumption as food	Introduction of exotic or invasive species may lead to direct predation on commercially or culturally significant species. Overharvesting of lower level aquatic food web species (e.g., krill, anchovies, sardines) for feedstock may degrade ocean ecosystems.
Medicinal Resources	Marine-derived pharmaceuticals		Marine-derived pharmaceuticals (e.g., carrageenan)	
Ornamental Resources	Shells, pearls, aquarium fish, or coral		Shells, pearls, aquarium fish, or coral	
Energy and Raw Materials	Algae used for non-food purposes (e.g., fertilizer, energy)		Algae used for non-food purposes (e.g., fertilizer, energy)	
Water Storage			Aquaculture ponds may retain water for irrigation during dry seasons.	Aquaculture ponds may remove or divert water from natural systems and human use.

ECOSYSTEM GOODS AND SERVICES TYPES	FISHERIES		AQUACULTURE-MARICULTURE	
	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
Air Quality	The oceans produce 50 percent of the oxygen we breathe.	Motor vessels (especially diesel) produce pollutants such as nitrous oxides and fine particulate matter that negatively affect air quality.	Healthy coastal ecosystems purify the air of contaminants (e.g., dust, foul odors).	Overstocking may generate excess ammonia and other odors. Abandoned aquaculture ponds may produce windblown fine particulates from dried pond bottoms.
Biological Control	Resilient food webs sustain high- value species and control opportunistic species.	Overfishing and bycatch of some predator species may allow opportunistic species, such as jellyfish or squid, to thrive.	Rice-fish polycultures provide pest control as the fish feed freely in flooded fields. The filtering of coastal water by shellfish may reduce pathogen populations.	Impacts on species that limit populations of opportunistic species, such as jellyfish or squid. Sewage-fish aquaculture and overstocking in both pond and open pens may allow pathogenic organisms to thrive.
Climate Stability	Marine ecosystems are large components of the global hydrological cycle, extra-regional weather patterns, and local and regional climate (e.g., moderating temperatures).		Both marine and freshwater ecosystems often influence local and regional climates (e.g., moderating temperatures).	Degrading or destroying mangrove ecosystems leads to large losses of stored carbon.
Disaster Risk Reduction	Coral reefs, mangrove forests, and kelp forests dampen and attenuate waves, reducing breaking wave velocity.	Overfishing can reduce the resilience of coral reefs; mangroves can be overharvested	Coastal communities face reduced storm surge where coral reefs, mangrove forests, kelp forests, and other coastal	Degrading or destroying coral reefs, mangrove forests, and other coastal ecosystems reduces storm

ECOSYSTEM GOODS AND SERVICES TYPES	FISHERIES		AQUACULTURE-MARICULTURE	
	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
		for fish smoking and processing; kelp may be overharvested ; and disruptions to the food web may allow aggressive feeders (e.g., sea urchins) to decimate kelp ecosystems.	ecosystems remain intact.	surge protection for coastal communities.
Dispersal of Genetic Materials and Ambient Fertilization	Dispersal of gametes, larvae, and angiosperm by currents and tides supports basic reproductive processes and intra-species diversity.	Disruptions to local currents (e.g., overharvesting kelp) may affect the reproductive processes of other species.	Dispersal of gametes, larvae, and angiosperm by surface water supports basic reproductive processes and intra-species diversity.	Disruptions to local currents (e.g., diversions, artificial ponds) may affect the reproductive processes of other species.
Soil Formation	Detritus (e.g., whale falls) and other nutrients support benthic food webs.	The removal of wetlands and dredging for navigation may disrupt soil formation processes in both wetlands and benthic systems.	Detritus and other nutrients support benthic food webs.	Degrading or destroying mangrove and other wetland ecosystems disrupts soil-building processes.
Soil Quality		Nutrient cycling within ocean sediments may be affected by dredging and trawling.	Integrated, extensive agriculture-aquaculture systems (e.g., rice-fish polycultures) contribute nutrients directly to agricultural soils. Irrigation from nutrient-rich aquaculture ponds	Excess waste below fish pens may create anoxic benthic conditions. Irrigation from brackish aquaculture ponds may salinize or acidify agricultural soils.

