RESEARCH PROGRAM ON Fish

Led by WorldFish

Photo credit: Aminul Islam/WorldFish

Accelerating climate resilience of aquatic food systems

Global climate change impacts the food, land and water systems upon which life depends. Aquatic foods – animals, plants and microorganisms harvested and grown in water – play a significant role in sustainably feeding and nourishing the world, but are increasingly impacted by climate change through gradual warming, ocean acidification and changes in the frequency, intensity and location of extreme events.

Aquatic food systems, including marine, brackish and freshwater ecosystems, fisheries and aquaculture production systems, and the many and diverse value chain actors, are especially vulnerable to the impacts of climate change.[1] By 2100, marine and freshwater fisheries and freshwater aquaculture in all countries are expected to face high levels of climate threat,[2] with low-income countries experiencing the most significant risk to health, equity and sustainability as a result.[3] This disproportionate impact is partly due to the spatially variable impacts of climate change.[4] Ocean warming, for example, forces marine species to migrate toward the poles to cooler waters.[5] As a result, tropical marine fish supplies are highly vulnerable and the redistribution of global fish catch potentials are expected to favor temperate regions over tropical regions.[6] This shift in "aquatic wealth" is projected to severely impact food availability in low- and middle-income countries. While climate mitigation activities can reduce these risks, such negative outcomes cannot be entirely prevented given that a certain degree of climate change is unavoidable.

Despite the global importance of aquatic food systems, there has been insufficient attention by policymakers in climate-related policies (e.g. Nationally Determined Contributions, National Adaptation Plan of Actions). This has been further exacerbated by a chronic investment gap in addressing climate change. The CGIAR Research Program on Fish Agri-Food Systems (FISH) has developed innovations that respond to the climate challenge and evidence to inform policy and investment decisions that build resilience of aquatic food systems. FISH's work focused on low- and middle-income countries in Africa, Asia and the Pacific, where there is the highest concentration of vulnerable fisheries- and aquaculture-dependent communities and where the consequences of continued inaction will be catastrophic.

Building resilience of aquatic food systems

Traditional climate change adaptation interventions have often focused on short-term coping mechanisms, but resilience requires enhancing the ability of small-scale actors in aquatic food systems and fisheries- and aquaculture-dependent communities to withstand shocks and cope with future climate risks. Critical policies, investments and social networks are instrumental to their success.[7] FISH research and innovation identified four key components for climate resilient aquatic food systems:

1. reduced vulnerabilities by reducing risk and exposure to hazards
2. increased ability to predict or anticipate climate hazards
3. enhanced capacity to respond to climate hazards
4. increased availability and accessibility of viable livelihood opportunities.

Key messages

- Climate change impacts on aquatic food systems place vulnerable communities with limited adaptive capacities at most risk. Policy and investment interventions require a positive bias in favor of the most vulnerable.
- Building resilient aquatic food systems requires a holistic approach that reduces exposure to climate hazards, increases ability to predict and capacity to respond to hazards, and ensures availability of viable livelihood opportunities.
- Access to climate information services for aquatic food system actors is critical for securing livelihoods, food and nutrition security, and sustainability goals under climate change.
- Aquatic food systems offer diverse options for viable and inclusive livelihoods, many of which can be positive for nature and people, such as seaweed farming or integrated rice-fish systems.
- Aquatic food systems generate less greenhouse gas emissions than terrestrial food systems; however, there is scope for continued innovation to shift aquatic food systems toward a more sustainable and equitable future.
- Climate change interventions must recognize diversity among aquatic food system actors and their communities, and ensure marginalized actors are included and equity is a priority.

Action framework for climate resilient aquatic food systems

What needs to change

Fisheries- and aquaculture-dependent communities are among the most **vulnerable** to the impacts of climate change and are exposed to multiple climate risks.

Small-scale actors in aquatic food systems have **limited capability** to predict and respond to climate hazards.

There have been **limited policy and investment interventions** in creating viable livelihood opportunities for aquatic food system actors living in poverty.

Outcomes

Poverty
Reduced vulnerabilities to climate and economic shocks lead to increased benefits from enhanced food and nutritional security, and employment and income opportunities.

