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Accelerating Transformation in Aquatic Food Systems through Holistic and Inclusive Innovation

Building and Strengthening Innovation Ecosystems

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Background Paper for the Science-Policy Lab on Innovations for Sustainable Aquatic Food Systems

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About the Science-Policy Lab

The Science-Policy Lab on Innovations for Sustainable Aquatic Food Systems, to be held on December 8-10 in Cape Town, South Africa, aims to bring together representatives from academia, government, the private sector, and civil society to collaboratively develop recommendations for building and strengthening inclusive and equitable innovation ecosystems in aquatic food systems.

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For more information, please visit:
https://www.slu.se/en/collaboration/international/slu-global/projects-and-themes/programmes/sasi-spi/

The **African Interdisciplinary Laboratory in Sustainable, Nutrition-Sensitive Marine Aquaculture (LIMAQUA)** is SASi-SPi's partner in producing this background paper and co-organizing the Science-Policy Lab in South Africa. LIMAQUA conducts an interdisciplinary research and training programme to tackle nutritional and sustainability challenges of aquatic food systems in the region. Based in South Africa, the laboratory is led by the South African Department of Forestry, Fisheries and the Environment (DFFE) and the French National Research Institute for Sustainable Development (IRD).
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1. Introduction

Aquatic foods, including fish, invertebrates, and algae, play a crucial role in ensuring food security and nutrition for billions of people, providing 15% of the total animal protein and 6% of all proteins consumed worldwide (FAO, 2024). Besides being a source of healthy proteins, aquatic foods are the main source of essential omega 3 fatty acids, such as docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), and are critical sources of micronutrients, including iron, zinc, calcium and vitamins (Golden et al., 2021). They are highly diverse, with currently more than 2370 taxa harvested from the wild and over 600 species or species types cultured, and their nutritional profiles vary across species (Golden et al., 2021). Compared with terrestrial animals, aquatic food species perform better in terms of environmental stressors such as greenhouse gas, nitrogen, and phosphorus emissions, as well as land and water use (Gephart et al., 2021). Combined with their higher nutritional value, aquatic foods represent nutrient-dense food sources with a lower environmental footprint, supporting pathways to healthy and sustainable diets (Gephart and Golden, 2022). However, despite their undeniable importance for human health and wellbeing, aquatic foods are often overlooked in food system discussions and decision-making, with debates and decisions predominantly focused on agriculture and livestock (Bennett et al., 2021). In many countries, capture fisheries and aquaculture are managed with a primary focus on economic interest, positioning aquatic organisms as a natural resource rather than a crucial contributor to food security and wellbeing. Several actions have been proposed to shift this paradigm, including integrating aquatic foods into the food system decision-making, supporting the role of small-scale actors in providing nutrition and supporting local communities, and promoting nutrition-sensitive aquatic food systems (Tigchelaar et al., 2022).

Historically, capture fisheries have been the main source of aquatic foods. However, fishery catches have remained relatively constant over the last three decades, while aquaculture has grown exponentially to meet the world's demand for aquatic foods. In 2022, aquatic food production reached 223 million tonnes, and for the first time in history, aquaculture surpassed capture fisheries as the main producer of aquatic animals (FAO, 2024). To fully harness the potential of aquatic foods and optimize their role in equitably and sustainably nourishing the world's population, a transformation of aquatic food systems is necessary toward models that are sustainable, inclusive, and resilient (FAO, 2024, 2022). This transformation envisions expanding aquatic food systems and increasing contributions from capture fisheries, aquaculture, and related supply chains to provide nutritious, affordable, and healthy diets—particularly for the most vulnerable populations—while promoting equitable growth (Agostini et al., 2024).

Innovation is considered a key driver in food systems and is critical for the urgent transformation that food systems require (Herrero et al., 2020; HLPE, 2017). Defined as "a new solution with the transformative ability to accelerate impact", innovations can be "a product or service fueled by technology, or involve new ways of working, new business models or other pathbreaking improvements in delivering essential services to solve a complex problem" (IDIA, 2021). However, isolated innovations rarely yield positive results across multiple sustainability dimensions. Existing research and innovation frameworks are considered inadequate to fully drive food systems

transformations, as these represent complex and systemic processes that requires not only innovative technologies but also a comprehensive overhaul of principles, regulations, policies, markets, and governance (Herrero et al., 2021, 2020; Kok et al., 2019). Therefore, rethinking how we approach innovation itself is essential to achieve meaningful transformation in food systems (Kok et al., 2019).