ECOSYSTEM GOODS AND SERVICES TYPES	FISHERIES		AQUACULTURE-MARICULTURE	
	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
			also may contribute to soil fertility.	
Soil Retention	Coral reefs and calcareous algae supply sand for beaches and tourism.	Coastal kelp forests reduce the sand-scouring potential along the coasts.		Degrading or destroying mangrove and other wetland ecosystems may cause significant erosion.
Water Quality	Nutrient cycling in ocean waters supports healthy marine habitats.	Shipwrecks and spills (e.g., fuel, oil) may degrade water quality locally or regionally.	The filtering of coastal water by shellfish can improve water quality in healthy marine habitats.	May contribute excess nutrients, leading to groundwater pollution, algal blooms, and eutrophication, reducing dissolved oxygen in both natural and cultivated systems. Suspended solids may also degrade water quality. Health risks from algal blooms may be concentrated and extended by shellfish populations.
Water Capture, Conveyance, and Supply	Tides move water throughout intertidal zones, supporting intertidal species and habitat.	Changes to aquatic vegetation may affect local currents and surface water flows.	Surface water flows are a major source of water for all terrestrial uses.	Infrastructure (e.g., diversions, impoundments) has a direct effect on surface water flows.

ECOSYSTEM GOODS AND SERVICES TYPES	FISHERIES		AQUACULTURE-MARICULTURE	
	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
Navigation		Lost fishing gear (e.g., ghost nets) may reduce the natural productivity of habitats, foul boat propellers, or even present a navigational hazard.		Coastal pens, especially degraded or abandoned pens, may present navigation hazards.
Habitat and Nursery	Habitat is critical to sustaining resilient populations of fish, shellfish, and seaweed, including species that may not have direct economic or cultural value, but which are important to ecosystem function overall. Species may live in multiple habitats during their full lifecycle; habitat for adults often differs from breeding and nursery habitat(s) for the same species.	Lost fishing gear (e.g., ghost nets) may create hazards within critical habitat, including reefs and ocean banks. Similarly, the use of toxic substances (e.g., cyanide) degrades habitat. The destruction of reefs, shoals, and inshore habitat may harm critical breeding and nursery habitat for commercial and other critical species. Trawling may damage habitat for the lower level aquatic food web (e.g., eelgrass, benthic communities) that supports	Habitat is critical to sustaining resilient populations of fish, shellfish, and seaweed, including species that may not have direct economic or cultural value, but which are important to ecosystem function overall. Species may live in multiple habitats during their full lifecycle; habitat for adults often differs from breeding and nursery habitat(s) for the same species.	Exotic/invasive species may outcompete commercially or culturally significant species. Excess nutrients from intensive systems may degrade natural habitat (eutrophication). The destruction of reef, coastal, and inshore habitat may harm critical breeding and nursery habitat. Dredging may damage habitat for the lower level aquatic food web (e.g., eelgrass, benthic communities) that supports the food chain.

ECOSYSTEM GOODS AND SERVICES TYPES	FISHERIES		AQUACULTURE-MARICULTURE	
	ECOSYSTEM GOODS AND SERVICES FROM MARINE ENVIRONMENTS	ADVERSE EFFECTS	ECOSYSTEM GOODS AND SERVICES FROM COASTAL AND FRESHWATER ENVIRONMENTS	ADVERSE EFFECTS
		the food chain.		
Aesthetic Information	Views of healthy marine and coastal ecosystems are highly valued.	Protecting coral reefs and beaches that appeal to individual observers.	Views of healthy coastal and freshwater ecosystems are highly valued.	Protecting coral reefs, beaches, and wetlands that appeal to individual observers.
Cultural Value	Subsistence or traditional use of fish, shellfish, and seaweed Traditional livelihoods	Overharvesting for commercial markets may degrade or destroy traditional livelihoods.	Traditional agriculture-aquaculture systems (e.g., rice-fish polycultures)	Aquaculture may displace or outcompete traditional livelihoods.
Recreation and Tourism	Fishing as a pastime; fishing culture as tourism attraction	Impacts on bird or whale watching, SCUBA diving, sailing, etc.	Fishing as a pastime; fishing culture as tourism attraction	Potential impacts on nature-based tourism (e.g., pollution, habitat degradation); impacts on charismatic species
Science and Education	Research on marine ecosystems informs engineering and education.		Research on aquatic ecosystems informs engineering and education. Aquaculture systems are researched for their innovation potential, as well as the monitoring of externalities.	