Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies

APEC OCEAN AND FISHERIES WORKING GROUP

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RESEARCH REPORT

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EXECUTIVE SUMMARY

By **2050**, the **global population** is projected to reach **9.7 billion**[1], with 68% of people residing in urban areas[2]. This demographic shift underscores the growing need for a sustainable and diverse protein supply, with seafood playing a crucial role in meeting global food demands. In 2022, global aquaculture production reached a record **130.9 million tons**, accounting for **51% of total aquatic animal production**, surpassing capture fisheries for the first time as the leading producer of aquatic animal products (FAO, 2024). As the fastest-growing food production sector, aquaculture is fundamental to global food security. However, traditional culture techniques in the sector face mounting challenges in keeping pace with demand. Rising energy and fuel costs, climate change, environmental pollution, and resource limitations, such as shrinking arable land, dwindling freshwater supplies, soil degradation, and nutrient depletion, all threaten production. Ensuring the sector's sustainability is no longer optional, it is imperative for securing future food systems and maintaining ecological balance.

Currently, the majority of global aquaculture production originates from **developing economies**, where **small-scale aquaculture (SSA)** represents the dominant production model. SSA includes the farming of fish, crustaceans, mollusks, and aquatic plants on a relatively small scale, whether for subsistence or commercial purposes. It is a cornerstone of rural economies, supporting livelihoods, food security, and economic development in many regions worldwide. SSA plays a critical role in poverty alleviation by providing income and employment, particularly in areas where alternative economic opportunities are limited, while also being essential to global food security and nutrition by supplying high-quality protein, essential fatty acids, vitamins, and minerals that are crucial for combating malnutrition.

Beyond its economic and nutritional significance, SSA also enhances food system resilience by diversifying food sources and reducing dependence on wild fish stocks. It also has the potential to contribute to climate change adaptation through integrated farming practices that optimize resource use, such as aquaponics, polyculture, rice-fish farming systems, among others. Despite its benefits, SSA faces challenges such as **limited access to finance, technical knowledge gaps, market constraints, and vulnerability to climate change impacts** (Tucciarone et al., 2024).

Addressing these challenges through policy support, capacity-building programs, and infrastructure investment is crucial for unlocking the full potential of SSA as a driver of sustainable aquaculture development. Tackling the sustainability challenge in aquaculture requires a **comprehensive approach that integrates environmental, social, and economic dimensions**. Policies and programs that improve resource efficiency, enhance resilience to environmental shifts, and provide financial and technical support to small-scale aquaculture farmers are key. Promoting sustainable practices, such as responsible feed use, efficient water management, and the adoption of eco-friendly farming techniques, can significantly reduce SSA's environmental footprint while strengthening long-term productivity and social benefits for the actors involved.

The **APEC region** is the world's leading aquaculture hub, accounting for **80.3% of global production** (APEC, 2023). Among the world's top 10 aquaculture producers, four APEC economies hold prominent positions: China (#1), the largest global producer, responsible for over 60% of farmed aquatic animals; Indonesia (#3), a major producer of shrimp, tilapia, and catfish; Viet Nam (#4), a leading exporter of pangasius (catfish) and shrimp; and Chile (#8), the second-largest farmed salmon producer (FAO, 2024). During the past decade (2011-2020), the

[1] United Nations. (2022). Global Issues: Population. Accessed on: 07 February 2025. Available in: https://www.un.org/en/global-issues/population

[2] United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN. Accessed on: 07 February 2025. Available in: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

aquaculture sector in APEC economies has generated an average of **11.3 million jobs per year**[3] (APEC, 2023).

This report examined how APEC economies support the sustainable development of aquaculture enterprises, particularly micro and small-scale producers, across the entire aquaculture value chain. The objective is to assist APEC economies to enhance sustainable aquaculture production while balancing the needs of farmers with environmental protection. By promoting sustainability in the APEC region, aquaculture can be positioned as a competitive, diversified sector that remains economically viable, socially inclusive, and environmentally responsible over the long term.

The present report used four main instruments to gather insights into the topic, including: (1) a digital questionnaire completed by government officials from the aquaculture sectors of eight APEC economies (Brunei Darussalam; Chile; Papua New Guinea; New Zealand; Peru; the Philippines; Chinese Taipei; and Thailand); (2) in-depth virtual interviews with key aquaculture stakeholders, including officials from governmental and intergovernmental organizations, as well as scientists from Australia; Canada; Chile; Malaysia; Mexico; and the Philippines (see Annex 2 for a complete list); (3) a comprehensive bibliographic review and (4) a two-day virtual workshop with the participation of government officials from various APEC economies. These instruments helped identify the key barriers to SSA's sustainable development and highlighted successful policies, programs, and actions that some APEC economies have effectively implemented.

This report was prepared within the scopes of the project OFWG 01 2023: "**Research and Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies**". The report is divided into three chapters covering the following topics: (1) How sustainable is small-scale aquaculture worldwide and in the APEC region?; (2) What initiatives have been taken by APEC economies to enhance the sustainable development of small-scale aquaculture?; and finally (3) General recommendations and conclusions for the improvement of the sustainability of the small-scale aquaculture sector in the APEC region. The key findings from each chapter are presented next as briefs abstracts:

Chapter 1: How sustainable is small-scale aquaculture in the APEC region? This chapter delves into the primary challenges faced by SSA in the APEC region for its sustainable development, considering the three pillars of sustainability: economic, social, and environmental aspects. Key economic challenges include the limited revenues generated, difficulties in scaling production, and in the development of alternative livelihoods. Social challenges are marked by informality, the lack of social protection systems, and persistent gender inequalities. On the environmental front, the impact of SSA is poorly studied with more focus on the negative environmental externalities of large-scale aquaculture. Finally, natural disasters and climate change pose a significant threat to aquaculture sustainability.

Chapter 2: What public and private initiatives in favor of the development of sustainable small-scale aquaculture have been developed in the APEC region? This chapter outlines the diverse public and private initiatives supporting the sustainable development of SSA in the APEC region, emphasizing the importance of strategic planning, governance, financial assistance, capacity building, innovation, social inclusion, and environmental management. These initiatives collectively aim to foster a sustainable, resilient and thriving SSA.

Chapter 3: Action plan to secure the sustainable future of the small-scale aquaculture sector in the APEC region. To ensure the sustainability and resilience of SSA in APEC economies, we propose five main strategies: strengthening governance, improving economic viability, enhancing social inclusion, leveraging technology, and building climate resilience. Clear regulations, reduced bureaucracy, and market access improvements will enhance governance and economic viability. Addressing social challenges, such as informality and gender inequality, requires formalization programs and expanded protection. Investment in research, technology transfer, and capacity-building will improve SSA's competitiveness, while climate resilience must be strengthened through adaptation plans, emergency response mechanisms, and climate-smart

[3] Data includes 17 APEC economies obtained from the OECD database: Employment in aquaculture.

aquaculture. Implementing these strategies through targeted actions will ensure SSA’s long-term sustainability and inclusivity.

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LIST OF ABBREVIATIONS

AFCD	Agriculture, Fisheries and Conservation Department of Hong Kong, China
AREL	Limited resources aquaculture
ASC	Aquaculture Stewardship Council
ASEAN	Association of Southeast Asian Economies
ATJ	Alter Trade Japan
BMP	Best management practices
CGIAR	Consultative Group for International Agricultural Research
CONAPESCA	Mexican Commission for Aquaculture and Fisheries
COPPESAALC	Commission on Small-Scale and Artisanal Fisheries and Aquaculture in Latin America and the Caribbean
CRCNA	Cooperative Research Centre for Developing Northern Australia
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization
GAP	Good aquaculture practices
GIEWS	Global Information and Early Warning System
Ha	Hectare
HACCP	Hazard Analysis & Critical Control Point
IMARPE	Sea Institute of Peru
IMIPAS	Mexican Institute for Sustainable Fisheries and Aquaculture Research
IMTA	Integrated multitrophic aquaculture
IUU	Illegal, unreported and unregulated
LPMUKP	Indonesian Maritime and Fisheries Business Capital Management Institute
LSP	Local services providers
MARBIDICO	Maryland Agricultural & Resource Based Industry Development Corporation
PCO2	Partial pressure of carbon dioxide
pH	Potential of hydrogen
PRODUCE	Ministry of Production of Peru
SERNAPESCA	Chilean Fisheries and Aquaculture Service
R&D	Research & development
SDG	Sustainable development goals
SSA	Small-scale aquaculture
SME	Small and Medium-sized Enterprises (SMEs)

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INTRODUCTION

Aquaculture is the fastest growing food producing sector in the world. In 2022, world aquaculture production produced more aquatic food than fisheries reaching 130.9 million tons, valued at USD 313 billion (FAO, 2024). Small-scale enterprises are a crucial component of total aquaculture production in most economies. In Asia and Latin America, they predominate. Small-scale aquaculture (SSA) plays a vital role in socio-economic development, poverty alleviation, and food security. Despite these contributions, SSA businesses are often vulnerable due to their informality, limited or non-existent access to finance, and low skill levels.

Aquaculture makes important contributions towards achieving the Sustainable Development Goals (SDGs) of the agenda 2030. The two more direct contributions are to **zero hunger and good health and well-being**. However, aquaculture also contributes indirectly to **clean water and sanitation, responsible consumption and production, climate action, life below water, and life on land**. Moreover, considering associated and related contributions, aquaculture can contribute to up to 15 out of the 17 SDGs (Troell et al., 2023) Similar to capture fisheries, aquaculture is a sector dominated by small-scale actors. Securing its role as a sustainable food source will require focused policy intervention and regulation to mitigate environmental impacts while enhancing livelihood opportunities, improving food access and safety, and driving supply chain innovations and transformation.

The sustainability of the aquaculture industry depends on effective policies and regulations that ensure the preservation of aquatic ecosystems, excellence in production, and the incorporation of new technologies, as well as government support and cooperation among involved stakeholders. The aquaculture sector has demonstrated resilience, overcoming the impacts of various stressors, including global shocks such as financial crises and the COVID-19 pandemic, as well as regional or local constraints like disease outbreaks.

Securing the sustainable development of small-scale aquaculture also involves fostering equitable access to resources and markets. This includes ensuring that small-scale farmers have access to affordable credit, quality inputs, and fair market opportunities. Capacity-building initiatives, such as training and extension services, can empower small-scale aquaculturists with the knowledge and skills needed to adopt sustainable practices and improve productivity.

In conclusion, the sustainability of small-scale aquaculture is not only vital for the livelihoods and food security of millions but also for achieving broader environmental and socio-economic goals. By addressing the vulnerabilities and promoting sustainable development, we can ensure that small-scale aquaculture continues to thrive and contribute to a more equitable and sustainable future. This report aims to provide insights into the current state of small-scale aquaculture, identify key challenges and opportunities, and propose actionable strategies to enhance its sustainability.

There is a notable disconnection between science and public policy concerning what the sustainable development of aquaculture means. Bridging this gap requires a synthesis of multidisciplinary knowledge on complex problems that affect political decisions. Designing and implementing processes to support informed management by stakeholders is essential. This participatory process should integrate the opinions and knowledge of citizens, public policymakers, and all stakeholders with scientific information and procedural rationalities to adapt to new problems and needs, and to plan and implement effective responses.

This report aims to explore initiatives for the sustainable development of the SSA sector in the APEC region, considering the three pillars of sustainability: economic, social, and environmental. Through this comprehensive analysis, we seek to provide actionable recommendations to support the growth and sustainability of SSA enterprises.

CHAPTER 1: How sustainable is small-scale aquaculture in the APEC region?

The primary objective of this report is to analyze how APEC economies are supporting the sustainable development of aquaculture enterprises, with a particular focus on micro and small producers across the aquaculture value chain. To establish a strong foundation for this analysis, the report begins by providing a comprehensive definition of aquaculture, small-scale aquaculture (SSA), and sustainable aquaculture, ensuring a clear framework for data interpretation. It then examines general perceptions of aquaculture sustainability and evaluates the sector's current status through the lens of its three core pillars: economic, social, and environmental sustainability. The methodology used for the elaboration of this report is detailed in Annex 1.

Main aquaculture systems

The FAO defines aquaculture as: "the farming of aquatic organisms including fish, mollusks, crustaceans, crocodiles, alligators, turtles, amphibians and aquatic plants". Farming implies some form of human intervention in the process to enhance production, such as breeding, regular stocking, feeding or protection from predators. Many classifications for aquaculture systems are currently being used. Depending on the production techniques employed can be classified as intensive, extensive, or semi-intensive (**Figure 1**). **Intensive** systems are characterized by high densities in artificial enclosures with high-quality artificial feed, while **extensive** systems have lower densities in natural or artificial enclosures, with no feed input. Lastly, **semi-intensive** systems are in-between systems with intermediate densities, the use of fertilizers to enhance natural feed production, complementary artificial feed or the simultaneous farming of more than one species (polyculture). In addition, according to the number of species and the synergy between them, systems can be **monoculture** (1 species), **polyculture** or **integrated multitrophic aquaculture (IMTA)**, which uses many species from different trophic levels to enhance production and reduce waste, simulating a food web (Tidwell, 2012).

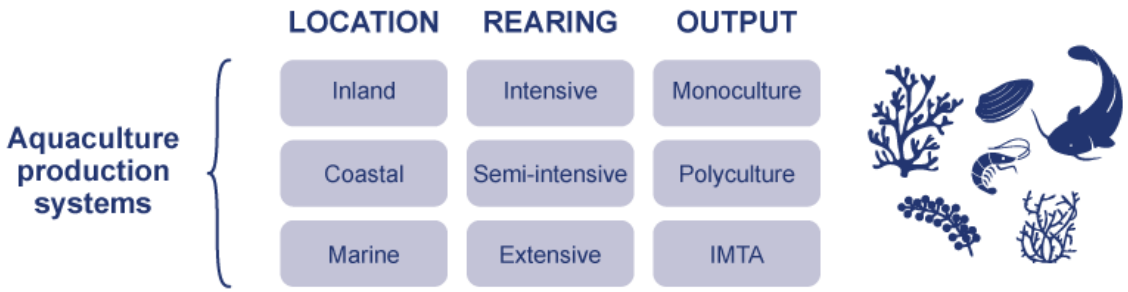

Figure 1. *Main classification of aquaculture production systems.*

Definition of small-scale aquaculture across APEC economies

Key findings:

The diverse nature of SSA systems across APEC economies demands the establishment of specific definitions to effectively support and regulate the sector.

The term small-scale aquaculture (SSA) has several **definitions that vary significantly across different economies and contexts**, reflecting the diverse nature of aquaculture practices and the unique socio-economic and environmental conditions in each region. The FAO defines SSA as a diverse group of systems, it includes: 1) those involving limited investment in assets and minor operational costs, primarily utilizing family labor and integrating aquaculture as one of several livelihood activities (previously known as Type 1 or rural aquaculture); and 2) systems where aquaculture is the principal livelihood source, with substantial investments in time, labor, infrastructure, and capital (referred to as Type II SSA system). In addition, common elements characterizing SSA include ownership or access to aquatic

resources, family or community ownership, and relatively small landholdings. SSA can involve farming both low and high-value species and is conducted in various containment systems such as ponds, cages, pens, raceways, barrels, bottles, and jars (Bondad-Reantaso & Subasinghe, 2013).

As part of the present study, aquaculture officials from government institutions across the APEC region were asked to define SSA according to their respective economies' regulations. Their responses varied significantly (**Table 1**), with two officials indicating the absence of a legal definition. Most respondents emphasized small production volumes as a key component, with some specifying defined limit values. Definitions also varied based on different production systems, reflecting distinct maximum production values according to the farmed species. This variability highlights the diverse nature of SSA across the region, underscoring the **importance of context-specific definitions to effectively support and regulate the sector**.

Table 1. *Surveyed officials' perspectives on the definitions of small-scale aquaculture in the APEC region and its estimated contribution (%) of SSA to total aquaculture.*

ECONOMY	DEFINITION	PROPORTION OF SSA [a]
Brunei Darussalam	*Aquaculture farmers with small production volume.*	*60%*
Chile	*It is an activity carried out by legal or natural people that aims at the production of hydrobiological resources in bodies of water and/or on land for restocking or marketing purposes.*	*29.7%*
Peru	*Aquaculture operations that operate with relatively small production units, low inputs and low capital investment.*	*Total: 98.6%. Limited resources aquaculture (AREL) or subsistence aquaculture: 75.9%; Micro and small aquaculture (AMYPE) 22.7%. Only 1.4% considered large aquaculture*
Papua New Guinea	*Family owned and run plays a significant role in food security, employment opportunities and income generation of the majority local communities.*	*Small Scale= 20,000, Medium=1000, Large scale= less than 20 (expressed in numbers) Equivalent to 95%*
Mexico	-	*80%* [b]
New Zealand	*A farm with an area up to 4ha, with mussels or oysters. Salmon farming cannot be small scale.*	*15%*
The Philippines	*No legal definition available yet at the economy level. We informally categorize SSA based on species. For finfish that's 1 ha and below, for seaweed that's a quarter of a ha and below, and for shellfish that's 1-2 rafts only*.	Data deficient [c]
Chinese Taipei	*We don't define the concept of small-scale aquaculture officially.*	*35%*
Thailand	*The Fisheries Department has not yet set a clear definition, but it will be divided according to the size of the area, less than or equal to 32,000 m^2 is considered small.*	*80%*

[a] Approximate values. Expressed in percentage compared to total aquaculture enterprises in each economy.
[b] Response was given during in-depth interviews and not as part of the questionnaire as the rest of responses.
[c] According to the surveyed official.