2. A holistic and inclusive approach to innovation

Based on insights from multi-stakeholder dialogues held during the 2021 United Nations Food Systems Summit, **a holistic and inclusive approach to innovation** in food systems has been proposed. This approach integrates technological, social, institutional, and policy advancements as levers for food systems transformation. It emphasizes the importance of collaboration through multi-stakeholder partnerships, the meaningful involvement of vulnerable groups[1], and the creation of supportive innovation ecosystems[2] that incorporate both new and traditional knowledge, making effective use of data and collective expertise to drive sustainable and equitable outcomes (FAO and WEF, 2022). Several guiding principles have been identified that underpin a holistic and inclusive approach to innovation in food systems (Table 1).

Achieving transformation in food systems requires innovation across several critical domains. Recognizing the importance of innovation as a fundamental enabler of food systems transformation, the 2021 United Nations Food Systems Summit introduced the Innovation Lever of Change[3]. This initiative highlighted four key areas where holistic and inclusive innovation can catalyze change:

1. Promoting **innovation ecosystems** at national and regional levels.
2. Encouraging **societal and institutional innovations**
3. Employing and supporting new and existing **knowledge and technology**
4. Enhancing and integrating **data and digital systems**.

Given that innovation ecosystems provide a critical foundation for innovation processes, this background paper—as well as the Science-Policy Lab organized in Cape Town, South Africa—will focus on how to build and strengthen innovation ecosystems to enable holistic and inclusive innovation in accelerating transformation in aquatic food systems.

[1] This includes groups that are often excluded, such as women from diverse backgrounds, Indigenous groups, and various categories of youth, among others.

[2] For an innovation to scale or thrive in a specific environment, certain enabling conditions must be present—this is known as the innovation ecosystem (IDIA, 2021).

[3] https://www.unfoodsystemshub.org/docs/unfoodsystemslibraries/fss-community/chapter-2/unfss_-innovation-lever-policy-brief-draft-21-july-2021-1.pdf?sfvrsn=55e045c0_1

Table 1. Guiding principles for a holistic and inclusive innovation approach. Based on FAO & WEF (2022).

1. Protect rights and ensure equitable participation	Innovation processes should safeguard the rights of all stakeholders to participate equitably in decision-making. This entails adopting an approach that acknowledges that different types of actors across intersecting social markers have varied contributions and opportunities to participate in innovation.
2. Integrate and leverage diverse knowledge systems	Transforming food systems requires the integration, valuation, and trust of various forms of knowledge—scientific, technological, Indigenous, and localized—to ensure inclusivity, encourage participation of diverse knowledge holders, and achieve nature-positive outcomes.
3. Build just and inclusive innovation ecosystems	To develop vibrant and agile innovation ecosystems at scale, it is essential to promote open-access and open-source solutions, encourage collective action, facilitate differentiated knowledge sharing among diverse stakeholders, reduce barriers for new entrants by providing access to financing and technical support, develop complementary infrastructure, and support learning-by-doing coalitions.
4. Promote the ethical development and use of digital tools	Digital technologies and data platforms, guided by ethical and inclusive standards, have the potential to reconfigure value chains and marketplaces to create more efficient and climate-smart food systems. Ensuring data privacy, security, and equitable access is essential, alongside collaboratively identifying critical gaps, reducing biases, protecting consumers, and fostering co-creation and scalable solutions.
5. Aim for positive social and environmental impacts	Innovation should contribute to nature-positive and sustainable outcomes, enhancing biodiversity, ecosystem health, and resilience, while ensuring equitable livelihoods and reducing disparities.
6. Prioritize frugal innovation	Novel and re-engineered solutions should prioritize affordability, simplicity, and efficiency while minimizing costs and resource use. This approach makes innovations accessible to resource-constrained or cost-conscious markets, particularly in emerging economies.
7. Strengthen resilience	Innovations should bolster the resilience of food systems to environmental, economic, and social shocks and stresses by developing practices and technologies that enhance adaptability, reduce vulnerability, and support sustainable livelihoods. Building innovation ecosystems to identify and scale solutions is crucial, particularly in areas vulnerable to systemic risks such as climate extremes, economic shocks, and conflicts.