Environment
Climate-aware investment and policy interventions lead to improved aquatic resources management—the primary asset of people living in poverty.

Equity
Investment and policy interventions in climate resilience benefit those who are furthest behind.

1. Reduce vulnerabilities by reducing risk and exposure to hazards

Transformation of aquatic food systems to greater resilience involves reduction of climate risks through management of hazards, exposure and vulnerability. FISH research has drawn attention to the fact that improving adaptive capacity requires actions across multiple domains, including (i) assets people can draw upon in times of need, (ii) flexibility to change strategies, (iii) ability to organize and act collectively, (iv) learning to recognize and respond to change, and (v) agency to determine whether to change or not.[8] In other words, a systems approach is required. While infrastructure is commonly prescribed for minimizing climate risks, addressing risks to fisheries and aquaculture is particularly suited for nature-based approaches, including seaweed farming, rice field fisheries, mangrove regeneration and coral reef restoration, measures that are often less disruptive to the environment and more locally sustainable (Box 1).[9]

2. Increase ability to predict or anticipate climate hazards

Climate variability affects aquatic food systems in multiple ways, including higher water temperatures uninhabitable for some species, rapid temperature fluctuations leading to fish mortality, and erratic or intense rainfall events that cause harvest losses. Increasing access to climate information and quality forecasts tailored to aquatic food systems can empower producers and other value chain actors to manage risks. However, contextualized services for aquatic food systems using timely and reliable climate information are scarce. To begin addressing this, FISH collaborated with partners in Bangladesh and India to improve climate information services for fish farmers, and have begun scaling these services in both countries (Box 2). Innovations in fish stocking times, species selection, harvesting and pond management have been shown to offer practical options for farmers to manage risks. These experiences provide the foundation for new climate information services to better secure aquatic food systems in an increasingly variable climate.

3. Enhance capacity to respond to climate hazards

The ability of aquatic food system actors to predict climate hazards must be complemented with enhanced capacity to respond to or minimize climate-induced disaster risks. In Bangladesh, for example, FISH and partners have trained key value chain actors, who have further disseminated the knowledge to fish farmers and support agents (fish farm managers, hatchery managers, fish breeding professionals), on managing climate risks. To scale this further, FISH is collaborating with other projects and partners. For instance, the "Aquaculture: Increasing Income, Diversifying Diets and Empowering Women in Bangladesh and Nigeria (IDEA)" project has adapted training materials on managing climate risks in aquaculture operations. Training is expected to reach 200 local service providers and equip them to provide advice and material inputs (e.g. lime to reduce acidity of pond water) for managing climate risks to their client base, about 200 fish farmers for each provider.

Box 1. Seaweed farming as a nature-based approach in Bangladesh

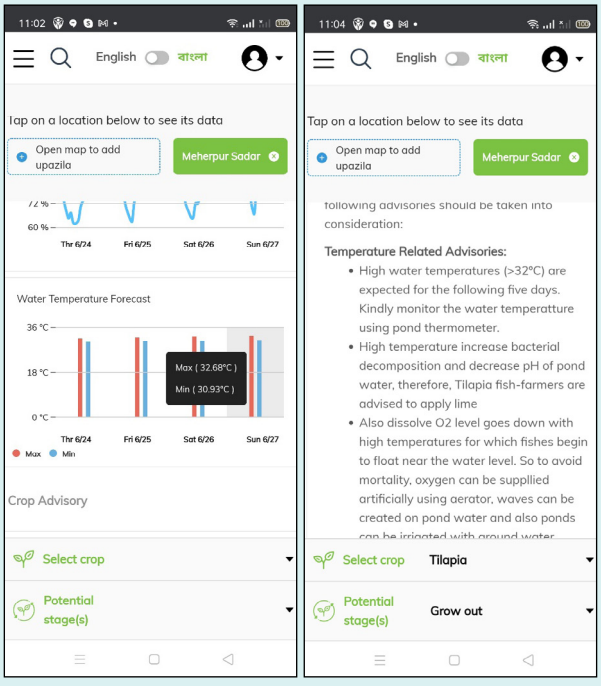
Seaweed farming is increasingly showing potential to mitigate climate change (carbon sequestration, low-carbon food production) and contribute to adaptation and resilience (protect shorelines, manage local ocean acidification and de-oxygenation).[10] In Bangladesh, seaweed farming shows promise as 200 species of seaweed have been identified, 10 of which are considered commercially important. In the coastal waters of Cox's Bazar, edible species of seaweed fall under three major categories (i) green seaweed (*Caulerpa* sp., *Ulva* sp., *Enteromorpha* spp.), (ii) red seaweed (*Hypnea* sp., *Gracilaria* spp., *Gelidium* sp.) and (3) brown seaweed (*Padina* sp., *Sargassum* spp).