During the interviews, an official of the Chilean Fisheries and Aquaculture Service (SERNAPESCA) gave more insights into the definition of SSA in their economy:

> *"SSA in Chile is an activity carried out by natural and legal persons who cultivate hydrobiological resources, such as fish, bass, mollusks, mussels, scallops, oysters, sea urchins, algae, among others. The major difference from large-scale aquaculture (typically referred to as industrial aquaculture) lies in the limits on surface area and maximum annual production. For example, in the case of artisanal fishing organizations and indigenous communities, the maximum production volumes can be up to 2,000 tons/year, and the maximum surface area is up to 50 hectares*".

Another key aspect addressed by the questionnaire and interview was the relative contribution of SSA to total aquaculture production among APEC economies, which is highly variable (See **Table 1**). Some economies, such as Chile; New Zealand, and Chinese Taipei, reported a lower contribution from SSA enterprises, with percentages of 29.7%, 15%, and 35%, respectively. In contrast, Brunei Darussalam; Mexico; Papua New Guinea; Peru, and Thailand reported a high contribution of SSA to total aquaculture, with figures of 60%, 80%, 95%, 73.1%, and 80%, respectively. These variations highlight the diverse roles that SSA plays in different economies, suggesting differences in policy support, resource availability, and market structures. High contributions of SSA in certain economies suggest a **strong dependence on small-scale operations for local food security and livelihoods**, while lower contributions in others might indicate a more industrialized and large-scale approach to aquaculture. Understanding these dynamics is crucial for tailoring support and development programs to enhance the sustainability and productivity of SSA across the APEC region.

Key message:

Some APEC economies rely more heavily on SSA operations than others. Therefore, regulations should be tailored to reflect these differences, ensuring adequate support, sustainability, and economic viability for small-scale producers.

Definition of sustainable aquaculture

The term sustainability has been widely acknowledged as a crucial element in the ideal development of aquaculture. Despite its current recognition and relevance, on occasions the concept of sustainability in aquaculture is not clearly defined and can often be confusing (Boyd et al., 2020). Sustainable aquaculture can be defined as the **cost-effective production of aquatic organisms that harmonizes with ecosystems and local communities** (Valenti et al., 2011). To achieve sustainable aquaculture, these systems must include economic, social, environmental and ecological aspects into account, and systems that do not fulfill these requirements should not be considered sustainable aquaculture (Lowanshi et al., 2024).

To ensure sustainability, aquaculture systems must be bolstered across the three pillars of sustainability: economic, social and environmental (Boyd et al., 2020; Lowanshi et al., 2024):

Key message:
Sustainable aquaculture must be:
Economically viable
Socially responsible
Environmentally responsible and eco-friendly

During the interviews, a brief definition of aquaculture sustainability emphasized its three key dimensions: social, environmental, and economic. One interviewee stated:

"SSA is sustainable from the social, environmental, and economic point of view because it contributes to the food security of many families and is maintained over time."

Sustainable aquaculture is a tangible concept that can be effectively evaluated. Quantitative indicators of economic, environmental and social sustainability have been developed to help researchers and policymakers assess the sustainability of different aquaculture production systems within their economies. From 2003 to 2016, Valenti et al. (2018) devised a series of quantitative indicators, combining top-down and bottom-up methods, alongside practical observations in experimental and commercial aquaculture facilities. They proposed a total of 56 indicators, comprising 14 economic, 20 social and 22 environmental (See **Table 2**).

Quantitative indicators like these can be used in the aquaculture sector to assess farms, regions, or different segments, and in research and development to evaluate new technologies or compare experimental treatments. Certifying organizations can classify products, consumers can choose sustainable options, investors can evaluate projects, and policymakers can assess and monitor public policies. They **facilitate diagnostics, identification of strengths and weaknesses, goal setting, action planning, and evaluating the effectiveness of actions and policies** (Valenti et al., 2018).

Key message:

Quantitative indicators of sustainability are essential for assessing aquaculture performance, guiding research, supporting certifications, informing consumer choices, attracting investment, and shaping effective policies.

Table 2. *Indicators of sustainability for aquaculture systems covering the three dimensions and the major principles of sustainability according to Valenti et al. (2018).*

Economic indicators	[1)] Ratio between net income and initial investment; [2)] Internal rate of return; [3)] Payback period; [4)] Benefit-cost ratio; [5)] Net present value; [6)] Net profit; [7)] Negative externalities; [8)] Positive externalities; [9)] Annual income; [10)] Permanence of the farmer in the activity; [11)] Risk rate (includes 11 factors); [12)] Diversity of products; [13)] Diversity of markets; [14)] Invested capital generated in the activity
Social indicators	[1)] Development of local economy; [2)] Use of local workers; [3)] Remuneration of work per unit of production; [4)] Investment to create direct employment; [5)] Investment to create total employment; [6)] Proportion of self-employments; [7)] Permanence in the activity; [8)] Required work per unit of occupied area; [9)] Required Work per Unity of Production [10)] Safety at workplace; [11)] Local consumption of production; [12)] Pay equality; [13)] Proportional cost of work ; [14)] Income distribution ; [15)] Access to health-insurance programs; [16)] Schooling ; [17)] Participation in outside community activities; [18)] Gender inclusion; [19)] Racial inclusion; [20)] Age inclusion
Environmental indicators	[1)] Use of space; [2)] Dependance on water; [3)] Use of energy; [4)] Proportion of renewable energy; [5)] Use of nitrogen; [6)] Use of phosphorus; [7)] Efficiency in the Use of energy ; [8)] Efficiency in the use of nitrogen; [9)] Efficiency in the use of phosphorus; [10)] Production actually used; [11)] Potential of eutrophication; [12)] Potential of organic pollution; [13)] Potential of siltation; [14)] Potential of global warming [15)] General chemical pollution; [16)] Pollution by hormones; [17)] Pollution by heavy metals; [18)] Potential of acidification; [19)] Accumulation of phosphorus; [20)] Accumulation of organic matter; [21)] Accumulation of particulate material; [22)] Risk of farmed species

General perceptions on sustainability of the SSA in APEC economies

Key findings:

There are indications that aquaculture policies in the APEC region are less robust in addressing the environmental pillar of sustainability compared to the economic and social dimensions.

Gaining insight into the perspectives of diverse aquaculture stakeholders in APEC economies is an invaluable resource for the formulation of more inclusive policies within the aquaculture sector. For this report, policymakers from the aquaculture sector were questioned about whether their governments were adequately addressing the economic and social sustainability needs of SSA) producers in their economies (**Figure 2**). The responses indicated that the majority of APEC economies (n=6; 75%) agreed that these needs were adequately covered. Additionally, one economy (12.5%) totally agreed with this statement, and only one economy disagreed (12.5%). The interpretation of this data has some limitations, as government officials might be reluctant to provide negative responses that could reflect poorly on their own administration. Nonetheless, a significant contrast emerged in their responses when asked about the environmental components of sustainability (See **Figure 3**).

When the officials were questioned about whether their governments were adequately addressing the environmental sustainability needs of SSA producers (**Figure 3**), the responses revealed that most officials (n=4; 50%) were neutral, neither agreeing nor disagreeing with the statement. Three officials (37.5%) agreed that these needs were adequately covered, and only one official (12.5%) totally agreed with the statement. It is evident that most government officials are more cautious about the environmental sustainability performance of the aquaculture sector in their economies compared to the economic and social aspects. This may probably indicate **passive recognition that aquaculture policies are more deficient on the environmental pillar of sustainability.**

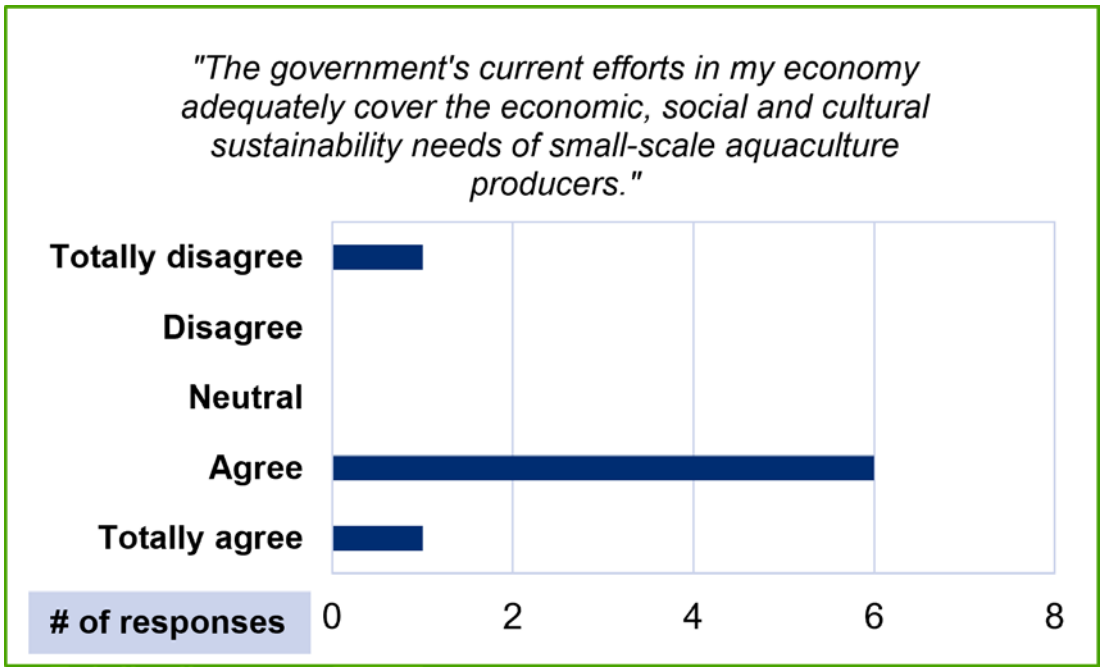

Figure 2. *Government officials from the aquaculture sector in APEC economies' agreement with the statement "the government's current efforts in my economy adequately cover the economic, social and cultural sustainability needs of SSA producers."*

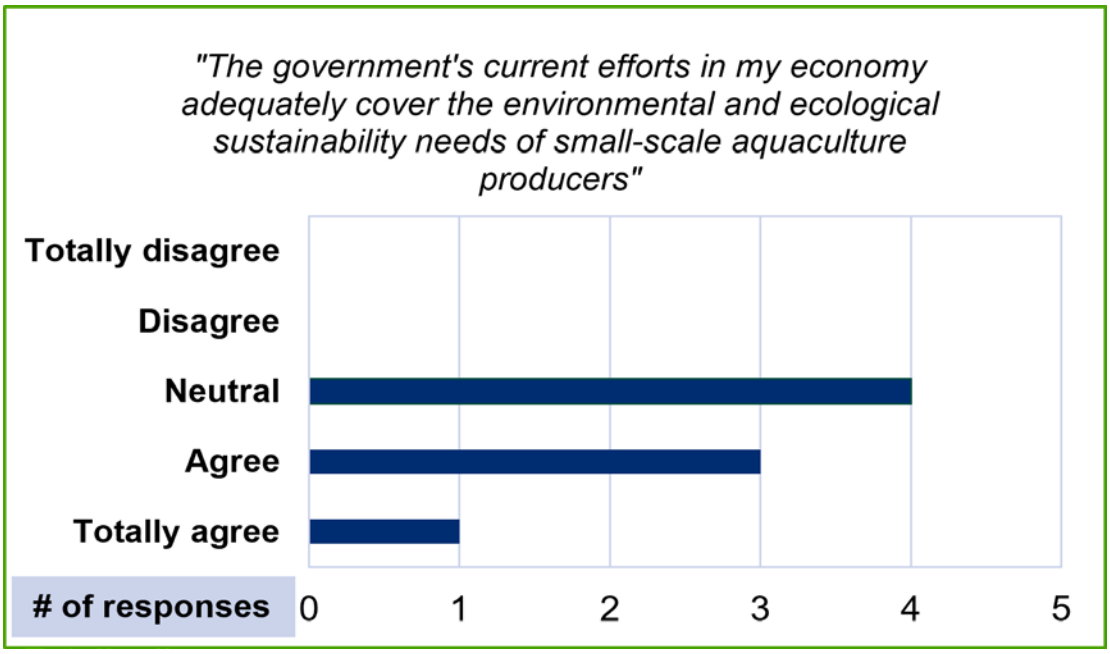

Figure 3. *Government officials from the aquaculture sector in APEC economies' agreement with the statement "the government's current efforts in my economy adequately cover the environmental and ecological sustainability needs of SSA producers."*

Main sustainability challenges for aquaculture

Aquaculture plays an important role in global food security and nutrition, providing a growing share of the world's seafood supply. However, its rapid expansion brings significant sustainability challenges that must be addressed to ensure its long-term viability. Key concerns include environmental impacts such as water pollution, habitat degradation, and resource depletion; social challenges like labor practices and community displacement; and economic pressures such as market volatility and rising input costs. Addressing these challenges is essential to minimize aquaculture's ecological and societal footprint while maintaining its contribution to global food systems. A recent study by Tucciarone et al. (2024) provides valuable insights into how sustainable aquaculture research has evolved over the last 30 years, offering a data-driven perspective on emerging trends, challenges, and potential solutions (See Box 1).

Box 1. *Main sustainability themes and challenges in aquaculture research.*

A systematic literature review conducted by Tucciarone et al. (2024) used text mining and topic analysis on 1,111 peer-reviewed articles to identify the most relevant themes and challenges in sustainable aquaculture research over the last 30 years (1989–2023).

The review identified that the scientific output on sustainable aquaculture has quadrupled between 2017 and 2023. Alternative aquaculture systems such as **Biofloc**, **Integrated Multi-Trophic Aquaculture (IMTA)**, and **Recirculating Aquaculture Systems (RAS)** gained traction after 2010, while **aquaponics** became a focus only around 2015.

The **15 main research topics** identified by topic analysis were:

- Disease management: Studying probiotics, essential oils, herbal extracts, vaccines, and microbiome research to prevent and treat diseases in aquaculture.
- Marine species potential: Exploring the farming potential of different marine species.
- Coastal ecosystems: Understanding the environmental impact of aquaculture in coastal areas.
- Fish and plant integration: Research on aquaponics systems.
- Chemical analysis: Assessing water and feed quality.
- Wastewater treatment: Methods to manage and minimize aquaculture waste.

- Research and innovation: The role of technological advancements in aquaculture sustainability.
- Global food demand: Examining aquaculture's contribution to food security.
- Economic impact of aquaculture: Studying the financial viability of sustainable practices.
- Shrimp quality: Research on improving shrimp farming and product quality.
- Sea conditions: Environmental factors affecting aquaculture.
- Genetics in aquaculture: Genetic improvement, breeding, and biodiversity conservation.
- Protein replacement in feeds: Investigating alternative protein sources to replace fishmeal and fish oil.
- Optimization of aquatic life: Enhancing growth rates, stocking densities, and feed efficiency.
- Social policy: Examining regulatory frameworks and public perception of aquaculture.

From these topics, three stood out as the most studied challenges in sustainable aquaculture: **Optimization of aquatic life**, **genetics in aquaculture** and **disease management**. The field has also increasingly addressed **alternative feeds**, **wastewater treatment**, and **integrated farming** systems to reduce environmental impacts and improve sustainability. However, challenges remain in regulatory frameworks, cost-effectiveness of sustainable practices, and public perception.

Government officials can use the findings from this and similar studies to develop targeted policies that support biosecurity measures, sustainable feed alternatives, and integrated aquaculture models. By funding research on disease control, incentivizing low-impact farming technologies, and promoting regulatory consistency, policymakers can ensure that aquaculture remains both economically viable and environmentally responsible while meeting the rising global demand for seafood.

Challenges to economic sustainability

Aquaculture enhances community resilience by generating jobs, revenue, and business development, preventing outmigration, and strengthening financial resources. Expanding beyond traditional aquaculture farming, modern aquaculture supports diverse production systems and stimulates upstream and downstream industries like feed production, processing, and transportation. While some fear it may displace wild fisheries, aquaculture has instead boosted seafood consumption and reinforced fisheries infrastructure. Aquaculture attracts investment, improves local economies, and enhances disaster preparedness by increasing tax revenue for infrastructure. Its year-round production ensures greater market resilience, as seen in its faster recovery from COVID-19 (APEC, 2023). Overall, sustainable aquaculture strengthens local economies and mitigates environmental and economic shocks.

Limited revenue generation for SSA

A crucial aspect for the long-term development of SSA enterprises is their economic viability. An official from the Policy Analyst Ministry for Primary Industries in New Zealand identified the **limited generation of revenues as one of the main challenges for the sustainable development** of the SSA in their economy in their economy:

Key findings:

Aquaculture stakeholders across APEC economies agree that the primary economic challenge to sustainable SSA development is the limited revenue generation.

"The volume that small-scale farmers can produce can be a constraint because at a small scale, some products won't generate enough revenue to be economically viable (may not cover operating costs). Small scale farmers may not have the infrastructure to grow, harvest, and process products themselves through vertical integration. This could constrain the revenue gained and make them dependent on partnerships/agreements with the large companies."