3. Building and strengthening sustainable, inclusive, and equitable innovation ecosystems for aquatic food systems

3.1 Defining innovation ecosystems

The International Development Innovation Alliance (IDIA) defines an innovation ecosystem as "made up of enabling policies and regulations, accessibility of finance, informed human capital, supportive research markets, energy, transport and communications infrastructure, a culture supportive of innovation and entrepreneurship, and networking assets, which together support productive relationships between different actors and other parts of the ecosystem. These factors are all important, regardless of whether the innovation is scaling through public, private pathways,

or a combination of both" (IDIA, 2021). Although various definitions of innovation ecosystems exist, it has been suggested that definitions can be categorized along a continuum depending on the ecosystem's emphasis. These include:

- **Entrepreneurial innovation ecosystems**—which prioritize the innovator.
- **Innovation-oriented ecosystems**—which focus on the innovation process itself
- **Mission-driven innovation ecosystems**—which target particular development challenges, providing opportunities to create a unified sense of purpose and identity among diverse ecosystem actors and encouraging the co-design and evaluation of new forms of partnership and collaboration.

The targeted nature of mission-driven ecosystems may lead to impacts that are more evident and rapid compared to the broader social and economic benefits typically associated with general entrepreneurship support or innovation-focused strategies (IDIA, 2021).

3.2 Tailoring innovation ecosystems for aquatic food systems transformation

To effectively drive transformation in aquatic food systems, innovation ecosystems must be carefully designed and reconfigured to meet the specific needs and challenges of these systems. Innovation ecosystems should be structured to reconfigure policies, incentives, financial mechanisms, and socio-economic services to promote rapid and sustainable uptake of innovations, tailored to the unique contexts of aquatic food systems across different regions (FAO & WEF, 2022).

The complexity of innovation ecosystems offers multiple entry points for their strengthening. Most interventions focus on addressing specific gaps or weaknesses, but such 'deficit-based' approaches often risk oversimplifying the challenges by treating them as isolated problems that can be resolved with one-time interventions. A systemic approach to ecosystem strengthening, which considers the dynamic interactions between interdependent components within innovation ecosystems, acknowledges existing assets, builds upon them, and recognizes the need for continuous, rather than isolated, processes, is therefore more suitable (IDIA, 2021).

For the purpose of this background paper, we have focused on five key dimensions of innovation ecosystems to consider when planning strengthening interventions, including (i) collaboration and networks, (ii) inclusivity and equity, (iii) capacity building and training, (iv) policy and governance support, and (v) access to resources and funding:

3.2.1 Collaboration and networks

Effective innovation ecosystems in aquatic food systems necessitate improving collaboration models, developing new partnerships, and ensuring inclusive and equitable decision-making processes. These collaborative efforts facilitate the sharing of knowledge, resources, and best practices; foster interdisciplinary and intersectoral approaches; and create synergies that can accelerate innovation. This requires a shared understanding of the challenges and long-term outcomes by engaging with diverse stakeholders—including fishers, aquaculture farmers,

researchers, policymakers, private sector representatives, non-governmental organizations (NGOs), and local communities—and conducting in-depth analyses of issues (FAO & WEF, 2022). Interdisciplinary and cross-sector collaborations are essential for addressing diverse and complex socio-ecological challenges (Gammage et al., 2024). Integrating natural and social sciences can lead to more holistic and effective solutions (Olson and Pinto da Silva, 2024). Collaborative research practices that span traditional disciplinary boundaries enable the co-production of knowledge and foster more integrated and participatory approaches, highlighting the importance of social sciences in understanding human-environment interactions and informing aquatic food systems management and change (Olson & Pinto da Silva, 2024). Collaboration must be context-specific, locally driven, address community-specific needs, and align with national and global priorities (FAO & WEF, 2022).

Establishing and supporting Food Innovation Hubs can serve as key mechanisms for promoting innovation in food systems. These hubs operate as neutral, inclusive multi-stakeholder platforms that connect academia, governments, civil society, the private sector, and investors, facilitating public-private partnerships and scaling up impactful initiatives (FAO & WEF, 2022). Living labs—which are user-centric innovation environments that facilitate collaboration among stakeholders in real-life settings—are increasingly used in aquatic food systems initiatives to co-create, test, and validate new technologies, services, products, and systems (Lie et al., 2023; Pokupec et al., 2024). Additionally, public-private partnerships play a crucial role in aquaculture development by attracting investment, fostering technology transfer, and improving access to markets (Murekezi et al., 2024). Partnerships for innovation, technology, and knowledge transfer can address challenges such as limited access to finance, inadequate infrastructure, and lack of technical expertise by pooling resources and expertise from both the public and private sectors. These collaborations enhance the capacity of small-scale aquaculture farmers and rural communities to participate in the modern aquaculture sector using the latest technologies and allow for the inclusion of local and Indigenous knowledge, leading to more sustainable and efficient practices (Murekezi et al., 2024).