In a new initiative to reduce climate vulnerability and create employment and income opportunities, FISH and partners are supporting women and youths involved in seaweed farming in coastal regions of Bangladesh. Coastal seaweed farming using nets or longlines is often labor intensive but requires low capital investments and uses simple farming technology, allowing for the participation of poor people.[11] After seedlings are attached to nets or ropes and placed in clean, stable saline water, a first harvest can be made within 15 days. After harvest, wet seaweed is sold in local markets and dried seaweed, or other value-added products, can be sold in both domestic and international markets. Preliminary research reveals that for every USD 1 invested, seaweed farmers can earn up to USD 11.[12] Local seaweed production may also help diversify diets, provide food and shelter for juvenile marine aquatic species, sequester carbon, and reduce eutrophication. Such nature-based approaches provide new opportunities to equitably address the triple challenges of poverty, biodiversity loss and climate change.

However, financial exclusion of fish farmers inhibits their ability to pay for goods and services to manage climate risks. To overcome this challenge, the IDEA project is facilitating institutional arrangements to ensure fish farmers have access to financial services and products. Therefore, enhancing capacity of fisheries- and aquaculture-dependent communities to respond to climate risks requires a systems approach that involves various actors, sectors, constraints, capacities and incentives.

Box 2. Local climate information services for aquaculture in Asia and Africa

A collaboration between FISH and the CGIAR Research Program on Climate Change, Agriculture and Food Security has explored the application of climate information services in aquatic food systems in Bangladesh and India. A new web-based interface for authentic, localized, timely, actionable and simple climate information services was developed for fish farmers in Bangladesh and is now hosted on Agvisely. This system translates weather information into a decision-making tool for fish farmers to reduce associated climate risks. The system is based on a decision framework on temperature and rainfall thresholds for the grow-out phase of four widely cultivated and economically important fish species in Bangladesh (tilapia, rohu, banga, golda), with local-level data from the Bangladesh Meteorological Department and water temperature from reference ponds. Automated processing of the input data triggers the decision framework to generate advisories for farmers in response to the forecasted climatic situation. By providing relevant climate information and equipping farmers with tools to respond, this novel system helps farmers manage risks related to temperature and rainfall variability in day-to-day aquaculture operations. The new climate information services have been progressively extended to 1000 fisheries extension workers in Bangladesh with an expectation of reaching 100,000 fish farmers in 2021. The knowledge and experience have also been adapted in the State of Odisha, India, where climate advisories have been integrated into a mobile phone advisory system. The approach is also being applied in Zambia and the Southern African Development Community, where it is expected to help improve the capacity of fish farmers to predict and manage local climate risks in that region.



4. Increase availability of viable livelihood opportunities

An inclusive, sustainable and cost-effective way of building resilience of fisheries- and aquaculture-dependent communities is identifying and increasing access to viable livelihood opportunities.[13] FISH has explored a diversity of innovations with promise, including integrated rice-fish systems, genetically improved tilapia strains, climate risk management practices for fish and shrimp farms in the Mekong Region, and low-carbon tilapia farm management in Egypt, that demonstrate encouraging employment and income opportunities (Box 3).

Livelihood opportunities under a changing climate can be viewed along analogous pathways, either immanently, where biophysical changes will favor some production systems, or intentionally, through significant investment in identifying and creating new viable livelihood opportunities.[14] Enhanced understanding of both immanent (passive) and intentional (active) pathways under climate change can aid policy and investment interventions needed for securing viable and inclusive aquatic food system livelihoods.