A similar recognition was given by an official of the General Direction of Aquaculture from the Ministry of Production of Peru (PRODUCE):

> "*The challenge we have in Peru is for limited resources aquaculture (AREL) producers to scale their production levels, in such a way that they enter the market with greater production and being more competitive; This will result in an increase in their income and an improvement in the economy of their families.*"

The deficient generation of revenues and the lack of associativity were recognized among the main concerns for SSA farmers in the Philippines. As described by a member of the Bureau of Fisheries and Aquatic Resources in the Philippines:

> *"(SSA farmers) cannot achieve scale economy and fishers engaged in aquaculture are not organized".*

Research plays a crucial role in identifying the key barriers to economic viability in small-scale aquaculture enterprises, ensuring that policies and support programs effectively address these challenges. For instance, a study on economic indicators in the seaweed value chain in the Zamboanga Peninsula, Philippines, revealed that nursery operators and small-scale farmers earn significantly less than other actors in the value chain, such as traders, processors, and exporters. This disparity is largely due to the farmers' limited asset ownership, restricted access to quality inputs (such as seed), and gaps in skills, knowledge, and networks. The authors suggest that targeted interventions, such as technical assistance, could help improve farmers' participation and profitability (Ramirez et al., 2020).

Key message:

Limited education, skill gaps, and urban-rural disparities hinder SSA households from diversifying their livelihoods. Effective interventions must address these barriers through targeted education, training, and job creation

Barriers for livelihood diversification in SSA

SSA farmers and fishers, particularly in rural areas, can significantly benefit from diversifying their livelihoods to enhance economic sustainability. However, despite its potential advantages, rural households often face considerable barriers that hinder their ability to pursue alternative income sources.

A study on small-scale fisheries and aquaculture households in Viet Nam identified three primary constraints to livelihood diversification: limited desire, abilities, and opportunities to engage in alternative economic activities (Hanh & Boonstra, 2019). A key barrier is educational and skill deficiencies, particularly among older generations, who have spent decades in fishing and aquaculture and often lack formal education or literacy. Younger generations show greater willingness to explore alternative livelihoods but encounter challenges such as inadequate education, lack of vocational training, and limited job opportunities aligned with their skills (Hanh & Boonstra, 2019). Additionally, while Viet Nam's structural economic changes have created more income diversification opportunities, these remain largely concentrated in urban areas, making access difficult for rural households. Social and economic capital—such as financial resources and professional networks—also influence who can successfully transition to alternative livelihoods (Hanh & Boonstra, 2019).

To effectively promote livelihood diversification, interventions must account for generational differences and the unique social and ecological contexts of fishing and aquaculture households. Strengthening education, vocational training, and labor skills, alongside creating alternative employment opportunities, is essential for reducing reliance on fisheries and fostering sustainable livelihoods in SSA communities.

Challenges to social sustainability

Key message:

Aquaculture sustainability must go beyond economic and environmental aspects to address social inequalities, informal practices, and the lack of protections for small-scale producers.

Much of the academic research, policies, and strategies on aquaculture sustainability have primarily focused on economic and environmental dimensions, while critical aspects of social sustainability remain largely overlooked. Key concerns such as unequal access to resources based on gender, inequitable distribution of benefits, and the disconnect between aquaculture benefits and local community needs have received far less attention. Moreover, misconceptions among policymakers regarding the criteria for socially sustainable enterprises may further hinder progress in this area.

While aquaculture indeed plays a crucial role in livelihoods and food security, this perspective fails to account for prevalent informal practices that are neither socially nor environmentally sustainable. Additionally, the absence of social protection systems, conflicts with local fisheries, gender inequalities, and limited access to aquaculture benefits for indigenous communities (where present) further highlight gaps in achieving true social sustainability.

This presents a major challenge, especially considering that the majority of global and APEC-region aquaculture production occurs in developing economies, where smallholder enterprises dominate and constitute a significant portion of the workforce. If the socio-economic costs and benefits of aquaculture continue to be neglected in policy development, small-scale producers risk exclusion from broader societal and economic benefits, further exacerbating inequalities in the sector.

Lack of social protection systems

Social protection can be defined as a set of interventions whose objective is to reduce social and economic risk and vulnerability, and to alleviate extreme poverty and deprivation. Social protection systems in aquaculture rely on three types of programs to achieve such objectives[4].

Social protection systems for aquaculture:

Social assistance: cash and in-kind transfers.
Social security: contributory programs that protect people from the financial impacts linked to old age, unemployment, illness, shocks, among others.
Labor market interventions: protective measures to enhance employment opportunities, improve skills of workers and offer livelihood support.

In this regard, FAO's SocPro4Fish[4] project aims to compile information on the social protection systems available for fishers, fish farmers, and fish workers, promoting policies that institutionalize social protection and address gender-specific needs in the sector. Currently active in Colombia, Paraguay, and Tunisia, the project seeks to expand globally, demonstrating its impact on poverty reduction, resilience building, and natural resource management through gender-responsive interventions.

In 2019, the FAO mapped the social protection systems available for small-scale aquaculture in Latin America and the Caribbean, particularly the limited resources aquaculture (AREL). The report presented a diagnosis of the vulnerabilities and specific needs on social protection systems, policies and programs that exist in the Latin American region, while including public

[4] Food and Agriculture Organization (FAO). Social Protection for Fisheries and Aquaculture (SocPro4Fish). Accessed on: 07 February 2025. Available in: https://www.fao.org/in-action/social-protection-for-fisheries-and-aquaculture/background/en

policy recommendations and a roadmap to strengthen the social protection of artisanal fishermen and AREL.

Informality in the aquaculture sector

The aquaculture sector in developing APEC economies is composed of a high proportion of informal small-scale enterprises, primarily staffed by self-employed individuals and workers without written contracts who earn less than the legal minimum wage and lack social insurance coverage. This precarious situation leaves them highly vulnerable to external shocks, as demonstrated during the COVID-19 pandemic (APEC, 2023). Furthermore, it makes the sector susceptible to other disruptions, such as natural disasters and the impacts of climate change. This group includes small-scale farmers, migrant workers, women, ethnic minorities, harvesters, gleaners, and vendors (FAO, 2021).

High levels of informality in aquaculture are a persistent problem in some Latin American economies. In Peru, according to government officials of the aquaculture sector, informality is a major challenge in the SSA sector, however a precise percentage of the informal aquaculture enterprises present in Peru remains to be determined and an economy wide survey would give insights into the magnitude of the challenge and would allow to determine if policies in favor of the formalization of small-scale producers are being effective. A similar situation was highlighted during interviews with Mexican aquaculture officials:

> *"There is much more small-scale aquaculture than what is recorded by the authority, which is Conapesca, the oversight and regulation authority, and formal commercial aquaculture represents only a small part of the activity in Mexico".*

The prevalence of informal and illegal activities can significantly impact aquaculture governance, leading to the creation of complex hybrid institutional entanglements with formal practices and frameworks. This phenomenon has been recently examined in the context of the Peruvian scallop (*Argopecten purpuratus*) aquaculture industry in Northern Peru (Box 2).

***Box 2.** Interlink between illegal, informal and formal practices and frameworks in the Peruvian bay scallop aquaculture industry in Sechura, Peru.*

Background of study

The Peruvian government granted concessions for enterprises to develop commercial farming of Peruvian bay scallop (*A. purpuratus*) in Sechura bay, amid increased demand for scallop on the global market. Legal frameworks were developed with a view to formalizing the industry in this region. In 2013, the Sechura bay accounted for 80% of Peruvian and 50% of Latin American scallop production. Peruvian bay scallop is almost exclusively exported, with 67% sold to Europe, and 23% marketed within the Americas (Damonte et al., 2023).

Main problem and objective

Despite the government's efforts, informal and illegal activities persist around the concessions but also interlink with formal practices and frameworks.

Research methodology

Primary data: Interviews with experts, informal conversations and semi-structured interviews with representatives of different value chain actors, including farmers, workers (divers), and state authorities.

Secondary data: Literature review and systematized quantitative and qualitative secondary information obtained from the Ministry of Production of Peru (PRODUCE) and the media.

Main findings

Unsustainable, informal and illegal practices are present along the Peruvian scallop value chain in Sechura, mixed in hybrid forms of governance. The main findings of the research were:

- Grow-out areas installed illegally within areas declared as not suitable for aquaculture.
- Operating concessions that are not (yet) formalized.

- Presence of several informal/illegal scallop processing plants
- Products are not landed at official sites and are brought directly to local markets, hence avoiding any sanitary inspection.
- Conflicts with authorities and lack of trust.
- The state's weak enforcement capacity, due to a lack of resources among other factors, has resulted in the incomplete implementation of formal regulatory institutions.

Conclusions

Producers are by-passing state regulatory power by perpetuating informal and illegal practices. Consequently, state regulatory initiatives have failed to meet their formalization goals, while formal, informal, and illegal practices coexist, intertwined in hybrid institutional entanglements. Finally, it is essential to empower and involve local producers and stakeholders in knowledge networks to understand and eventually solve governance problems.

Gender inequalities in the SSA

Women play a vital role in aquaculture, nonetheless women's contributions to aquaculture often go unrecognized due to a gendered division of labor in the seafood industry, where women hold low-income jobs, mostly the secondary sector, while men occupy top positions, in both primary and secondary sectors. According to the FAO, women represent 21% of the workforce in the primary fisheries and aquaculture sectors, although this number rises to 50% when counting both primary and secondary sectors (FAO, 2022). The aquaculture post-production sector is particularly female-dominated, with women comprising 56% to 99% of the workforce (Kruijssen et al., 2018).

The gendered division of labor in aquaculture varies across economies depending on socio-cultural norms, technology and the sector's economic significance. In China, it has been reported that women engage in all aspects of aquaculture from pond construction to harvesting, while in other rural areas of Asia, their participation is more restricted (Kusakake & Thongprasert, 2022). Asia accounts for 98% of the women employed in aquaculture, with more than half working full time—a higher proportion than men (51% vs. 40%) (Kusakake & Thongprasert, 2022).

Key message:

Women's contributions to aquaculture are significant yet underrecognized due to gendered labor divisions and a lack of sex-disaggregated data, hindering efforts to address gender inequality in the sector.

Roles in small-scale and subsistence aquaculture systems are typically maintained within the family. Consequently, incorporating gender approaches to analyze these systems can reveal the contributions and roles of both women and men, which might not be apparent in traditional market analyses. In the Philippines, Ramirez et al. (2020) examined the extent to which adoption of seaweed farming in the Zamboanga Peninsula has transformed the socioeconomic status of the women and men involved in the seaweed value chain. The study revealed that though men are very visible in the different nodes of the value chain, about 60% of farming activities are actually performed by women (and children), while men handle tasks related to planting, cleaning of farm areas and harvesting. Additionally, women are significantly involved in post-harvest and marketing segments. However, women are most of the time not directly paid for their efforts due to the family nature of the analyzed ventures.

Despite their significant participation, women's contributions remain underrepresented in data and policies, limiting efforts to address gender disparities in small-scale aquaculture (SSA). In this regard, **the use of sex-disaggregated data is a critical tool for identifying gender inequalities and assessing the effectiveness of policies**. However, at the economy level, sex-specific data on women's participation in SSA is often scarce or entirely absent, leading to their exclusion from official statistics, development programs, and institutional frameworks. This data gap hinders efforts to understand gender issues and advance gender equality. A clear example is the OECD open database on Employment in Fisheries, Aquaculture, and Processing, which

includes data from 14 out of 21 APEC economies but provides sex-disaggregated data for only three economies (Chile; the Philippines; and Thailand) (See Table 3). This lack of reporting further obscures women's role in the sector. Incorporating sex-disaggregated data in research and policy development would provide a more comprehensive understanding of the challenges and realities faced by women in small-scale fisheries and aquaculture.

Table 3. *Employment (total number of jobs) in the primary aquaculture sector in selected APEC economies (2020-2021).*

Economy	Gender	2020	2021	Variation 2020-2021
Australia	Both	7000	7000	0%
Chile	Female	2266	2111	-6.84%
	Male	8869	8141	-8.21%
Japan	Both	32260	30754	-4.67%
Korea	Both	34634	35281	1.87%
Mexico	Both	56250	56250	0%
New Zealand	Both	900	830	-7.78%
The United States	Both	7344	7664	4.36%
Indonesia	Both	2238847	2252701	0.62%
Malaysia	Both	20261	21241	4.84%
Peru	Both	6755	7320	8.36%
The Philippines	Female	ND	82619	-
	Male	ND	165349	-
Chinese Taipei	Both	88520	85342	-3.59%
Thailand	Female	254518	251621	-1.14%
	Male	280307	275077	-1.87%
Viet Nam	Both	1754096	1773399	1.10%

ND: No data.
Source: OECD database on Employment in fisheries, aquaculture and processing.

Addressing gender inequality in aquaculture requires not only better data but also active efforts to ensure inclusive participation in research and policy development. For the present report, a digital questionnaire was distributed among APEC officials in the aquaculture sector, yielding a balanced response rate with equal representation of females and males (**Figure 4**). This outcome aligns with one of the project's objectives—achieving at least 30% female participation. Inclusive projects consistently track gender-related goals, ensuring that women's perspectives are considered in policy discussions and decision-making processes. A similar approach must be used when designing public policies.

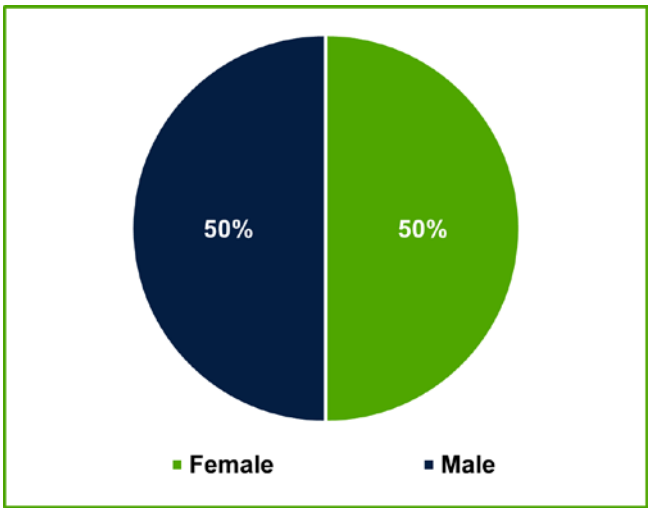

Figure 4. *Gender participation in the digital questionnaire and interviews used to elaborate the present report.*

Challenges to environmental sustainability

Aquaculture is a rapidly growing food production technology, but there are significant concerns related to its environmental impact. The environmental impacts of aquaculture are more related to large-scale enterprises, however numerous small-scale production systems in limited areas can be impactful to the environment. In addition, aquaculture is sensitive to natural disasters and climate change impacts.

Aquaculture offers several ecosystemic services. Such services are sometimes not so obvious for the general population and even when recognized they can be affected by shifts in public perception, which can greatly influence the enjoyment and benefits people derive from ecosystem services. For example, in British Columbia, Canada negative views on offshore finfish aquaculture have led to industry stigmatization, prompting marketing campaigns to counter this reputation (Singh et al., 2020).

Environmental impacts of small-scale aquaculture

Key message:

Aquaculture offers environmental benefits over traditional livestock farming, but its sustainability depends on responsible management. To minimize its ecological and social impacts, the industry must adopt best practices, regulatory frameworks, and technological innovations that balance production with environmental and community well-being

Aquaculture is often regarded as a low-impact food production system compared to other animal-based industries. In Papua New Guinea, aquaculture has been identified as having a lower impact on biodiversity than fishing, which is classified as high-impact (White et al., 2021). Additionally, aquaculture presents opportunities to enhance environmental sustainability by reducing greenhouse gas emissions, land use, terrestrial acidification, and water consumption in certain production systems compared to terrestrial livestock farming. However, some freshwater aquaculture systems may contribute to eutrophication and local water scarcity (Poore & Nemecek, 2018).

The environmental and ecological impacts of aquaculture vary widely depending on the production system. Intensive cage farming, for instance, releases fish feces and uneaten feed into the environment, which can accumulate in sediments, fueling microbial activity that leads to hypoxic or anoxic conditions and the production of toxic sulfides and methane. Finfish aquaculture can also alter water quality parameters such as dissolved oxygen, pH, salinity, and organic and inorganic matter levels. Additionally, the discharge of chemicals and pharmaceuticals can further impact surrounding ecosystems.

To mitigate the negative impacts of aquaculture, a combination of management tools is essential. Best management practices (BMPs), alternative culture systems, regulatory frameworks, voluntary incentives, and technological innovations all play a role in reducing environmental and social risks. Moving forward, aquaculture must continue to integrate legal frameworks, cutting-edge technologies, and improved operational practices to ensure its sustainable development while minimizing its ecological and social footprint.

Global analysis of environmental sustainability in aquaculture
Jiang et al. (2022) developed an index to measure resource consumption and environmental impacts of aquaculture. Using a footprint method grounded in life cycle inventory data from existing literature, the authors devised a food-energy-water-carbon composite sustainability index, with scores ranging from 0 (not sustainable) to 100 (completely sustainable). The findings indicated that the global sustainability of aquaculture is generally low, with an average score of 26 (More information on **Box 4**).

Box 3. *Water, energy and carbon footprint of global aquaculture.*

According to Jiang et al. (2022), in 2018, global aquaculture production consumed about 1765.2 × 10^3 TJ of energy, 122.6 km^3 of water, and emitted 261.3 million tons of greenhouse gases. Significant disparities in resource efficiency and environmental impacts were observed among economies, with developing economies typically being less efficient and having higher environmental impacts. This underscores the need for comprehensive environmental impact assessments across various aquaculture sectors and highlights the potential for achieving global sustainability by addressing inequalities between economies with differing developing statuses. The study emphasizes the importance of integrated management and policymaking to attain sustainable aquaculture globally.