Community-based fisheries management further exemplifies the importance of integrating local knowledge and practices with national scaling efforts, underscoring the need for coordinated, context-specific initiatives. Successful scaling depends on strong partnerships among governments, NGOs, and local actors, ensuring that initiatives remain adaptable and effective across diverse contexts (Léopold et al., 2019; Steenbergen et al., 2022). These partnerships are crucial for adapting to local ecological and social conditions, requiring a dynamic approach to governance. Co-management in small-scale fisheries illustrates how collaborative governance models can foster local learning and institutional development, which are essential for addressing over-exploitation and environmental changes (Léopold et al., 2019).

By fostering collaboration and networks across various sectors and disciplines, aquatic food systems can leverage collective expertise and resources to address complex challenges and drive innovation. Such collaborative efforts are essential for developing sustainable and adaptive solutions that meet community-specific needs and contribute to nutrition security and livelihoods.

Box 1: Aquaponics Living Lab in Kenya

An aquaponic system in which aquaculture fish waste is recycled to grow horticultural crops, creating a sustainable, closed-loop food production system.
© Henk Stander.

The INCiTiS-FOOD project, funded by the European Union and launched in January 2023, aims to address pressing challenges of food and nutritional security, environmental pressures from food production, and environmental justice in Africa. Operating in Kenya, Ghana, Nigeria, Sierra Leone, Cameroon, and Gabon, the project focuses on co-creating cutting-edge circular agri-food technologies, practices, and business models to build an inclusive, sustainable, and accessible food system.

A core component of the project is the establishment of Living Labs, serving as incubators and accelerators of innovation that will continue beyond the project's duration. These Living Labs employ a user-centric approach and apply a Lean Start-up Methodology* to launch innovative technologies, services, practices, and products, empowering stakeholders to shape the future of food in Africa. One such Living Lab is located at Egerton University in Kenya. This dedicated initiative focuses on developing an aquaponics production system, in which fish waste from aquaculture provides nutrients for the soil-free cultivation of horticultural crops. The plants, in turn, cleanse the water by taking up nutrients, and water is recirculated back to the fish tanks. This symbiotic relationship minimizes water consumption, reduces reliance on chemical fertilizers, and optimizes resource utilization. The Living Lab engages stakeholders such as farmers and their associations, researchers, and consumers, aiming to enhance the capacity of small-scale farmers to adopt innovative practices. By linking potential urban and peri-urban agri-food innovations to the Living Lab, the project promotes circularity, increases local production, processing, and marketing of healthy and nutritious foods, and strengthens scientific capacity in Africa. Additionally, it contributes to conceptualizing the Water-Energy-Food-Ecosystem (WEFE) nexus for city-region food system assessments, promoting a resource-efficient and resilient circular economy, and reducing vulnerabilities by enhancing opportunities for vulnerable groups.

*Approach to develop new products and services that emphasizes rapid prototyping, iterative design, and validated learning through user feedback.
Source: https://incitis-food.eu

3.2.2 Inclusivity and equity

Inclusivity and equity are essential to ensure that all stakeholders have equal opportunities to participate in and benefit from innovation processes in aquatic food systems. Inclusive innovation ecosystems foster sustainable and equitable transformation by integrating diverse perspectives and knowledge systems into decision-making and innovation. By embracing different viewpoints and reducing barriers to participation, these ecosystems can address emerging trends and power imbalances, leading to more effective and representative outcomes (FAO & WEF, 2022).

Inclusive multi-stakeholder structures are fundamental in co-creation processes, ensuring accessible and representative decision-making from the start. These structures must be adaptable to address emerging challenges and must support the participation of marginalized communities. They should support respectful two-way knowledge sharing, proactively engage those underrepresented or impacted by decisions, and ensure equitable benefit sharing (Agostini et al., 2024; FAO and WEF, 2022). Continuous monitoring and evaluation are essential to ensure that initiatives benefit intended groups. Additionally, protecting participation rights is crucial and

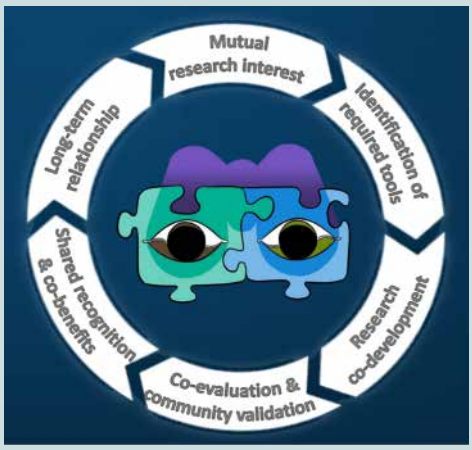
includes fostering safe dialogue spaces where all actors, including small-scale producers, women, Indigenous peoples, and youth, can contribute without exclusion (FAO & WEF, 2022).