Box 3. Integrated rice-fish production offers a viable livelihood opportunity in Southeast Asia

FISH innovations are not limited to new practices, as researchers have also explored the vast potential of traditional and indigenous knowledge when revitalizing sustainable practices, such as integrated rice and fish systems in Cambodia and Myanmar. Rice-fish systems, which over the past decades have been replaced by monoculture rice production, have been proven to increase production and profits as well as improve livelihoods and food and nutrition security.[15] Co-production of fish in rice fields has been shown to enhance water and land use efficiency, reduce climate-induced risks like crop failure, be adaptable for diverse fish species, including temperature and salinity tolerant species, help rehabilitate degraded landscapes, and as such, offer a viable livelihood opportunity under changing climate. Between 2016 and 2020, the 4854 farmers in Cambodia who adopted improved rice-fish systems have experienced 60 percent and 27 percent increases in income and fish consumption, respectively.[16] This integrated production system has opened a new frontier for climate-resilient aquatic food production in Cambodia and Myanmar.[17]

The way forward

In addition to enhancing our understanding of the impacts of climate change on aquatic food systems, FISH research has produced inclusive, sustainable and cost-effective approaches to reduce vulnerabilities, enhance abilities to predict and respond to climate hazards, and identify viable livelihood opportunities under climate change. The research has also revealed key areas for attention in building and sustaining climate resilient aquatic food systems into the future.

- Aquatic food systems are complex, non-linear systems with diverse actors, networks and interactions. Therefore, **responses to climate change impacts on aquatic food systems** and the implications for ecological, economic and social systems can only be **understood with an integrated systems approach**. Collectively a shift toward a more holistic approach that accounts for multiple systemic challenges, including governance, market systems and financing, is essential to achieve impact at scale.
- Aquatic food systems can generate less greenhouse gas emissions than terrestrial food systems, but there is scope for further reductions as negative externalities increase burdens on fisheries- and aquaculture-dependent communities, constrain

sustainable development, and exacerbate poverty and resource use conflicts. Therefore, more focus is needed on **identifying emission mitigation opportunities** to move aquatic food systems toward a more sustainable and equitable future **and ensuring aquatic food systems are integrated in national climate policies**. To this end, FISH and partners have developed a digital prototype, FishScores, to monitor environmental impacts of aquaculture systems. Once scaled and widely disseminated, it can play an important role in filling critical data gaps and identifying intervention points to put aquatic food systems on a low emission pathway.

- **Climate change policies and investments must recognize diversity** among aquatic food system actors and their communities. In particular, FISH found that climate change policy engagement with gender equality remains hampered by assumptions that limit effectiveness and fairness. Pursuing evidence-based gender transformative approaches at all scales, investing time and resources in gender research, program design, monitoring and evaluation, and engaging with good practices along all nodes of aquatic food systems are **critical to ensuring gender equality and social equity in climate change work**.
- While most climate resilience interventions aim to achieve ecological, economic and social gains, they often fail to deliver a "net political gain" as determined by complex value preferences of key actors and decision-makers. **Solutions that require public sector investments**, and research informing them, must recognize the **need to deliver social, ecological and political gains to be an acceptable option** to the public-choice maker. Development and standardization of an underpinning framework that considers political outcomes alongside ecological, economic and social outcomes is a key step to connecting climate resilience research and policy in practice.

Notes

[1] Barange M, Bahri T, Beveridge MCM, Cochrane KL, Funge-Smith S and 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 pp.

[2] Tigchelaar M, Cheung WWL, Mohammed EY, Phillips MJ, Payne HJ, Selig ER, Wabnitz CCC, Oyinlola MA, Frölicher TL, Gephart JA et al. 2021. Compound climate risks threaten aquatic food system benefits. *Nature Food* 2:673–82. doi: 10.1038/s43016-021-00368-9

[3] Lam VWY, Cheung WWL, Reygondeau G and Sumaila UR. 2016. Projected change in global fisheries revenues under climate change. *Scientific Reports* 6:32607.

[4] Asch RG, Cheung WWL and Reygondeau G. 2018. Future marine ecosystem drivers, biodiversity, and fisheries maximum catch potential in Pacific Island countries and territories under climate change. *Marine Policy* 88:285–94.