The aquaculture revolution in Asia has been driven not by high capital investments and complicated technology packages, but through low-tech, rural small-scale developments. However, aquaculture is highly reliant on environmental commons such as water availability and quality, feed sourcing, and nutrients. Regulatory frameworks governing these areas already exist in other productive sectors. Consequently, institution building in aquaculture will likely necessitate cross-sector collaboration and adaptation (Partelow et al., 2023).

Sustainability challenges linked to the impressive aquaculture expansion and intensification in certain areas require a grounded understanding of institutions and their evolution. This aspect of governance can serve as a well-informed foundation for leveraging institutional frameworks to achieve desirable sustainability outcomes in the aquatic food sector.

Is there a market for eco-labelled aquaculture products?

Key message:

Growing consumer's demand for eco-labelled seafood highlights the need for better marketing, awareness, and accessible certification to drive sustainable aquaculture.

As global demand for seafood rises, sustainable aquaculture has become a key focus for both producers and policymakers. However, the success of sustainability initiatives depends not only on production practices but also on consumer behavior and market demand for eco-labelled products. Box 3 presents a case study that examines consumer preferences for eco-labelled aquaculture products in Viet Nam, based on research conducted by Xuan (2021).

Box 4. *Consumer preferences for eco-labelled aquaculture products in Viet Nam.*

The study by Xuan (2021) investigated consumer preferences for eco-labelled shrimp in Viet Nam, focusing on their willingness to pay for certified products compared to conventional shrimp, using a discrete choice experiment with 353 consumers from Khanh Hoa province and Ho Chi Minh City.

Key findings on consumer preferences for eco-labelled products:

- ✓ Consumers value eco-labelled shrimp over conventional shrimp:
  Willingness to pay for eco-labelled shrimp ranges from 6% to 51% higher than for conventional shrimp.
- ✓ Preference for third-party certification:
  Shrimp labelled with the Aquaculture Stewardship Council (ASC) logo (a third-party certification) received the highest premium price, while shrimp certified under VietG.A.P (Viet Nam's government certification) had the lowest premium, despite being the most recognized by consumers.
- ✓ Perceived consumer effectiveness influences purchasing decisions:
  Consumers who believe their individual choices contribute to sustainable aquaculture are willing to pay more for eco-labelled products.
- ✓ Market and Policy Implications:
  Marketing campaigns to raise awareness about eco-labels could improve adoption. The VietGAP certification is more accessible for farmers, but international certifications like ASC and GlobalGAP may be more attractive for export markets. Policy efforts should focus on bridging the knowledge gap and promoting the economic and environmental benefits of certified aquaculture.

Conclusion:

There is strong consumer interest in eco-labelled shrimp in Vietn Nam, but preferences vary based on certification type, consumer awareness, and perceived effectiveness in supporting sustainability. Policies and marketing strategies should leverage this demand to promote sustainable aquaculture practices and encourage broader adoption of eco-certifications.

Similar findings have been reported in Malaysia by Kamaruddin et al. (2023), who examined consumer preferences and willingness to pay (WTP) for farmed fish compliant with Good Aquaculture Practices (GAP). Their study revealed a strong preference for certified fish, with consumers willing to pay 43% to 114% more than for non-GAP fish. Higher education, income, aquaculture knowledge, and sustainability awareness were key factors driving greater WTP. However, GAP certification remains underutilized due to high costs, low perceived benefits for farmers, and limited price differentiation in the market. To promote wider adoption of GAP and support sustainable aquaculture, improved marketing strategies, consumer awareness campaigns, and premium pricing models are essential.

Impact of natural disasters on aquaculture sustainability

The impact of natural disasters and climate change on aquaculture varies widely across economies due to differences in geography, infrastructure, farmed species, and adaptive capacity. While some regions experience severe production losses from extreme weather events, others may be more resilient due to advanced infrastructure, climate adaptation measures, or government support programs. The effects of climate-related hazards on aquaculture must be addressed at a regional level, allowing for targeted risk assessments and localized adaptation strategies.

In the Philippines, where milkfish aquaculture plays a vital role in food security and livelihoods, understanding the specific vulnerabilities and challenges faced by producers is critical for strengthening the sector's resilience. Macusi et al. (2021) highlighted the vulnerability of milkfish aquaculture in the Philippines', particularly in the fisheries management areas 6 and 9. Key hazards include typhoons, flooding, unpredictable rainfall, rising water temperatures, and sea-

level rise, which severely impact production, trading, and processing. Extreme weather events damage pond dikes, causing fish escapes, increased mortality, and lower yields, while flooding and transport disruptions reduce market quality and drive down prices. Limited cold storage and ice-making facilities further contribute to post-harvest losses. Farmers face financial instability due to infrastructure damage and declining productivity, increasing their vulnerability to income loss and food insecurity. The impacts are more severe to SSA actors. To mitigate these challenges, stakeholders emphasize the need for reinforced pond structures, better cold storage, alternative feeds, improved hatcheries, and financial assistance to enhance the sector's resilience to climate-related risks.

The APEC region is an area susceptible to pronounced fluctuations on weather patterns derived from the El Niño Southern Oscillation (ENSO) which can have profound effects on the aquaculture sector, with the small-scale aquaculture sector being usually the hardest hit. Recently, the FAO (2023) issued a report on the effects of the El Niño phase of the ENSO system on agriculture, livestock, fishing and aquaculture with recommendations for action. The main negative impacts by type of manifestation (low precipitation, higher precipitation, sea temperature changes) derived from that research are described on the table below (Table 4).

Table 4. *Summary of expected negative impacts of the "El Niño" on the aquaculture systems by type of manifestation.*

Lower precipitation	Decrease in eggs and fry due to changes in species reproduction
	Changes in phytoplankton production and thus food for cultivated species
	Mortality in farming centers due to lack of oxygen and stressful conditions
	Conflict over water use during periods of droughts with other sectors
Higher precipitation	Mortalities of farmed species
	Invasion of unwanted species in cropping systems
	Damages to production centers and infrastructure
	Deterioration of water quality and risk of contamination
	Loss of fish found in ponds and cages
Sea temperature changes	Affectation on the physical and physiological condition of cultivated species
	Increase in diseases in cultured aquatic organisms and greater spread of pathogens in general
	Increases in harmful algal blooms causing fish kills

Data obtained from the FAO Global Information and Early Warning Center (GIEWS).

Insights on adaptive capacity of aquaculture

Within the aquaculture context, adaptive capacity can be defined as the ability of aquaculture operators to adjust to the challenges imposed by climate and environmental changes to adapt to the challenges, take advantage of opportunities, and to effectively respond to their consequences (Ward et al., 2022). A study developed in 2020, explored California shellfish aquaculture operators' perceptions of the impacts of climate and environmental change, and identified explicit strategies suggested by farmers to adapt to these changes (Ward et al., 2022). The full findings of this study are presented in **Box 5** (Ward et al., 2022).

Box 5. *California shellfish farmers: Perceptions of changing ocean conditions and strategies for adaptive capacity.*

The main environmental factors impacting shellfish as identified by Californian shellfish farmers, with descriptions of how each factor could operate are presented next:

- ✓ Disease/pathogens: Increase mortality and temporary closures of operations.
- ✓ Shifts in species populations: Can directly affect shellfish and shellfish harvest.
- ✓ Eelgrass: Eelgrass can grow around cultures, however, is protected by regulations.
- ✓ Algal blooms: May cause mortality or lead to temporary closure to operations.
- ✓ Kelp: Wild kelp serves as a primary food source for cultured abalone.
- ✓ Shifts in carbonate chemistry: Carbone chemistry parameters such as water pH and pCO_2 can reduce shellfish calcification, growth, and survival.
- ✓ Increasing rainfall: Can augment run-off, sedimentation, blooms, alter marine pathogens or alter seawater carbonate chemistry and salinity.
- ✓ Water temperature: Can alter marine pathogen populations, shellfish physiology, spawning, and exacerbate mortality rates.
- ✓ Cloud cover: In intertidal zones or shallow water can lead to desiccation and stress.
- ✓ Pollution: Can induce pathogen or algal blooms.
- ✓ Changes in wind parameters: Can impact numerous factors such as carbonate chemistry, water temperature, dissolved oxygen, and kelp cover, which can have negative impacts on shellfish production.
- ✓ Air temperature: Can induce increased desiccation and thermal stress.
- ✓ Dissolved oxygen: Can manifest as increased mortality or reduced growth.
- ✓ Sediment: Can impact shellfish by increasing turbidity or, in the case of on-bottom culture, through scouring, burial, or depth alterations that directly affect the shellfish and culture equipment. It can be induced by rainfall events or altered hydrodynamics.
- ✓ Changes in hydrodynamics: Can modify nutrient composition and favor sediment deposition.
- ✓ ENSO: During the “El Niño” phase of this natural event, the predominant warm water can reduce kelp populations, increase pathogens and mortalities.
- ✓ Water level rises: Sea level rise is of particular importance for farms in bays and estuaries when considering how the culture locations and total suitable areas for shellfish culture within their permitted lease areas may change in the future.

Meanwhile, the main adaptive capacity strategies identified by Californian shellfish farmers can be categorized as policy/networking, farm management, and science.

Policy and networking approach

The policy and network strategies should permit new operations and simplify or clarify permit changes for existing ones, developing networks among growers, managers, policymakers, and scientists to share information and establish best practices, securing funding, and monitoring water quality parameters are all essential steps to support sustainable aquaculture development.

Farm management approach

Effective farm management strategies include growing in multiple locations, diversifying species, incorporating multiple lifecycle stages, and adopting new or varied gear types. Additionally, success in aquaculture relies on balancing retail and wholesale markets, optimizing pricing and marketing strategies, managing water intake efficiently, maintaining temporal flexibility, and utilizing variable ploidy techniques to enhance resilience and productivity.

Science approach

Advancing scientific research requires enhancing knowledge of shellfish health, developing genetically resistant strains, improving water quality monitoring, studying environmental impacts, and exploring the benefits of polyculture to promote sustainable and resilient farming practices.

CHAPTER 2: What public and private initiatives in favor of the development of sustainable small-scale aquaculture have been developed in the APEC region?

The necessities of SSA systems are numerous as seen in the previous chapter. In this chapter, public and private initiatives that have been established to promote sustainable SSA within the APEC region will be explored. By examining these efforts, we aim to identify the best practices, successful strategies, and areas for improvement that can support the growth and sustainability of small-scale aquaculture enterprises. Studies on stakeholders' perceptions are crucial for defining coping strategies and enhancing resilience in the SSA aquaculture industry. A case study of is presented in **Box 6**.

Box 6. *Status, supply chain, challenges, and opportunities to advance oyster aquaculture in northern Viet Nam.*

Background

Oyster aquaculture is a relatively new but rapidly growing and highly successful industry in Viet Nam. In 2023, Ugalde et al. analyzed the status, mapped the supply chain, and identified challenges and opportunities to advance oyster aquaculture in northern Viet Nam.

Objective

The study aimed to understand the industry's current state, distribution networks, and key challenges. Additionally, the research explored potential opportunities such as the better utilization of oyster shells as by-products and the exploration of carbon offset schemes to enhance economic and environmental sustainability.

Results

The authors conducted a comprehensive survey of industry representatives spanning the entire oyster supply and value chain, from hatcheries to consumers and exporters. A total of 22 respondents were surveyed. The respondents highlighted several key technologies and policy interventions necessary for improving the efficiency and sustainability of oyster aquaculture in the region. These included:

1. Linking production and consumers.
2. Changes in water or land management policies.
3. Financial support to get loans with low interest.
4. QR-codes for origins and traceability.

Interestingly, none of the respondents considered new species diversification to be helpful.

The top 5 key challenges identified for oyster production and oyster supply chain in the region were:

1. Spatial and marine development planning
2. Market price variation and consumers
3. animal health and biosecurity
4. Collaboration/coordination along the supply chain
5. Lack of monitoring

There is justification to promote the use of oyster shell by-products. On the other hand, the potential for carbon offset schemes is complex, but economic mechanisms exist and how these may be relevant is an opportunity for oyster aquaculture with growing interest.

Strategic plans for aquaculture

In this section, we delve into various strategic plans aimed at fostering the development of sustainable aquaculture across different APEC economies.

In 2008, Brunei Darussalam's government developed the "Wawasan Brunei 2035" plan, a long-term development plan, whose primary objective is to diversify the economy away from its dependence on oil and gas resources. In this long-term plan, aquaculture is seen as a relevant economic activity that can contribute to such a goal. The volume of aquaculture products produced in Brunei is considered low, however due to its small population production value per capita is considered high compared to other ASEAN countries (Marsal et al., 2023).

The fisheries strategic plan for Papua New Guinea 2020-2030 is a comprehensive roadmap designed to guide the sustainable development of their fisheries sector. Recognizing the importance of fisheries in contributing to food security, economic growth, and livelihoods, the strategic plan employs a multifaceted approach, placing a significant emphasis on the development of aquaculture and coastal fisheries. Key emphasis is given to strengthen incentives that provide technical assistance, financial support, and capacity building programs for local communities to actively engage in aquaculture ventures.

In 2020, the Cooperative Research Centre for Developing Northern Australia (CRCNA) (Cobcroft et al., 2020) developed a proposal for the developing of the aquaculture sector in northern Australia, further highlighting the region's commitment to advancing aquaculture as a sustainable and profitable industry (See **Box 7**).

Box 7. *Recommendations for developing the aquaculture sector in northern Australia.*

In 2020, the CRCNA conducted a situational analysis of Northern Australia's aquaculture sector and outlined seven recommendations for its development, emphasizing future sustainability (Cobcroft et al., 2020). APEC economies with extensive territories, complex geography or regionally differentiated aquaculture systems should establish regional plans rather than a single, economy-wide solution. Encouraging the development of regional plans is crucial due to the distinct differences within the aquaculture sectors across various regions. The following recommendations can be applied to similar situations in other APEC economies or specific regions. The order of recommendations was determined through stakeholder input.

1. **Bolster biosecurity:** Both exotic and endemic pathogens pose a great risk to aquaculture. The proposed actions to increase this goal include:
   A. Aquaculture policies should be reviewed to enhance risk assessments and R&D programs for better biosecurity management.
   B. Increase pathogen understanding, documentation of risks, and the implementation of practical surveillance.
   C. Establish structures to develop high-health lines for key production species.

2. **Build skills to meet industry growth needs**: This recommendation aims to address the gap in skilled personnel needed to support new jobs in aquaculture. Proposed mechanisms include:
   A. Enhancing existing aquaculture education and training systems.
   B. Attracting more individuals to the sector through targeted campaigns and improved sector image.
   C. Promoting the engagement and participation of Indigenous communities in the aquaculture industry.
   D. Urgently improving visa conditions and programs for skilled migrant workers.

3. **Support market development and access for aquaculture both domestically and internationally**. Suggested activities include improving access to seafood trade data, organizing trade delegations to potential international markets, and enhancing consumer awareness campaigns.

4. **Match and target RD&E to key industry needs and outcomes**: Align RD&E with the economy-wide aquaculture strategy and other relevant plans. Focus research on industry needs and deliver value for investment to remove bottlenecks and support growth.

5. **Facilitate infrastructure development for key aquaculture development hubs**: To capture the opportunities that aquaculture development areas and zones can offer, it is essential to co-develop sites and hubs that meet infrastructure requirements and leverage investment. This includes enhancing supply chain logistics such as electricity, freight, and feed supply, among other critical needs.

6. **Build the industry as a means for Indigenous economic development and independence:** Indigenous Australians are responsible for managing 45% of the land and sea in Northern Australia. Several related proposals were listed including encouraging Indigenous involvement as investors and workers, fostering partnerships, supporting Indigenous branding and certification, providing education and scholarships, and integrating training and employment opportunities into aquaculture development hubs.

7. **Stronger and adaptive governance:** Additional planning is required to determine the exact mechanism for strengthened governance. Some suggestions included the establishment of a cross-sectorial forum.

Empowered and enhanced aquaculture governance

Changes within the private sector and in policies related to aquaculture are key areas with the potential to trigger disruptions in the sector. Official agencies in each economy can potentially prevent or mitigate the impacts of future crises through careful consideration of sector development and specific policy and how such policy might interact with the prevailing international landscape.

Governments should promote the development of databases that facilitate access to commercial information on fishing and aquaculture products, with emphasis on the differentiation of the origin of each product, so that this data can be used to estimate and analyze the situation of the sector and develop appropriate policies. In Papua New Guinea, cooperation between academia and the regulatory sector proved to be very useful in the development of an updated database on pearl shellfish fishing (Simard et al., 2021).Nowadays, there is an urgent need to expand socioeconomic data collection on SSA farmers, to develop more targeted policies.

The regulatory burden on various aspects of the US aquaculture industry has undermined its competitiveness, including the complexity and costs of environmental compliance, food safety, labor standards, interstate transportation, fish health and breeding practices (Anderson et al., 2019). Aquaculture producers, particularly SSA farmers, would benefit from the reduction of regulatory burdens that can mitigate the increased operational costs, delays in production, and reduced ability to innovate and expand their businesses.

Information given during the interview with an official from SERNAPESCA, Chile, gave insights into the status of the regulation for SSA in Chile (See **Box 8**).

Box 8. *Specific regulations for the development of small-scale aquaculture in Chile.*

In terms of sustainability, SSA in Chile is currently undergoing significant changes. Specific regulations for the development of SSA in Chile were first published in 2022 (D.S. Nº. 45/2022)[5]. These regulations are currently in the implementation phase. This process involves several stages:

1. Issuing resolutions to establish the necessary conditions.
2. Full implementation of these resolutions.
3. Ongoing monitoring to ensure compliance.