Addressing equity involves recognizing that people are often disadvantaged in multiple, overlapping ways due to social attributes such as gender, age, caste, ethnicity, disability, or geographic location. Understanding the intersectionality of these issues is critical to truly address inequities in aquatic food systems (Malapit et al., 2020). By considering how different forms of disadvantage accumulate and interact in specific contexts, innovation processes can be designed to be more inclusive and effective. Tools such as the Reach-Benefit-Empower-Transform (RBET) framework provide a way to better approach equity in research and innovation processes. By clearly defining goals, strategies, and indicators for addressing equity, stakeholders can move beyond simply identifying problems to taking action to address underlying causes and monitoring progress (Malapit et al., 2020). This framework can be applied to various aspects of equity, enabling projects to consider multiple dimensions of disadvantage and design interventions that empower marginalized groups.

Gender equity is a key component of inclusivity in innovation ecosystems. Despite women's significant contributions to small-scale and subsistence fisheries, their involvement is often limited by gender norms and socio-economic constraints (Nunan and Cepić, 2020). Dedicated efforts to challenge these norms and support women's leadership are necessary to ensure their meaningful involvement and empowerment within governance frameworks. Gender-responsive and gender-transformative approaches are vital for building resilience by recognizing and enhancing women's agency, integrating their knowledge into climate adaptation strategies, and addressing socio-cultural, economic, and mobility constraints (Adam et al., 2024). Implementing interventions that combine socio-ecological and gender analysis allows for tailored solutions that empower marginalized groups and strengthen the sustainability and equity of aquatic food systems (Adam et al., 2024).

Addressing these challenges requires strong partnerships, inclusive participation, and the development of coherent and context-specific policies aligned with national priorities and global sustainability goals. Ensuring the inclusion and support of small-scale fishers and aquaculture producers, women, Indigenous groups, youth, and emerging nations is essential for improving equity and power balances within aquatic food systems (Agostini et al., 2024). To amplify the voices of rights holders in governance and facilitate their meaningful participation in decision-making, localized and inclusive innovations, along with knowledge-sharing processes at local, national, and international levels, are necessary (Agostini et al., 2024). By acknowledging and addressing the multiple and intersecting forms of disadvantage that stakeholders may face, and by integrating diverse knowledge systems, innovation ecosystems can drive transformative change that benefits all. Implementing intersectional approaches and gender-transformative strategies, and fostering inclusive governance structures, are crucial steps towards more equitable and sustainable aquatic food systems.

Box 2: Integrating Indigenous and Western knowledge systems in aquatic food systems governance



A stepwise framework for applying the Two-Eyed Seeing approach to research. Reproduced from Reid et al. (2021) under CC BY-NC-ND 4.0 license (https://creativecommons.org/licenses/by-nc-nd/4.0/).

Integrating Indigenous and local knowledge systems into innovation ecosystems enhances inclusivity and equity in aquatic food systems. Indigenous approaches provide valuable insights for equitable and sustainable management. Two frameworks exemplify how Indigenous knowledge can coexist with Western science: the Waka-Taurua framework in New Zealand and the Two-Eyed Seeing approach in Canada.

In New Zealand, the Waka-Taurua (double canoe) framework serves as a metaphor for collaboration between Māori communities and government agencies in marine co-management (Maxwell et al., 2020). The two canoes represent Māori and non-Māori worldviews, each retaining its unique values and knowledge systems without forcing integration into a single framework. The shared platform symbolizes the negotiated space where both parties engage in respectful dialogue to jointly develop management strategies. This framework integrates Māori values such as kaitiakitanga (reciprocal environmental guardianship) with ecosystem-based management principles, facilitating balanced inclusion of Indigenous knowledge in governance (Maxwell et al., 2020).

Similarly, in Canada, the Two-Eyed Seeing (Etuaptmumk in Mi'kmaw) approach encourages using both Indigenous and Western knowledge systems together (Reid et al., 2021). It advocates learning from one eye with the strengths of Indigenous knowledge and from the other with Western science, for the benefit of all. This framework fosters knowledge coexistence rather than assimilation, respecting the integrity of each system. Two-Eyed Seeing approach has been applied in fisheries research and management, such as in the Slave River Delta, where Indigenous communities and scientists co-developed monitoring programs integrating traditional knowledge with scientific methods. This collaborative approach enhances understanding of ecosystem health and informs sustainable management practices (Reid et al., 2021).

These frameworks highlight the importance of building equitable partnerships and fostering knowledge coexistence in aquatic food systems. By integrating diverse knowledge systems, they enhance adaptive capacity and resilience, leading to more inclusive and effective governance.