[5] Pecl GT, Ward TM, Doubleday ZA, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday AJ, Hutchinson N et al. 2014. Rapid assessment of fisheries species sensitivity to climate change. *Climatic Change 127:505–20*. doi: 10.1007/s10584-014-1284-z

[6] Barange M, Merino G, Blanchard JL, Scholtens J, Harle J, Allison, E. H., Allen JI, Holt J and Jennings S. 2014. Impacts of climate change on marine ecosystem production in societies dependent on fisheries. *Nature Climate Change 4:211–16*. doi: 10.1038/nclimate2119

[7] Holling CS. 1996. Engineering resilience versus ecological resilience. *In* Shulze P, ed. Engineering within ecological constraints. Washington, DC: National Academy Press. 31–44.

[8] Cinner JE, Adger WN, Allison EH, Barnes ML, Brown K, Cohen PJ, Gelcich S, Hicks CC, Hughes TP and Lau J et al. 2018. Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change* 8:117–23. doi: 10.1038/s41558-017-0065-x

[9] IPCC. 2012. *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*. Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner G-K, Allen SK et al., eds. Cambridge and New York: Cambridge University Press. 582 pp.

[10] Duarte CM, Wu J, Xiao X, Bruhn A and Krause-Jensen D. 2017. Can seaweed farming play a role in climate change mitigation and adaptation?. *Frontiers in Marine Science 4:100*. doi: 10.3389/fmars.2017.00100

[11] Cai J, Lovatelli A, Aguilar-Manjarrez J, Cornish L, Dabbadie L, Desrochers A, Diffey S, Garrido Gamarro E, Geehan J, Hurtado A et al. 2021. Seaweeds and microalgae: An overview for unlocking their potential in global aquaculture development. FAO Fisheries and Aquaculture Circular No. 1229. Rome: FAO. doi: 10.4060/cb5670en

[12] Available on request.

[13] Islam MM. 2013. Vulnerability and adaptation of fishing communities to the impacts of climate variability and change: Insights from coastal Bangladesh. [PhD thesis] University of Leeds, UK.

[14] Morse S and McNamara N. 2013. Sustainable Livelihood Approach: A critiques of Theory and practice. Springer XVIII,190P

[15] Freed S, Barman B, Dubois M, Flor RJ, Funge-Smith S, Gregory R, Hadi BA, Halwart M, Haque M, Jagadish SV and Joffre OM. 2020. Maintaining diversity of integrated rice and fish production confers adaptability of food systems to global change. Frontiers in Sustainable Food Systems 4:207. doi: 10.3389/fsufs.2020.576179

[16] WorldFish. In prep. Feed the Future: Cambodia Rice Field Fisheries II Final Report. Phnom Penh, Cambodia: Feed the Future.

[17] See the FISH strategic brief "Integrated rice and fish systems" for more information.

Authors
Essam Yassin Mohammed,[1] Peerzadi Rumana Hossain,[1] Jacqueline Lau,[2] Md Abdul Wahab,[1] Malcolm C. M. Beveridge[1] and Nisha Marwaha[1]

Affiliations
[1] WorldFish
[2] James Cook University

Acknowledgments
This strategic brief is published by the CGIAR Research Program on Fish Agri-Food Systems (FISH), led by WorldFish in partnership with the International Water Management Institute, Wageningen University & Research, James Cook University and the University of Greenwich. FISH is a multidisciplinary research for development program designed in collaboration with partners and stakeholders to develop and implement research innovations that enhance the contribution of small-scale fisheries and aquaculture to reducing poverty, increasing food and nutrition security, and improving natural resource systems. Please visit fish.cgiar.org for more information.

This brief is one in a series of synthesis products published in 2021 to share learnings, outcomes and impacts from the FISH program. It is intended to stimulate actions and investments into fish and aquatic foods to realize their role in the transformation of food, land and water systems in a climate crisis. We extend thanks to all the contributors of this research and the reviewers of this brief.

This is a contribution to the following:

Citation
This publication should be cited as: Mohammed EY, Hossain PR, Lau J, Wahab MA, Beveridge MCM and Marwaha N. 2021. Accelerating climate resilience of aquatic food systems. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems. Program Brief: FISH-2021-16.