[5] SUBPESCA. (2024). Accessed in: 05 August 2024. Available in: https://www.subpesca.cl/portal/615/w3-article-113640.html

SSA has been present in Chile for over 25 years. These new regulations address the long-standing practices within this sector with adjustments to better suit segment. In the process approximately 996 SSA operators managing around 1,200 cultivation centers have been identified[6], including fish farms, aquaculture concessions, hatcheries, and areas dedicated to the management of benthic resources. Experimental aquaculture activities are permitted for up to two years, with a possible extension, while regular activities licensed prior to this regulation can continue indefinitely.

The project “Development of a Medium and Long-Term Strategic Plan for Small-Scale Aquaculture (APE) in Chile” is an initiative that is part of the strategic objectives of Undersecretary of Fisheries and Aquaculture (SUBPESCA) management, the development of this project will allow the configuration of a roadmap with actions to be implemented and objectives to be met, which will allow to survey to the APE as an economy wide aquaculture sector.

Measures that promote economic sustainability for SSA

Transition from fisheries to aquaculture

The decline in fish stocks in certain regions has impacted on the livelihoods of fishing communities, exacerbated by competition with other industries. The reduction in fisheries activities has led to economic challenges, weakening overall community resilience. Establishing aquaculture businesses in these areas can help support and sustain fisheries supply chains and working waterfronts, providing economic stability and alternative livelihoods.

In Maryland (United States), the wild-caught blue crab fishery faced severe pressure around 2008. prompting the state to implement conservation-driven initiatives. To support the transition, fishers were encouraged to cultivate oysters as an alternative to crab harvesting. In 2010, the Maryland Agricultural & Resource Based Industry Development Corporation (MARBIDCO) launched the Maryland Shellfish Aquaculture Loan fund, providing low-interest loans, an interest-only repayment period, and partial principal forgiveness (Parker et al., 2019). An assessment of the efficiency of the program revealed that MARBIDCO-funded oyster farms in Maryland achieved significantly higher net values and return rates compared to self-funded operations, demonstrating the program’s effectiveness in fostering economic resilience and sustainable aquaculture (Parker et al., 2019).

Promotion of larger scale farming for SSA

An official from Thailand's Department of Fisheries provided insights into a government initiative aimed at enhancing production in small-scale aquaculture farms through an associative plan. A brief description of the program is presented in **Box 9**.

Box 9. *Large-scale farming promotion system in Thailand.*

In 2015, the Ministry of Agriculture and Cooperatives of Thailand launched the first phase of the "**Large-Scale Farming Promotion System**." This initiative aims to group small-scale farmers in close proximity, enabling them to scale up production and establish comprehensive marketing networks throughout the supply chain. The program seeks to implement a unified production and management system, incorporating appropriate technology and innovation, and leveraging collaborative networks from various sectors.

Although initially focused on agricultural crops, aquaculture farmers have also benefited from this program. The main objective of the program is to improve production efficiency and competitiveness by reducing production costs and aligning production with market demands.

[6] Data obtained from an official from SERNAPESCA.

This collaborative approach ensures effective management, elevates quality standards, and meets the demands of the food, energy, high-value-added chemical, and pharmaceutical industries.

Financial assistance for SSA

Subsidies and the aquaculture sector

Government support can significantly enhance the sector's contributions by ensuring the health of fish stocks and ecosystems, increasing productivity, and building resilience. Subsidies are prevalent in the fisheries sector, with global estimations for 2018 reaching USD 35.4 billion (Sumaila et al., 2019). However, if subsidies are poorly targeted, they can lead to negative outcomes such as excess fishing capacity, overfishing, and illegal, unreported, and unregulated (IUU) fishing. Properly designed subsidies are crucial to avoid these adverse effects and promote sustainable practices within the industry (OECD, 2023). Policies that lower input costs, such as fuel subsidies, often favor large companies over small producers and are not the most inclusive. The OECD currently recommends that governments redirect their spending away from subsidies that promote fishing capacity and unsustainable practices, such as fuel and vessel support. Instead, they should focus on sustainable fisheries management, enforcement, and research into fish stock health and the impacts of climate change. This shift aims to promote more sustainable practices and long-term viability in the fisheries sector (OECD, 2023).

Similar to fisheries, many economies provide subsidies to the aquaculture sector to foster its growth. However, while subsidies for marine fisheries have been extensively studied and debated, there are only a few economy-scale studies specifically quantifying aquaculture subsidies. This gap highlights the need for more comprehensive research to understand the impact and distribution of aquaculture subsidies better. A case study regarding the application of research and development subsidies in the form of grants

For the present report, APEC economies were consulted regarding the application of subsidies specific to the aquaculture sector (**Table 5**). Half of the economies reported no specific subsidies for aquaculture. The most reported subsidies included: (1) subsidies for inputs such as feed, fuel, and equipment, and (2) subsidies for infrastructure development, including ponds and hatcheries. These are considered high to moderate risk subsidies, at least within the fisheries sector (OECD, 2023). Additionally, capacity-enhancing subsidies and subsidies for research and development were each reported by only one economy, which are considered of uncertain risk or no risk by the OECD (OECD, 2023).

Table 5. *Types of subsidies specific to the aquaculture sector applied by APEC economies according to government officials surveyed.*

ECONOMY / TYPE OF SUBSIDY	BD	CHL	NZ	PE	PNG	PHL	CT	THA
Direct financial subsidies		■						
Subsidies for inputs		■				■	■	
Subsidies for infrastructure development		■				■	■	
Capacity-enhancing subsidies		■					■	
Subsidies for research and development							■	
Other types of subsidies								■
There are no subsidies	■		■	■	■			

BD: Brunei Darussalam; CHL: Chile; NZ: New Zealand; PE: Peru; PNG: Papua New Guinea; PHL: the Philippines; CT: Chinese Taipei; THA: Thailand. Gray highlight indicates that the economy applies that type of subsidy in the aquaculture sector.

The Mexican government applies an annual subsidy for fishers and aquaculture farmers, the program is commonly known as “BIENPESCA”. This is a federal subsidy provided by the federal Mexican government to fishers (formerly called PROPESCA), delivered annually to support

fishing groups during closed seasons. Aquaculture farmers can also benefit from this monetary incentive which is delivered once a year for an approximate value of 7200 Mexican pesos or USD 376.[7]

Inclusive financial assistance

A global assessment of policy documents on injustices in aquatic food systems revealed a common shortcoming: policies often fail to outline or include mechanisms for different groups to participate in decision-making processes (Hicks et al., 2022). Financial assistance policies must ensure that all vulnerable groups are included and able to access these benefits.

The Mexican fisheries subsidy BIENPESCA recognizes vulnerable groups, as stated in its regulation:

> *"(The incentive) will prioritize from a gender and social inclusion perspective, fishers and aquaculture farmers located in rural areas, that belong to ethnic or indigenous groups, or Afro-descendant peoples, women and people with disabilities who are located within the municipalities in areas of high vulnerability and social marginalization".*

Nevertheless, during the COVID-19 pandemic, a scientific study pointed out some limitations of the BIENPESCA subsidy in Mexico. This subsidy is oriented towards producers, and since women typically engage in the fisheries secondary sector, only 28% of the beneficiaries of this subsidy during the pandemic were women (Lopez-Ercilla et al., 2021).

In Indonesia, the Maritime and Fisheries Business Capital Management Institute (LPMUKP), established in 2009 by the MMAF, provides funding schemes tailored to small-scale fish farmers and fishers. This initiative aims to enhance access to capital and business advice, alleviating dependence on high-interest loans from major cooperatives and middlemen who affect purchase prices. However, the effectiveness of LPMUKP is constrained by limited funding and human resources, hindering its ability to reach more small-scale fish farmers across Indonesia (APEC, 2023).

Supplying quality seed for SSA

During the interviews, representatives from Peru and Mexico emphasized the importance of programs that promote the local acquisition and development of seed and fry for SSA farmers, to reduce reliance on imported fry. They identified this as a crucial action for ensuring sustainable development. Additionally, they highlighted the need to develop local strains and support the creation of naturally resistant genetic lines as future measures to enhance sustainability in the sector.

In Mexico, both federal and state governments have implemented programs providing support for the acquisition of seed or subsidized fingerlings to SSA producers. The "Mexican Institute for Sustainable Fisheries and Aquaculture Research" (IMIPAS) administers the "**Promotion of Agriculture, Livestock, Fishing, and Aquaculture**" program, which provides direct support (it is not a loan) for small aquaculture producers for acquiring high-quality fry from private sources, while additionally offering technical guidance on fish breeding. The condition is that the private suppliers must have valid aquaculture health certification and the necessary installed capacity. An official from IMIPAS commented about this program,

[7] Equivalence calculated on 07 August 2024. Secretaria de Agricultura y Desarrollo Rural. [Secretary of Agriculture and Rural Development]. (2022). Accessed: 07 August 2024. Available in: http://www.apta.com.mx/apta2008/ce/dof/descargapdf/2022/07Julio/20220704/sadr22070410-5.pdf

"*I believe that one of the most valuable aspects of what we do are the seed improvement and technology transfer programs, because they focus precisely on increasing the capacities of small producers. We are fundamentally focused on small aquaculture producers in areas of high marginalization and priority municipalities, as they are the ones who urgently need this support to increase their well-being and improve their activity*." (IMIPAS official).

Moreover, the federal government, through the "Mexican Commission for Aquaculture and Fisheries" (CONAPESCA) has aquaculture centers that produce seed of various aquaculture species and distributes it at preferential prices to small producers in Mexico. According to a government official, although the number of operational aquaculture centers has decreased, a significant proportion remain active. Additionally, state governments have their own stocking and seed supply programs for SSA producers, operating independently of federal initiatives. These programs typically acquire seeds or utilize state laboratories to produce seeds, which are then distributed free of charge to aquaculture producers. For example, a research and technological transfer center in aquaculture in the state of Tabasco produces tilapia seed as a byproduct of its research. When available, this seed is donated without any obligation from the producers, although the reach of such programs is likely limited.

"We supervise the laboratories to ensure they meet the required seed quality. The producers just need to demonstrate that the funds were used to acquire the seed as intended. We are responsible for distributing these resources based on prioritization criteria established in the program's operating rules." (IMIPAS official).

During responses to the digital questionnaire a remarkable program developed by the Ministry of Production (PRODUCE) and the Sea Institute of Peru (IMARPE) in the Andean communities was presented in detail. The project: "**Technical assistance for high Andean and Amazonian areas**" consisted of the installation of prefabricated modules for re-incubating trout eggs and fingerlings in the Andean regions of Apurímac, Ayacucho, Huancavelica y Huánuco, from 2013 to 2023. The project consists of several steps. First, initial activities identify the potential of human capital, accessibility and availability of water resources. Subsequently, technical assistance is provided and the current demand for fingerlings is met (not covered by the local market). In addition, with the help of the regional management, prefabricated modules for reincubating trout eggs are installed and trout fingerlings are formalized, obtaining their resolution as Micro and Small Enterprise Aquaculture (AMYPE).

Research institutes are ideal agencies to develop such programs. In Viet Nam, the Research Institute for Aquaculture N°1, under the Ministry of Agriculture and Rural Development, has significantly contributed to the establishment and growth of oyster aquaculture by supplying high quality seed. As of July 2020, there were 267 small-scale hatcheries producing over 7 billion oyster seeds, with an estimated value of over USD 1.05 million. These hatcheries supply about 30% of the seed demanded by oyster farms in northern Viet Nam. While some seed is imported from China to meet demand, it has been reported that farmers prefer seed from local hatcheries due to its perceived better quality and higher survival rates during grow-out (Ugalde et al., 2023).

Extensive extensionist services for SSA

Small-scale aquaculture production systems in developing economies continue to face numerous challenges, with many farmers lacking access to the technical knowledge and skills necessary to improve productivity. As a result, these farmers lag behind in the blue revolution of aquaculture. In a study conducted by Obi et al. (2024), the impact of local service providers (LSPs) of extension services for aquaculture farmers in Bangladesh was assessed. The research found that LSPs had a significantly positive influence on various outcomes, such as increasing number of species cultured, higher productivity, larger share of fish sold, and larger revenue for farmers who received LSP extension services compared to those who did not. Furthermore, the study revealed that aquaculture farmers who received LSP extension services were more likely to adopt better management practices, such as dike construction, pond cleanliness, fish growth monitoring,

improved feeding routines, and fish hygiene, compared to those who did not receive the extension services.

Government officials from the aquaculture sector in APEC economies were consulted about the implementation level of extension services for the aquaculture sector in their economies. Only one respondent indicated that such systems were neither developed nor implemented in their economy (Papua New Guinea) (**Figure 5**). The remaining economies (n=7) demonstrated various stages of implementation. The question specifically addressed the implementation of "widespread and fully operational extension services and training networks for SSA farmers," with responses available on a six-point scale (0: Not developed or implemented; 1: Plans in development but not yet implemented; 2: Minimally implemented; 3: Partially implemented; 4: Largely implemented; 5: Fully implemented). Thailand reported that these systems are fully implemented in their economy (scale 5), the highest value on the scale. Peru, the Philippines, and Chinese Taipei reported that such systems are largely implemented in their economies (scale 4). Chile and New Zealand indicated that the systems are partially implemented (scale 3). Finally, Brunei Darussalam reported the lowest degree of implementation on the scale (scale 1, minimally implemented).

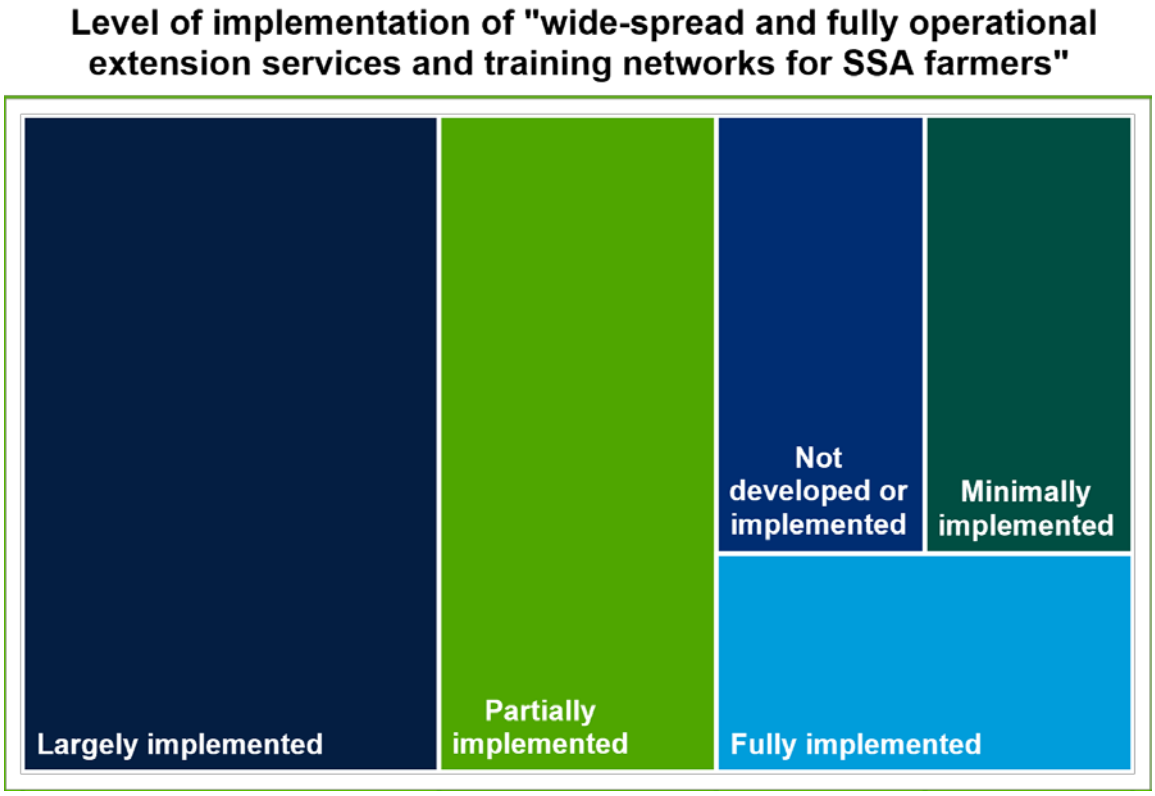

Figure 5. *Perceptions on the level of implementation of extension services and training networks in APEC economies.*

Innovation and technification for SSA

Investment in R&D, innovation and technology transfer for SSA

Public policy can play a pivotal role in driving production transitions and technological innovations to address economic, social and ecological challenges. In that sense, investment in R&D is key. According to aquaculture stakeholders from government agencies in the APEC region, investment in innovation and technology for small-scale aquaculture (SSA) is perceived as low by 50% of respondents (**Figure 6**). Additionally, 12.5% consider such investments to be moderate in their economy while 25% view it as high and 12.5% as very high. Individual responses can be seen in Table. These responses indicate a significant variation in perceptions and highlight the need for enhanced investment to foster technological advancements in SSA aquaculture.