Maxwell, K.H., Ratana, K., Davies, K.K., Taiapa, C., Awatere, S., 2020. Navigating towards marine co-management with Indigenous communities on-board the Waka-Taurua. Mar. Policy 111, 103722.

Reid, A.J., Eckert, L.E., Lane, J.-F., Young, N., Hinch, S.G., Darimont, C.T., Cooke, S.J., Ban, N.C., Marshall, A., 2021. "Two-Eyed Seeing": An Indigenous framework to transform fisheries research and management. Fish Fish. 22, 243–261.

3.2.3 Capacity building and training

Capacity building and training are paramount for developing the skills, knowledge, and competencies of individuals and organizations within innovation ecosystems. They are essential to strengthen local expertise, facilitate knowledge and technology transfer across diverse contexts (South-South, North-South, South-North, and North-North), and promote the integration of various knowledge systems and the generation of new insights (Agostini et al., 2024). At the same time, innovation ecosystems can facilitate knowledge sharing and capacity building through the development of communities of practice (FAO & WEF, 2022). Capacity building and training enable stakeholders to participate more effectively in innovation processes, adopt sustainable

practices, and respond to emerging challenges. In the context of aquatic food systems, capacity building and training encompass a wide range of topics, from technical training—such as sustainable aquaculture and fishing techniques, and aquatic food processing methods—to entrepreneurship development—providing business training to help stakeholders start and grow innovative enterprises. Additionally, training is crucial for fostering synergies between nutrition, food systems, and health as well as for raising awareness about the importance of aquatic foods for good nutrition and its potential to enhance food security and nutrition at the local level (Blackmore et al., 2022; Khan et al., 2021). Furthermore, effective communication and education are crucial to making innovations accessible to producers and consumers, promoting the adoption of new approaches and technologies (FAO & WEF, 2022).

Box 3: Digital training for remote fish farming communities

An aquaculture training course for a group of West African women at the Art Sunu Gueej aquaculture platform, financed by CAOPA (African Confederation of Professional Artisanal Fisheries Organizations). © IRD - Patrice Brehmer.

As value chains and transactions become increasingly digitized, many rural stakeholders face a growing risk of exclusion and marginalization from essential information and opportunities due to systemic barriers such as low literacy and the cost of technology, data, and power. To address this, WorldFish, in partnership with Learn.ink—a training and learning digital platform designed for use on low-end mobile devices—has developed various training courses. For instance, an online learning curriculum was created specifically for remote extension workers in fish farms. Utilizing a hybrid 'train-the-trainer' model, local project staff were empowered to deliver training to rural fish farmers on how to use relevant digital resources and tools to identify disease outbreaks, collect biological samples, and implement measures to mitigate the spread of diseases in aquaculture. As value chains and transactions become increasingly digitized, many rural stakeholders face a growing risk of exclusion and marginalization from essential information and opportunities due to systemic barriers such as low literacy and the cost of technology, data, and power. To address this, WorldFish, in partnership with Learn.ink—a training and learning digital platform designed for use on low-end mobile devices—has developed various training courses. For instance, an online learning curriculum was created specifically for remote extension workers in fish farms. Utilizing a hybrid 'train-the-trainer' model, local project staff were empowered to deliver training to rural fish farmers on how to use relevant digital resources and tools to identify disease outbreaks, collect biological samples, and implement measures to mitigate the spread of diseases in aquaculture. The digital training courses are designed to complement virtual meetings by being made available in advance. This allows participants more time to absorb and understand the concepts, leading to better engagement during the interactive sessions. The courses are hosted on the web, which eliminates the need for downloading or installing a mobile application (Tilley et al., 2022).

Tilley, A., Shikuku, K.M., Cohen, P.J., Khor, L., Henriksson, P.J., Hossain, P.R., Delamare-Deboutteville, J., 2022. Digital Innovations for resilient aquatic food systems. WorldFish.

Investing in human capacity and skills is essential for revitalizing aquatic food value chains, protecting livelihoods, enhancing human nutrition, and promoting resilience to future shocks. Training programs supporting sectoral development in fisheries and aquaculture should involve

promoting nutrition-sensitive approaches. Additionally, offering practical digital literacy training to stakeholders across aquatic food supply chains can support the digitalization of these systems, enhancing the efficiency of advertising, marketing, input procurement, and the provision of technical advice and payment services (Belton et al., 2021). By addressing systemic barriers such as low literacy and limited access to technology, capacity building and training initiatives must ensure that all actors, including those in rural and marginalized communities, can fully participate in and benefit from innovation processes (Tilley et al., 2022).

3.2.4 Policy and governance support

Policy and governance support are essential for developing and implementing policies, regulations, and institutional frameworks that enable innovation in aquatic food systems. Existing regulatory frameworks should be reviewed and updated to remove barriers that hinder the adoption of new technologies while ensuring consumer protection. At national and regional levels, fostering innovation within aquatic food systems necessitates the development of comprehensive food strategies that encourage collaboration among various sectors, including health, environment, energy, trade, climate, transport, and regional planning. Developing balanced food-related policies that integrate public and private sector interests are vital for sustainable and inclusive innovations (FAO & WEF, 2022). A significant challenge in aquatic food systems is the lack of integrated food policies and management frameworks that balance multiple dimensions of sustainability and address incoherence across food systems, including ensuring synergies between aquatic and terrestrial food systems. Integrating aquaculture and fisheries into broader national food policies and coordinating efforts between agriculture and fisheries ministries can facilitate the transfer of knowledge and resources, promoting sustainable practices and enhancing food security (Agostini et al., 2024; Naylor et al., 2023). Effective policy approaches require reframing aquatic foods as food rather than merely natural resources and integrating them into a food systems approach. This involves broadening policy contexts beyond solely production to consider issues such as equitable access, nutrition-sensitive approaches, and the inclusion of aquatic foods in public health strategies (Bennett et al., 2021; Farmery et al., 2021; Robinson et al., 2022; Tigchelaar et al., 2022). This reframing can help build political commitment to link fisheries and aquaculture with nutritional outcomes and public health, which has historically been lacking (Bennett et al., 2021; Farmery et al., 2021), and underscores the need for robust multi- and interdisciplinary science to inform policy (Agostini et al., 2024). For instance, a nutrition-sensitive governance framework for fisheries, particularly in low- and middle-income countries, could contribute to uncovering the power dynamics that limit disadvantaged and vulnerable communities' access to and control over the nutritional advantages of aquatic foods. This framework highlights the need to reevaluate traditional fisheries governance—typically focused on regulating resource exploitation—to encompass a broader range of stakeholders involved in the fisheries value chain and the factors influencing access to aquatic foods, including processing, storage, and distribution (Allegretti and Hicks, 2023).

Box 4: Key challenges in aquaculture governance

Acadjas are a traditional West African aquaculture technique in which submerged tree and shrub branches create artificial habitats that promote the growth of certain fish species in lakes and lagoons. © IRD - Christian Levêque.

Aquaculture governance faces unique challenges due to the sector's vast diversity in production systems, species, and environments. Unlike other large food production systems, aquaculture produces hundreds of species in various contexts—from freshwater ponds and raceways to offshore mariculture—leading to a diversity of governance needs and challenges. This diversity results in countries exhibiting under-regulation, over-regulation, or a lack of cohesive policies altogether. One primary challenge is managing shared environmental resources or 'commons,' such as water quality and quantity, physical space, and genetic diversity. These resources often create collective action problems where individual interests (e.g., maximizing production) conflict with collective interests (e.g., sustainable use and long-term resource availability). Effective governance of these commons requires robust institutions—comprising rules and norms—that coordinate actions among diverse stakeholders to mitigate overuse and ensure equitable access. Aquaculture often lacks established property rights, state policies, legislation, and farmer cooperatives that are more common in agriculture and capture fisheries. This absence makes it difficult to regulate resource use, manage environmental impacts, and support small-scale producers. Additionally, aquaculture must navigate land–water–sea connectivity issues and cross-sectoral interdependencies due to shared risks and resource competition with sectors like fisheries, agriculture, and coastal development (Partelow et al., 2022).

Partelow, S., Schlüter, A., O. Manlosa, A., Nagel, B., Octa Paramita, A., 2022. Governing aquaculture commons. Rev. Aquac. 14, 729–750.

3.2.5 Access to resources and funding

Access to resources and funding is essential for stakeholders to develop and implement innovative ideas. National governments should prioritize innovation by creating pathways for food systems transformation and committing to allocate funding to food-related research and development (FAO & WEF, 2022). However, aquatic foods have largely been underrepresented in key food policy dialogues and associated funding priorities (Bennett et al., 2021).

Adequate and responsible long-term investment from both public and private sectors is critical, focusing on knowledge development, research and development, and physical infrastructure. Support for small and medium-sized enterprises and start-ups through targeted financing facilities, awards, and incentives is also vital to drive transformation (FAO & WEF, 2022). Creating dedicated financing institutions, fostering public-private partnerships, and improving data reporting infrastructure can enhance access to resources and funding for vulnerable aquatic food producers (Bennett et al., 2024).