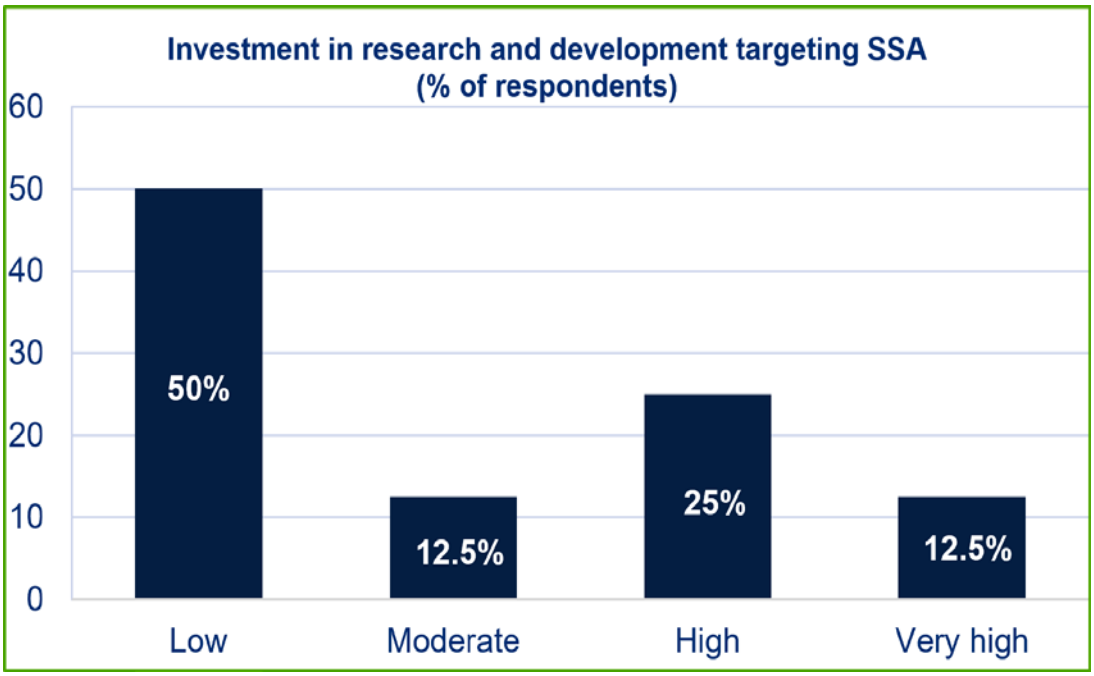

Figure 6. *Categorization of investment in research and development targeting SSA according to government officials from the aquaculture sector in APEC economies.*

Governments should not be alone in the investment on R&D for aquaculture. Innovation projects are more oriented towards cross-disciplinary knowledge exchange and interaction with other sectors. The academic sector and private sector are key components of the engagement in innovation-oriented projects.

Differences among the private models for investment in innovation in aquaculture chains exist. Conventional inshore aquaculture relies more on incremental innovation to achieve operational efficiencies. In contrast, offshore aquaculture relies on radical innovation, including new business models, with an extended timeline from research. Most companies in the aquaculture value chain operate with lean teams and when interested in innovation focus on solutions with immediate or near-term impacts. As a result, strategic barriers arise, presenting challenges in identifying and seizing long-term opportunities (Coffay et al., 2024).

Reception towards innovation in the SSA sector

Another critical aspect is the reception of fish farmers towards innovation. In a prior APEC report, insights into the main difficulties for the effectiveness of research, innovation and technology transfer of digital tools for the fisheries and aquaculture sector in Indonesia were highlighted, with one of the main ones being that producers have very little interest in using new technologies it due to their strong attachment to their local and personal knowledge-based experience (APEC, 2023). For the present report, when consulted about the reception of SSA to technology transfer in APEC economies, most respondents considered that farmers were cautious towards innovation (Brunei Darussalam; Chile; Peru and Chinese Taipei) (**Table 6**). Papua New Guinea representatives considered that a neutral position towards innovation and technology transfer was sustained by farmers in their economy. While New Zealand and Thailand representatives considered that farmers in their economies were open to innovation.

Table 6. *Perceptions of investment in research and technology for the SSA sector and reception of farmers to technology transfer.*

Economy	Investment in research and technology	Reception of SSA to technology transfer
Brunei Darussalam	Low	Cautious towards innovation
Chile	Low	Cautious towards innovation
New Zealand	Low	Open to innovation
Papua New Guinea	Low	Neutral
Peru	Moderate	Cautious towards innovation
The Philippines	High	Open to innovation
Chinese Taipei	High	Cautious towards innovation
Thailand	Very high	Open to innovation

The invention and innovation of suitable technologies that adapt to the aquaculture environment of each APEC economy are crucial for the development of aquaculture. Many APEC economies have invested heavily in government programs to support aquaculture research, invention and innovation. However, one of the most deficient points is regarding technology transfer.

In Brunei, the "**Institute of Brunei Technical Education"** (IBTE) of Agro-Technology and Applied Science Campus" develops specific courses such as the specific course of the Technical Education Certificate (NTec) in aquaculture and Higher Technical Education Certificate (HNTec). Agrotechnology specialized in Aquatic Science is offered as part of the education system.

The "**Program for Innovation in Fisheries and Aquaculture"** (PNIPA) from the Ministry of Production of Peru, with support from the World Bank and the Food and Agriculture Organization (FAO), was a key actor that promoted innovative projects and success stories throughout the economy. The first phase of the project consisted of a US$40 million debt operation to finance the program. The second phase of the project was recently cancelled, however other economy-wide programs such as the Peruvian Program for Technological Development and Innovation (ProInnóvate), a program from the Ministry of Production of Peru that promotes and consolidates innovation, innovative entrepreneurship, and technological and productive development in Peru, although not a specific program for the fisheries and aquaculture sector, has recently added aquaculture as a priority in their grant calls. This program is a debt operation with the Inter-American Development Bank (IDB) for up to US$100 million.

In Thailand, the "**Young Smart Farmer Project**" aims to develop new-generation of aquaculture farmers with the ability to replace elderly aquaculture farmers and motivate the younger generation to take up farming. These new aquaculture farmers must have the potential to apply modern technology to enhance production efficiency, management, and agricultural product marketing. The goal is for them to become aquaculture leaders in their local areas and establish cooperative networks at all levels.

Measures that promote social sustainability

The level of implementation of socially responsible programs for aquaculture in APEC economies was consulted among policymakers of the aquaculture sector, with 75% of respondents stating that their economies have some degree of implementation of such policies. Peru, the Philippines and Chinese Taipei (37.5%) agreed that these policies were partially implemented in their economies. Brunei Darussalam; New Zealand and Thailand (37.5%) considered that these programs were largely implemented in their economies. Chile and Papua New Guinea (25%) affirmed that these programs were currently not implemented but there were active plans for development.

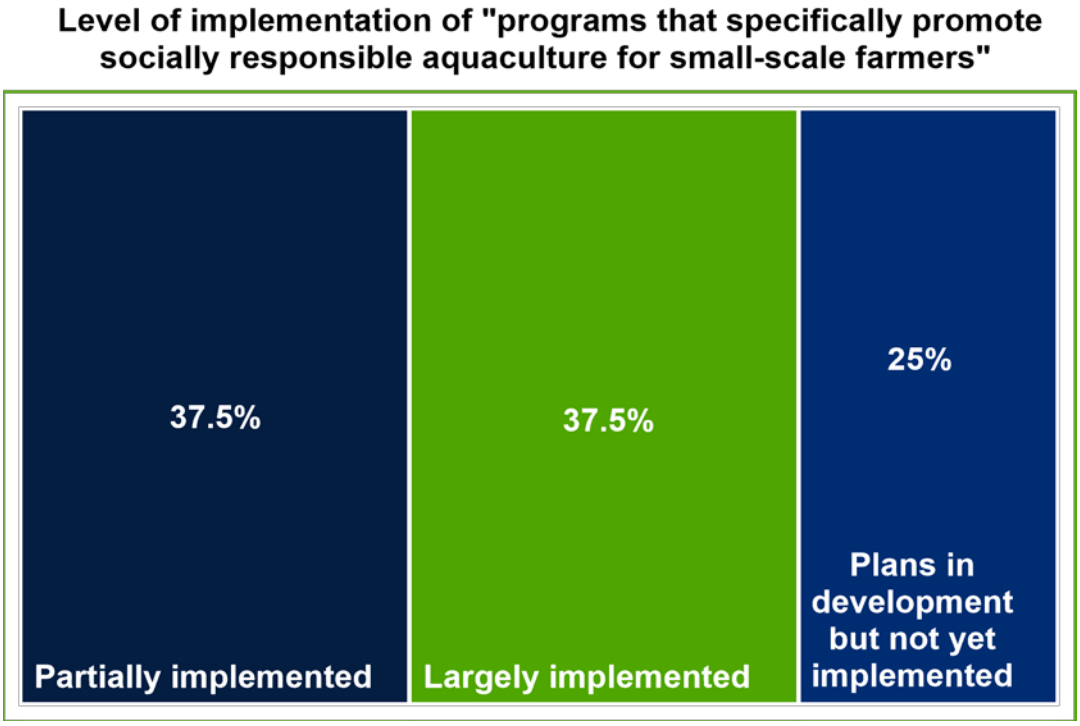

Figure 7. *Perceptions on the level of implementation of socially responsible aquaculture programs for SSA in APEC economies.*

Associativity of small-scale farmers

Associativity in small-scale aquaculture plays a crucial role in enhancing the sustainability and economic viability of the sector. By forming cooperatives and associations, small-scale aquaculture farmers can pool resources, share knowledge, and access better financing and market opportunities. This collective approach helps overcome challenges related to limited resources and market access, enabling small producers to benefit from economies of scale, improved bargaining power, and enhanced technical support. Associations also facilitate the dissemination of best practices and innovations, contributing to increased productivity and sustainability. Furthermore, through collaborative efforts, these groups can more effectively engage with policymakers and other stakeholders, ensuring that the interests and needs of small-scale aquaculture farmers are adequately represented and addressed in regional development strategies. The promotion of associativity thus emerges as a pivotal strategy for fostering resilient and thriving small-scale aquaculture communities.

When consulted about the status of associativity in the SSA sector, APEC government officials agreed that there was a moderate to very high level of associativity among aquaculture farmers (75%) (**Figure 8**). A New Zealand representative considered that the level was very high, Thailand officials from the Department of Fisheries agreed that it was high. Meanwhile, Brunei Darussalam; Peru; the Philippines and Chinese Taipei indicated that it was moderate. On the other hand, Chile and Papua New Guinea considered it low.

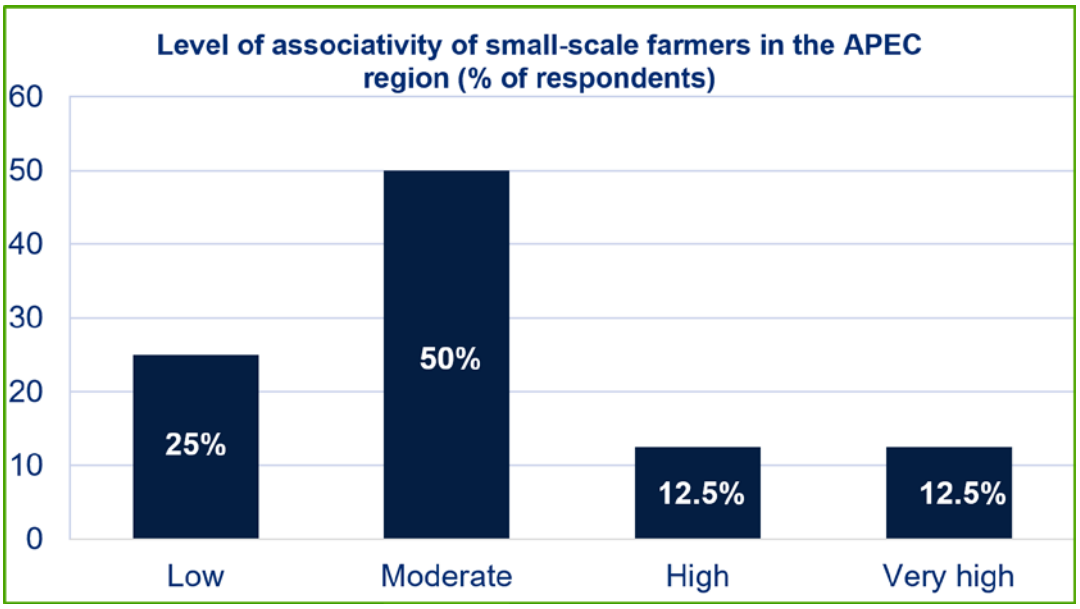

Figure 8. *Perceptions of the level of associativity of SSA in APEC economies.*

Promotion of gender inclusive aquaculture policies

Gender equity is a crucial component for socially responsible aquaculture, yet the industry remains far from achieving this goal. Despite aquaculture being the fastest-growing food production sector in the world, opportunities for women have not kept pace with industry growth. This can be attributed to inequities in training, financing, and decision-making power, among other institutional and systemic socio-cultural, economic, and political factors. A key government strategy to solve this challenge is the adoption of gender inclusive policies.

Policymakers from the aquaculture sector in APEC economies were consulted regarding the implementation of gender-inclusive policies. The survey results revealed that 100% of respondents reported some degree of implementation of such policies in their economies (**Figure 9**). Notably, the Philippines and Thailand (25%) reported the highest level of implementation, stating that these policies were fully implemented. Next, Peru and Chinese Taipei (25%) indicated that these policies were largely implemented within their economies. Representatives from Papua New Guinea and New Zealand (25%) considered these programs to be partially implemented. Meanwhile Chile and Brunei Darussalam (25%) acknowledged that these programs were minimally implemented at present.

These results represent a significant step in the right direction, demonstrating progress in gender-inclusive policy implementation. However, they also highlight the ongoing need to further integrate gender-inclusive aspects within the policies of fisheries and aquaculture ministries. An important question remains: which approaches are most effective to achieve gender equity in aquaculture?

In 2021, the government of Chile published a report about the status of men and women in the fisheries and aquaculture sector, showing that economy-wide, the sector is composed of 25% women and 75% men. The report included details of numerous gender disparities still present, however it also showed minor advances (Government of Chile, 2021). The development of similar tools should be considered across all APEC economies, and more importantly, sustain them in the long term, not only to map the status, but to monitor the effectiveness of actions and policies towards women's equality in aquaculture.

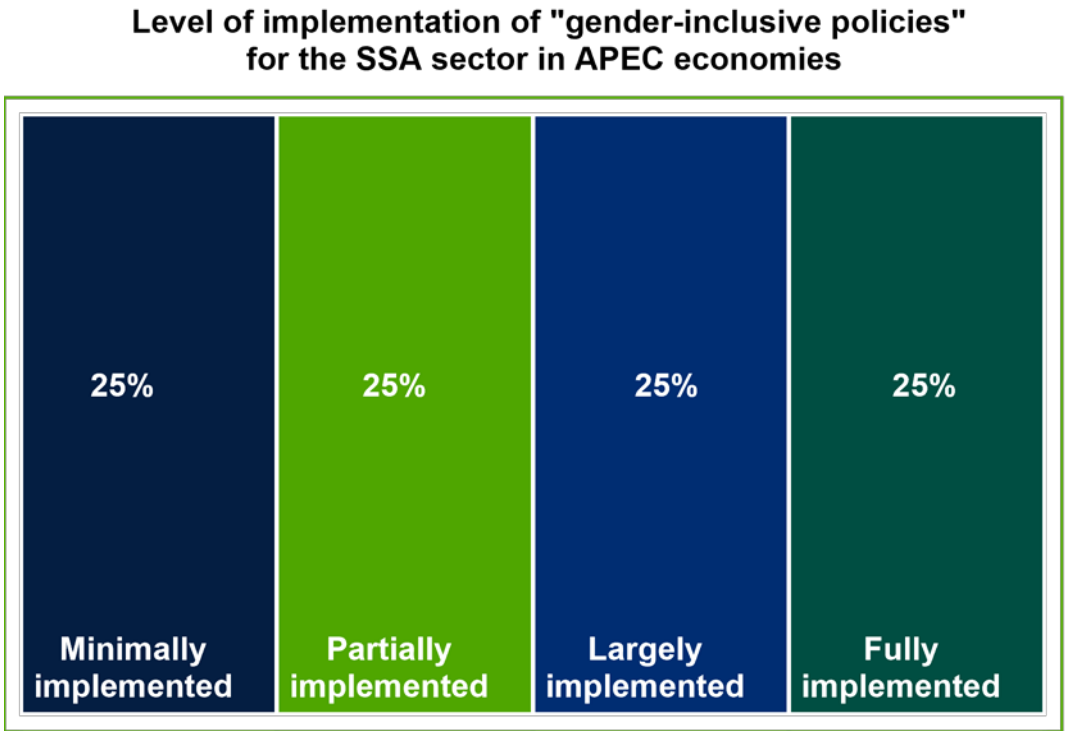

Figure 9. *Perceptions on the level of implementation of gender inclusive policies for the SSA sector in APEC economies.*

A policy brief from the CGIAR Research Program on fish agri-food systems analyzed gendered patterns and barriers within fish agri-food systems, identifying four pathways for enhancing gender equality and women's empowerment in fish agri-food systems (Adam et al., 2021):

Key pathways to address gender inequity:

Pathway 1 Gender-inclusive and gender-responsive innovations.
Pathway 2 Inclusive livelihoods and wealth generation.
Pathway 3 Inclusive governance.
Pathway 4 Gender-transformative approaches to address underlying structural barriers.

A brief description of each pathway according to the authors is presented below:

- Pathway 1: Gender equity considerations must be embedded into every stage of innovation development, dissemination, and adoption. This involves moving beyond male-focused innovation processes to include explicit assessments of women's needs and engaging women as innovators.
- Pathway 2: The development of inclusive livelihoods and wealth generation for women requires the establishment of enabling factors. These include supportive family relationships, educational opportunities for women, strategies to prevent asset loss through social protection, investments in women's social networks, and equitable inclusion of women in decision-making processes at all levels.
- Pathway 3: Inclusive governance can be achieved by adopting gender-responsive policies, guided by gender data gaps, and amplifying women's voices and leadership.
- Pathway 4: Gender-transformative approaches are necessary to engage both women and men in addressing structural barriers, such as restrictive gender norms and relationships, within fish agri-food systems.

Aquaculture can benefit from following similar approaches to accelerate progress on gender equity. For this, it requires increased commitment and collaboration from all major stakeholders including government, private sector and civil society.

In 2013, FAO published the guide: "Good Practice Policies to Eliminate Gender Inequalities in Fish Value Chains." The document points out recommendations for policy reforms and targeted research to achieve gender equality in the fisheries sector. It outlines methods for assessing progress exploiting women's loss potential in fisheries, including the use of gender-sensitive indicators that can inform future policies and programs, for the development of such indicators the collecting of gender-disaggregated data is mandatory (FAO, 2013).

Measures that promote environmental sustainability

Several strategies are applied by APEC economies to support the sustainable environmental development of aquaculture (**Table 7**). However, the degree or level of implementation differed greatly between economies. Among such actions are:

- Special regime for the management of effluents
- Incentives to encourage the restoration or rehabilitation of water resources by aquaculture farmers
- Eco-labeling schemes or certifications for SSA
- Emergency plans to respond to natural disasters or climate change.
- Insurance programs for SSA

Table 7. Level of implementation of actions that support the environmental sustainability of SSA in APEC economies.

ECONOMY LEVEL OF IMPLEMENTATION OF THE MEASURE	BD	CHL	NZ	PE	PNG	PHL	CT	THA
Special regime for the management of effluents of SSA sites	4*	2	5	3	0	3	3	5
Incentives to encourage the restoration or rehabilitation of water resources by aquaculture farmers	4	0	0	2	0	4	3	4
Eco-labeling schemes or certifications for SSA	2	1	4	2	0	3	3	4
Emergency plans to respond to natural disasters or climate change	0	5	4	3	0	3	4	4
Insurance programs for SSA	0	0	3	2	2	3	2	1

BD: Brunei Darussalam; CHL: Chile; NZ: New Zealand; PE: Peru; PNG: Papua New Guinea; PHL: the Philippines; CT: Chinese Taipei; THA: Thailand. *The numbers indicate the level of implementation of the measure according to a defined scale. Scale of implementation: 0□ Not developed or implemented; 1□ Plans in development but not yet implemented; 2□ Minimally implemented; 3□Partially implemented ; 4□Largely implemented 5□Fully implemented

A Blue Economy strategy for the development of aquaculture should meticulously address several key factors: selecting species aligned with specific objectives and environmental conditions, ensuring the availability of cost-effective aquafeed supplies, choosing locations that minimize social impacts, and implementing technology and support facilities to enable production at affordable local prices. There are opportunities for synergy between mariculture and other sectors that could be beneficial. For instance, experiences integrating mariculture with artisanal fisheries activities on a seasonal basis, can enhance overall sustainability and efficiency (Cisneros-Montemayor et al., 2019).

The sustainable future of aquaculture depends on its ability to adapt. Integration of aquaculture enterprises with other productive activities is a key component of that pillar. For example, it has been proposed for northern Europe that existing marine infrastructure like offshore wind farms could be used to support the cultivation of bivalves and algae (Michler-Cieluch et al., 2009).

Continuous improvement in environmental performance of the aquaculture sector to reduce potential impacts, including through effective and efficient regulation, monitoring, and reporting tailored to specific sectors. Development of industry-specific codes of conduct and best practice guidelines for managing environmental impacts is also emphasized.

The establishment of policies promoting the circular economy in aquaculture is crucial for ensuring the sector's sustainable development. As aquaculture continues to expand to meet global food demands, traditional linear models of production and waste management pose significant environmental and economic challenges. A circular economy approach, which emphasizes resource efficiency, waste reduction, and the recycling of materials, offers a transformative pathway for aquaculture to minimize its environmental footprint while enhancing resilience and profitability. By integrating circular economy principles into policy frameworks, aquaculture can optimize resource use, reduce dependency on finite inputs, and mitigate the impacts of waste and pollution.

In Peru, **the roadmap towards a circular economy in the fishing and aquaculture subsectors** was recently approved in 2023 (DS. No. 011-2023-PRODUCE). This document will serve as a guide that includes artisanal, small- and large-scale fishing extraction, artisanal processing and aquaculture activities; it also aims to progressively adapt and encourage the transition from the linear model of consumption and production to a circular model that covers the maximum possible time of the life cycle of the materials that involve the cyclical flow of the actions of extracting, transforming, distributing, using and recovering (regenerating) materials and energy from products and services.

This roadmap is oriented around two thematic axes:

a. Promotion of the circular economy in fishing and aquaculture activities.
b. Development and promotion of incentives in the circular economy.

Likewise, three lines of action are proposed in this roadmap: a) Articulate public and private institutions, as well as interest groups for the transition towards a circular economy; b) Develop the regulatory framework related to the circular economy; and c) Promote business models, good practices, synergies and circular technologies. The document contemplates 17 specific actions proposed for the medium (5 years) and long-term (7 years). This guide is currently being implemented and represents a first step in the right direction.

Specific actions to be implemented by following this program include the exchange of information and experiences on the circular economy in fishing and aquaculture with institutions and individuals from the private sector. In addition, the aim is to integrate the circular economy approach into the training offered by the sector to fishing and aquaculture stakeholders. On the other hand, it is proposed to identify business models in these sectors where the incorporation of the circular economy is viable, and technical assistance will be provided for the adoption of such circular models. Measures will also be promoted to prevent and reduce the loss and abandonment of fishing gear and tackle, with the aim of avoiding the degradation of ecosystems. Likewise, activities and alliances between the public and private sectors will be promoted to facilitate the reuse of materials, discards and waste generated by fishing and aquaculture activities.

Carrying capacity programs

Carrying capacity can be defined as the level of resource use, by both humans and animals, that can be sustained over the long term by the natural regenerative power of the environment (Ross et al., 2013).

In Mexico, the “Mexican Institute for Sustainable Fisheries and Aquaculture Research “(IMIPAS) developed in 2019 the “**Carrying capacity program for aquaculture**”, where carrying capacity studies of selected water bodies are performed on demand. Due to the limited scope of the institute's operations, IMIPAS performs two or three studies per year on different bodies of water. These studies provide valuable tools for management authorities and producers to sustainably conduct aquaculture or fishing activities in

reservoirs, lakes, and lagoons throughout the economy. According to its website the program has developed 11 studies with three currently being undertaken.

The main objectives of the program are:
1. Provide information for Aquaculture Management Plans.
2. Constant updating through knowledge of new dynamic and stochastic models where new parameters associated with climate change are incorporated, and the use of technologies to reduce the number of field samples, to reduce costs and increase their efficiency.

An official from IMIPAS gave insights on how the selection of water bodies was performed:

> *"For example, if we receive a request indicating that a large aquaculture operation or a group of producers needs to know if they can expand, that triggers our need to conduct a study. Typically, the trigger is when the monitoring authority (CONAPESCA) informs us of a need due to producers requesting concessions or licenses for aquaculture in federal jurisdiction water bodies. Based on these needs, we prioritize which bodies of water to study and carry out those studies."*

In addition to this program, sometimes, Mexican state governments commission universities to conduct capacity studies on these bodies of water, but we have been doing them significantly since this workgroup was established. I am not directly involved in this area, but the workgroup has been active since the current director began, and I started at the same time as him.

Eco-certification schemes

Aquaculture eco-certification schemes provide standards against which individual farms are assessed, and those farms that comply with eco-certification criteria receive certified status. Several initiatives for the development of sustainability standards across the aquaculture production chain in the APEC region have been identified (See **Table 8**). Examples include the Malaysian Aquaculture Farm Certification Scheme (SPLAM), the Code of Good Environmental Practices by SIGES-Salmon in Chile (Cisneros-Montemayor et al., 2019) and the program "Accredited Fish Farm Scheme" in Hong Kong, China.

Table 8. *Certification schemes for aquaculture products available in the APEC region.*

Economy	Program	Agency	Brief description
Hong Kong, China	Accredited Fish Farm Scheme	Agriculture, Fisheries and Conservation Department (AFCD)	Brand local products and increase consumer confidence in fish quality
Indonesia	Ecoshrimp	Alter Trade Japan	Products from registered extensive shrimp farms in Indonesia that follow ATJ's own standards are labelled as "ecoshrimps"
Global	The Aquaculture Certification Council	Global Aquaculture Alliance	Sets best aquaculture practice standards
Malaysia	Malaysian Aquaculture Farm Certification Scheme or myGAP	Department of Fisheries Malaysia	Voluntary scheme that provides official recognition to aquaculture entrepreneurs who

			have practiced GAP and environmentally friendly concepts to ensure the safety, quality, consistency and competitiveness of the products
Indonesia	Indonesian Good Aquaculture Practices	-	-
Singapore	Singapore Good Aquaculture Practice for Fish Farming	-	-
The Philippines	Philippine's Code of Good Aquaculture Practices		
Thailand	Thailand Good Aquaculture Practices	Bureau of Agricultural Commodity and Food Standards Ministry of Agriculture and Cooperatives	The farming system prioritizes the health and welfare of the animals, environmental sustainability, and social responsibility. However, this standard does not include practices during the hatching and nursing stages.

Malaysia has had economy wide standards of Good Aquaculture practices since 2007 when Malaysia's Standard (MS 1998: 2007) General Guidelines for Good Aquaculture Practices was officially published. In 2017, the standards were revised to comply with ASEAN Good Aquaculture Practices requirements. The program promotes responsible and environmentally friendly farming practices to ensure high-quality, safe, and competitive products. The scheme emphasizes implementing HACCP at the source. Aquaculture entrepreneurs must meet specific criteria, apply, and pass an audit for certification. Once approved, they can use the myGAP logo to market their products during the certification period [8].

The government of Hong Kong, China, through its Agriculture, Fisheries and Conservation Department (AFCD) established the "**Accredited Fish Farm Scheme**"[9], an initiative designed to enhance the management and production standards of aquaculture farms. According to its official website the program was designed as a tool to enhance competition with imported aquatic food products and the lack of consumer confidence in fish and seafood. The AFCD program promotes good aquaculture practices, sets process standards, conducts regular testing, and provides certification to participating farms. It is marketed as a tool to achieve sustainable development in the local aquaculture industry.

Registered farms for this program must be cooperative and allow periodic inspections and sample collection by the AFCD. Samples of fish feed, water, and aquatic products are taken for analysis as needed. Products that approve the scheme get a certification seal that can make local aquaculture products stand out by branding. If production processes or products fail to meet standards, sales under this certification must cease and non-compliant farms will lose their registration and cannot re-register for one year.

[8] Department of Agriculture Sarawak. Available in: https://doa.sarawak.gov.my/web/subpage/webpage_view/203

[9] Government of Hong Kong, China. (2024). Accessed 29 July 2024. https://www.afcd.gov.hk/english/whatsnew/what_fis/what_fis.html#:~:text=The%20%22Accredited%20Fish%20Farm%20Scheme,certification%20services%20to%20participating%20farms

The private sector has also developed certifications schemes more oriented towards SSA products. Alter Trade Japan (ATJ) is a Japanese trading company established in 1989 through the joint investment of consumers' cooperatives and organic trading organizations. ATJ started the importation of "**Eco-shrimp**" produced in extensive traditional farms in Indonesia. Although not strictly a certification scheme, ATJ has been involved in the establishment of fair-trade arrangements, linked also to natural organic certification. Licensed farmers under this program employ extensive aquaculture methods that harness natural processes while protecting the environment. They prepare the soil and replace the water in aquaculture ponds, allowing young shrimp to grow without artificial feed, relying instead on natural plankton. The farming density is low, at about 3 to 4 shrimp per m^2, which is one-tenth of typical intensive farms, resulting in healthier shrimp without the need for antibiotics. Alter Trade Indonesia oversees regular pond inspections, manufactures products without anti-blackening agents or water-retaining materials, and provides comprehensive management from production to processing and export[10].

The adoption of good aquaculture practices (GAqP) among SSA farmers may be limited due to perceptions that the scheme is too complex and costly and is less profitable compared to non-GAqP production methods. In Malaysia, an economy-wide survey about consumers' preference and willingness to pay for GAqP-compliant farmed fish revealed that most Malaysian consumers prefer farmed fish, particularly seabass and African catfish and that consumers are willing to pay a premium price for GAqP-compliant farmed fish. Market insights indicate a strong preference for safe and healthy food products among consumers (Kamaruddin et al., 2023).

Factors such as age, education, income, and knowledge about aquaculture positively influence these aspects. Educated consumers and those with higher incomes are more likely to pay premium prices, while larger households are less willing to pay due to higher cost burdens. While concerns about negative attributes like taste and texture impact negatively (Kamaruddin et al., 2023).

The findings suggest that encouraging the adoption of GAqP practices requires the introduction of premium pricing for compliant products. Additionally, improved marketing strategies and consumer education about the benefits of GAqP-compliant products are necessary to increase adoption and build consumer trust. Addressing these challenges is essential for fostering sustainable aquaculture practices in Malaysia (Kamaruddin et al., 2023). Such findings are probably applicable to other economies in the region.

There is skepticism regarding the real impact of certification processes, particularly in small aquaculture enterprises in developing economies. These standards are targeted to medium and large-scale aquaculture enterprises and SSA could probably only benefit from these schemes if requested as an association of producers. Therefore, these incentives could generate a rift between large and small aquaculture operators, limiting the latter's access to markets, with lower socio-environmental gains.

Moreover, certification processes, even the ones developed for large aquaculture firms, are not exempt from challenges. Critical analysis during the certifications process of salmon industries in Chile, Norway and Scotland has evidenced that a major difficulty for auditors is translating local practices into standardized categories, which is complicated by geographical, legal, and organizational differences between economies (Amundsen & Osmundsen, 2019). In addition, auditors with little experience and technical expertise, or auditors with little familiarity with the site and company can be an obstacle and discourage discussions and negotiations for the obtention of such certifications (Amundsen & Osmundsen, 2019).

Mitigation strategies against natural disasters and climate change

Climate change is already disrupting aquaculture, with uneven impacts across APEC economies. Future negative effects are expected to be more severe in low-latitude economies due to high impacts and limited adaptive capacity. Proactive planning for climate-smart aquaculture is

[10] Alter Trade Japan. Available in: https://altertrade.jp/ecoshrimp

essential to prevent climate change and other environmental stressors from undermining the sector's potential contribution to achieving the Sustainable Development Goals (SDGs) (Norambuena et al., 2024).

Vulnerability assessment of aquaculture to climate change

A vulnerability assessment of aquaculture to climate change should serve as a baseline for an economy-wide adaptation strategy. This assessment will inform the design of adaptation strategies for climate change and protocols for responding to unforeseen external shocks, ensuring immediate response capacity and preventing the suspension of activities that harm producers.

Recently, the FAO published a report on the "Assessment of the state of advancement of policies and plans for adaptation to climate change in aquaculture in Latin America and the Caribbean" (Norambuena et al., 2024). This work responded to the recommendations contained in the reports of the regular meetings of the Commission on Small-Scale and Artisanal Fisheries and Aquaculture in Latin America and the Caribbean (COPPESAALC). The COPPESAALC recommended that member economies integrate provisions addressing natural disaster risks and climate change into their fisheries and aquaculture policies, plans, and programs. Additionally, the Commission emphasized the need to mobilize resources from global climate and environmental financial sources. It also advised on the need to formulate plans for emission mitigation, climate change adaptation, and impact reduction, including the use of clean energy and disaster risk analysis.

Adaptation to climate change risks and opportunities

Effective adaptation to climate change for the aquaculture sector requires management instruments to reduce vulnerability, complemented by training and awareness-raising among all stakeholders about climate change threats and risks. Within the scope of the commented report a group of experts was selected by FAO and evaluated the progress of Latin American and Caribbean economies in creating and implementing climate change adaptation policies for aquaculture. Additionally, the document provided guidelines for the design of an adaptation plan to strengthen the aquaculture sector in Latin America and the Caribbean against the impacts of climate change. This strategy is divided into 9 steps or stages and can be seen in **Figure 10** (Norambuena et al., 2024).

Some APEC economies have already established mitigation plans against climate change threats for the aquaculture sector. In Chile, "**The Climate Change Adaptation Plan for Fisheries and Aquaculture**" was established in 2015. The central objective of the plan is to strengthen the capacity of the fishing and aquaculture sectors to adapt to the challenges and opportunities of climate change, considering a precautionary and ecosystemic approach. The plan is structured into five specific objectives with 29 possible action measures (Ministerio del Ambiente de Chile [Chilean Ministry of Environment], 2015).

Environmental impacts of aquaculture can be mitigated and among the strategies for this the reuse and recycling of freshwater is key. Mariculture is a very interesting case, as it is farmed to produce quality food in the sea with little dependence on freshwater (Norambuena et al., 2024).