Accessible finance, particularly for vulnerable producers, is essential to transition to sustainable practices. Increasing finance can help these producers become bankable by addressing financial barriers and monitoring complexities. Identifying key metrics that demonstrate the viability of net-zero, nature-positive financing initiatives can boost investor confidence, facilitate project

expansion, and reduce verification complexities for producers (FAO & WEF, 2022). Capacity building and awareness raising on financial tools like insurance and credit schemes can help bridge the gap between financial institutions and small-scale producers (FAO, 2023). Simplifying loan application processes and designing flexible financial products tailored to the needs of these producers can further improve financial inclusion (FAO, 2023).

Small-holder aquaculture producers often lack access to financial risk management tools that are common in other food production sectors, making them vulnerable to economic risks such as environmental disasters, market fluctuations, and disease outbreaks (Watson et al., 2018). This vulnerability is exacerbated by limited access to credit and insurance services, which hinders their capacity to absorb losses and invest in sustainable practices (FAO, 2023). Innovative financing mechanisms, such as cooperative insurance schemes and payment for ecosystem services, can provide financial protection and incentivize the adoption of best management practices (Bennett et al., 2024; Watson et al., 2018). By addressing financial barriers, fostering an enabling environment for investment, and improving access to markets, stakeholders in the aquatic food system can access the resources and funding necessary to drive innovation, resilience, and sustainable transformation.

Box 5: Cooperative insurance for small-holder aquaculture in Myanmar

Fish farming in Hoi An, Cam Thanh region, Vietnam. As in Myanmar, thousands of farmers in Vietnam lose their production due to natural disasters. © IRD - Christian Levêque.

Aquaculture, while rapidly expanding, often lacks financial risk management tools that are common in other food production sectors. Small-holder aquaculture producers face significant risks due to environmental factors like floods, which can severely impact yields and revenues. In Myanmar, a study by Watson et al. (2018) developed a cooperative indemnity insurance scheme tailored for small-holder fish farmers to mitigate these risks. The cooperative insurance model involves farmers pooling funds into a mutual fund that provides payouts in the event of losses due to floods. This self-organized risk pool leverages the strong social capital within farming communities, reducing administrative costs and helping to mitigate issues like moral hazard and adverse selection. By collectively managing risk, farmers can achieve greater income stability and resilience against environmental shocks. Simulation results from the study indicated that investing 5–20% of annual revenue into the mutual fund could significantly reduce downside risk for farmers. The scheme not only offers financial protection but also incentivizes the adoption of best management practices, as farmers have a vested interest in minimizing losses to maintain the fund's viability. This cooperative approach exemplifies how innovative financial tools can enhance access to resources and funding for vulnerable producers, enabling them to transition to more sustainable and resilient practices.

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4. Conclusion and invitation to Science-Policy Lab participants

The transformation of aquatic food systems into sustainable, inclusive, and resilient models is a complex but essential endeavor. This background paper has highlighted the critical dimensions of innovation ecosystems that need to be strengthened to facilitate this transformation. By prioritizing collaboration and networks, we recognize the power of collective expertise and the synergies that emerge from interdisciplinary and cross-sector partnerships. Inclusivity and equity are not just ethical imperatives but practical necessities for the success of innovation ecosystems, ensuring that diverse voices are heard and that the benefits of innovation are shared broadly. By integrating diverse perspectives and knowledge systems, we can develop solutions that are more effective, context-specific, adaptive, and sustainable. Capacity building and training are paramount to empower stakeholders to actively participate in innovation processes, while supportive policy and governance frameworks create an enabling environment for innovation to flourish. Access to resources and funding ensures that innovative ideas can be developed and implemented, particularly by those who have historically been marginalized or underrepresented.

As we prepare for the upcoming Science-Policy Lab in Cape Town, South Africa, this background paper serves as a foundation for our discussions and collaborative efforts. The Science-Policy Lab will provide a platform for stakeholders from various sectors—including representatives of academia, government, private sector, and civil society—to engage in meaningful dialogue and co-create recommendations for building and strengthening inclusive and equitable innovation ecosystems in aquatic food systems.

We invite participants to reflect on the dimensions outlined in this paper and consider how they can contribute to fostering innovation in their own contexts. The Lab will be an opportunity to share experiences, identify challenges, and collaboratively develop strategies that can drive the transformation of aquatic food systems. By working together, we can harness the full potential of holistic and inclusive innovation to ensure that aquatic foods continue to nourish populations sustainably and equitably, now and in the future.

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