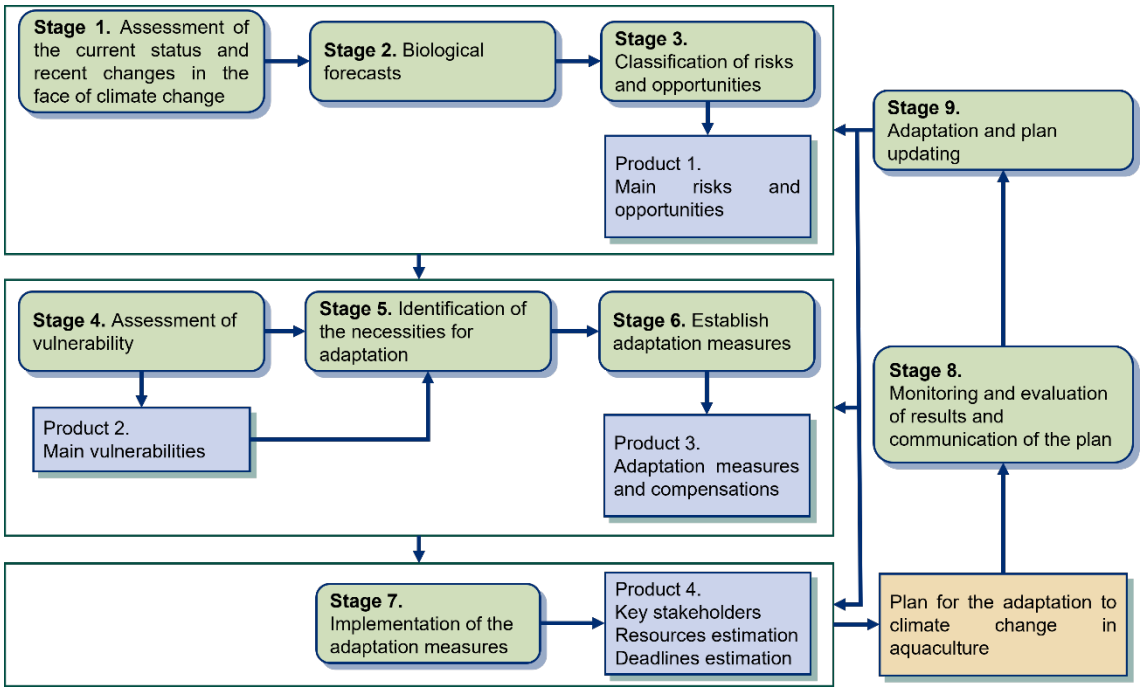

Figure 10. *Structured process proposal for a climate change adaptation plan for aquaculture, as proposed by Norambuena et al. (2024), translated to English.*

Seaweed aquaculture as a low environmental footprint activity

Seaweed aquaculture supports livelihoods and food security as most aquaculture production systems; however seaweed farming may provide more ecosystem services than most aquaculture alternatives. It absorbs excess nitrogen, preventing harmful algal blooms and prevents the creation of “dead zones”, it sequesters carbon in marine sediment. Seaweed also enhances biodiversity by offering food and habitat for marine species and can mitigate local ocean acidification.

Additionally, seaweed can help combat climate change by replacing carbon-intensive products like plastics and fertilizers. A recent report by The Nature Conservancy and Bain & Company has identified. However, the current demand for seaweed products is insufficient to support significant growth. Seaweed-based bioplastics and bio stimulants offer environmental benefits but are often more expensive than traditional and other green alternatives. To expand the market, seaweed must be positioned as a premium product or made more affordable through efficiency, better processing technology, or subsidies[11].

The seaweed industry also faces geographic and species limitations. Although over 12,000 seaweed species exist, five species make up 95% of cultivated seaweed, leaving the industry vulnerable to environmental shocks and diseases. Additionally, 98% of farmed seaweed comes from Asia, highlighting the need for geographic expansion to meet environmental goals.

Diversification of farmed species

Culturing a variety of additional or alternative species diversifies growers' products, potentially opening up new markets and ensuring product availability if one species performs poorly or is significantly impacted by a mortality event (Ward et al., 2022). However, some authors have proposed that cultivation of several species in a single economy could not be the most sustainable practice for a particular economy (Jiang et al., 2022). For example, China cultivated 86 different

[11] The Nature Conservancy. (2024). With the Right Tools, Seaweed Can Be an Important Piece of the Climate Puzzle. Accessed in: 24 July 2024. Available in: https://www.nature.org/en-us/what-we-do/our-insights/perspectives/blue-carbon-seaweed-nature-based-climate-solution/#:~:text=Seaweed%2C%20which%20requires%20almost%20no,carbon%2Dintensive%20products%20like%20plastic.

species of aquatic organisms in a variety of production systems in 2017, whereas Norway cultivated only 13 different species known to have less environmental impacts mostly in the marine cage system (Jiang et al., 2022). However, such statements can be contested.

CHAPTER 3: Action plan to secure the sustainable future of the small-scale aquaculture sector in the APEC region

The preceding chapters of this report have examined the key challenges to achieving sustainable development in the aquaculture sector across the APEC region, with a particular focus on the constraints affecting small-scale aquaculture (**Chapter 1**). Building on this analysis, **Chapter 2** highlighted successful initiatives that support sustainable development, particularly for small and micro-enterprises.

This final chapter presents policy recommendations derived from the insights of the previous chapters. These recommendations are structured into seven strategic areas, each accompanied by detailed guiding principles. They aim to enhance resilience against future crises and foster long-term, transformative sustainability by addressing all three pillars—economic, social, and environmental—with particular attention to small-scale aquaculture and vulnerable groups within the aquaculture value chain. Achieving meaningful and lasting change requires a comprehensive approach that integrates existing, reformed, and new policy mechanisms.

The proposed action plan aligns with the Aotearoa Plan of Action for implementing the Putrajaya Vision 2040[12], which APEC economies endorsed in 2021. The following sections elaborate on the five strategies, whose order reflects their role within an integrated framework rather than a ranking of importance.

Strategy 1: Strengthening governance and institutional support

SSA sustainability can be enhanced by means of clear regulatory frameworks, reduced bureaucratic burdens, and inclusive decision-making processes. Chile's approval of specific SSA regulations in 2022 highlights the need for specific policies that reflect SSA producers' realities. The simplification of licensing processes, improvement of access to market information, and the encouragement of cross-sectoral collaboration between governments, researchers, and industry stakeholders can drive more effective governance for SSA. Additionally, the expansion of data collection for socioeconomic variables, contributions to food security and sustainability indicators from SSA enterprises will enable more targeted policy interventions. By reinforcing institutional capacity and regulatory efficiency, APEC economies can create a more resilient and competitive SSA sector. Several suggested actions in line with this strategy are presented next:

Action1 - Evaluate the need for a strategic plan that explicitly addresses SSA, while incorporating sustainability goals to guide future policy formulations. These plans should be aligned with local economic, social, and environmental contexts to maximize their impact.

Action 2 - Promote transparent and participatory governance of vulnerable groups in policy development. Regular engagement between aquaculture stakeholders, including governments, industry, and producers, will ensure that policies reflect reality and address emerging challenges. Moreover, promote permanent coordination among government agencies. Streamlining administrative processes, improving policy consistency, and reducing regulatory overlaps will strengthen SSA governance.

Action 3 - Develop clear, inclusive, and flexible regulatory frameworks that accommodate SSA needs and adapt to evolving market and environmental conditions. These frameworks should ensure equitable access to resources, support sustainable production practices, and integrate climate resilience measures to safeguard SSA's long-term viability.

[12] Asia-Pacific Economic Cooperation. Accessed: 31 July 2024. Available in: https://aotearoaplanofaction.apec.org/#:~:text=The%20Putrajaya%20Vision%202040%20will,implementing%20the%20Putrajaya%20Vision%202040

Strategy 2: Improving economic viability and market access

Limited revenues, lack of organization, and market barriers pose significant challenges to SSA farmers. Many struggle to achieve intensive productive scale, lack access to financial resources, and remain highly dependent on intermediaries to reach markets. Strengthening market linkages, financial support mechanisms, and cooperative development can enhance the economic sustainability of SSA. Initiatives such as Thailand's Large-Scale Farming Promotion System, which allows small farmers to scale production and strengthen market access are a good example of such programs. Additionally, promoting livelihood diversification and training programs can improve producers' capacity to navigate market challenges. Several suggested actions in line with this strategy are presented next:

Action 1 - Facilitate promotion of large scale SSA systems either through the formation of cooperatives, and clustering models to increase production capacity and enhance competitiveness or through programs for scaling production. Promote the development of strong, empowered, and sustainable SSA farmers' associations. These associations can improve access to financial resources, facilitate collaboration with the government, enhance communication with academic institutions and NGOs, and accelerate technology transfers.

Action 2 - Expand financial and technical support, by improving SSA farmers' access to microcredit programs, grants, and subsidies to facilitate business growth. Strengthen financial inclusion measures to ensure support reaches vulnerable groups, taking inspiration from Mexico's BIENPESCA subsidy, which prioritizes rural aquaculture farmers. Notwithstanding, avoid input subsidies that may create a dependance relationship from farmers.

Action 3 - Strengthen value chain integration and market access. By enhancing post-harvest processing infrastructure, cold storage facilities, and direct market access initiatives, SSA farmers can retain more value from their products. The promotion of direct sales through cooperatives, digital marketplaces, and fair-trade arrangements to reduce dependency on intermediaries and improve profitability are aligned with this goal.

Action 4 - Promote livelihood diversification and skills development. Capacity-building programs for technification and development of alternative income sources can provide farmers with economic benefits to withstand periods of lower production. Rural youth and women often face additional barriers to participation and must have priority in such programs.

Strategy 3: Addressing social challenges and strengthening inclusion

Social sustainability in small-scale aquaculture (SSA) has often been overshadowed by economic and environmental considerations. However, addressing social inequalities, informal labor, and the exclusion of vulnerable groups is essential for ensuring the long-term resilience of SSA. Many SSA producers operate in informal settings, lacking social protection, labor rights, and legal recognition. Gender disparities are also prevalent, with women playing a significant but often unrecognized role in aquaculture, mainly occupying lower-income positions in the post-harvest sector. Indigenous communities and other marginalized groups also face barriers in accessing resources, decision-making, and financial support. Strengthening social protection systems, promoting gender equality, and enhancing formalization and labor rights will be key to making SSA more inclusive and sustainable. Several suggested actions in line with this strategy are briefly described next:

Action 1: Reassess formalization programs to introduce improvements such as simplified registration processes, financial benefits, or technical training benefits linked to formalization. Ensuring SSA farmers transition from informal to formal operations will enhance their access to funding, markets, and institutional support.

Action 2: Strengthen social protection systems. Expansion of social assistance programs to provide cash transfers and insurance mechanisms for SSA workers, reducing their vulnerability to economic and environmental shocks. Promote labor

market interventions that enhance employment opportunities, particularly for young people, women, and marginalized groups.

Action 3: Ensure gender equality in aquaculture policies. Adopt gender-responsive policies that promote equal access to financing, training, and leadership positions for women in SSA. Strengthen the collection of sex-disaggregated data to better assess and address gender gaps in aquaculture, following examples such as Chile's gender assessment of the fisheries and aquaculture sector.

Action 4: Enhance inclusivity for indigenous communities and vulnerable groups
Improve access to SSA resources, subsidies, and technical training for indigenous and rural communities. Ensure policies reflect their cultural and economic needs, integrating traditional knowledge into SSA development programs.

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Strategy 4: Leveraging science, technology, and capacity building

The adoption of scientific advancements, technological innovations, and capacity-building programs will guide the enhancement of sustainability and competitiveness for SSA. However, investment in research and development (R&D) for SSA remains low in many APEC economies, with varying levels of receptiveness to technology transfer among farmers. Overcoming technological and knowledge gaps requires greater public-private collaboration, enhanced innovation ecosystems, and farmer-oriented training programs. Some proposed actions are presented next:

Action 1: Increase investment in research and technology for SSA. Enhance public and private investments in SSA-focused R&D to develop innovations tailored to SSA producers. Governments should encourage industry-academia partnerships and establish grant programs that support adaptive technologies for SSA, particularly on topics that are essential for the future of aquaculture: improved water management systems, alternative feed sources, and disease-resistant strains.

Action 2: Strengthen technology transfer and farmer adoption of innovations. Facilitate effective dissemination of research outputs through structured extension services and farmer training networks. Many SSA farmers remain cautious towards innovation, requiring targeted efforts to increase trust and practical demonstrations of new technologies. Programs such as Thailand's Young Smart Farmer Project, which encourages the adoption of modern aquaculture techniques among young farmers, serve as effective models.

Action 3: Expand capacity-building initiatives and technical training. Develop comprehensive vocational training programs that focus on best aquaculture practices, financial literacy, and business management. Strengthen existing extension networks to ensure SSA farmers receive continuous support and mentoring. In Peru, initiatives like the Program for Innovation in Fisheries and Aquaculture (PNIPA) have successfully promoted farmer-driven innovation and skill development.

Action 4: Enhance digitalization and data-driven decision-making. Nevertheless, keep in mind that SSA can only benefit from certain digitalization strategies due to their financial and technical limitations. Promote the use of digital tools and real-time data monitoring to improve productivity and resource efficiency in SSA. Encourage mobile applications for market access, remote training, and production management.

Strategy 5: Strengthening climate resilience and disaster preparedness

Climate change and natural disasters are growing threats to SSA, with impacts varying significantly across APEC economies. Low-latitude economies are particularly vulnerable due to high exposure to extreme weather events and limited adaptive capacity. Without proactive adaptation measures, climate-related disruptions such as sea-level rise, changes in water temperature, ocean acidification, and extreme weather events could severely impact SSA productivity and profitability. Strengthening climate-smart aquaculture

practices, disaster preparedness, and risk management strategies is essential to enhance resilience across the sector. Some actions in line with this strategy are suggested:

Action 1: Conduct vulnerability assessments for SSA. Develop economy-wide vulnerability assessments to understand climate risks and exposure in SSA. These assessments should serve as a baseline for adaptation planning, helping identify the most at-risk regions, production systems, and communities.

Action 2: Develop and implement climate change adaptation plans. Formulate and implement structured adaptation strategies for SSA, incorporating climate-resilient production techniques, early warning systems, and emergency response plans. Chile's Climate Change Adaptation Plan for Fisheries and Aquaculture (2015) serves as an example of a structured approach that strengthens adaptive capacity.

Action 3: Enhance disaster preparedness and response mechanisms. Strengthen emergency response systems and early warning mechanisms to minimize losses from extreme weather events. Establish disaster recovery funds and insurance schemes tailored for SSA farmers to support rapid recovery from climate shocks.

Action 4: Promote climate-smart aquaculture and ecosystem-based approaches
Encourage the adoption of low-impact aquaculture systems, such as integrated multi-trophic aquaculture (IMTA), recirculating aquaculture systems (RAS), and seaweed farming, which offer resilience against climate variability while reducing environmental footprint.

Action 5: Build capacity and raise awareness on climate adaptation. Expand education and training programs focused on climate change risks, adaptive farming techniques, and disaster risk reduction for SSA farmers. Strengthening knowledge-sharing platforms will ensure that SSA producers have access to up-to-date climate information and best practices

REFERENCES

Adam, R., McDougall, C., Beveridge, M. C. M., & Marwaha, N. (2021). Advancing gender equality and women's empowerment in fish systems four pathways. *Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems. Program Brief: FISH-2021-10.*

Amundsen, V. S., & Osmundsen, T. C. (2019). Virtually the Reality: Negotiating the Distance between Standards and Local Realities When Certifying Sustainable Aquaculture. *Sustainability*, *11*(9), 2603. https://doi.org/10.3390/su11092603

Anderson, J. L., Asche, F., & Garlock, T. (2019). *Economics of Aquaculture Policy and Regulation*. https://doi.org/10.1146/annurev-resource-100518

APEC. (2023). *Project Report: Report and Workshop on Capacity Building to Improve Economic Reactivation in Sustainable Aquaculture*. https://www.apec.org/publications/2023/07/project-report-report-and-workshop-on-capacity-building-to-improve-economic-reactivation-in-sustainable-aquaculture

Bondad-Reantaso, M. G., & Subasinghe, R. P. (2013). *Enhancing the contribution of small-scale aquaculture to food security, poverty alleviation and socio-economic development.* https://www.researchgate.net/publication/323184223

Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., McNevin, A. A., Tacon, A. G. J., Teletchea, F., Tomasso, J. R., Tucker, C. S., & Valenti, W. C. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society*, *51*(3), 578–633. https://doi.org/10.1111/jwas.12714

Cisneros-Montemayor, A. M., Moreno-Báez, M., Voyer, M., Allison, E. H., Cheung, W. W. L., Hessing-Lewis, M., Oyinlola, M. A., Singh, G. G., Swartz, W., & Ota, Y. (2019). Social equity and benefits as the nexus of a transformative Blue Economy: A sectoral review of implications. *Marine Policy*, *109*, 103702. https://doi.org/10.1016/j.marpol.2019.103702

Cobcroft, J., Bell, R., Diedrich, A., Jerry, D., & Fitzgerald, J. (2020). *Northern Australia aquaculture industry situational analysis : project A.1. 1718119*. Cooperative Research Centre for Developing Northern Australia.

Coffay, M., Tveterås, R., Bocken, N., & Bogers, M. (2024). Sustainable business model innovation, dynamic capabilities, and organizational design: Insights from Norwegian aquaculture. *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3762

Damonte, G. H., Kluger, L. C., & Gonzales, I. E. (2023). Intertwined realities — hybrid institutions in the Peruvian fisheries and aquaculture sectors. *Maritime Studies*, *22*(2), 20. https://doi.org/10.1007/s40152-023-00309-1

FAO. (2013). *Good practice policies to eliminate gender inequalities in fish value chains*. Food and Agriculture Organization of the United Nations. www.fao.org/publications

FAO. (2021). *The role of social protection in the recovery from COVID-19 impacts in fisheries and aquaculture*.

FAO. (2022). The State of World Fisheries and Aquaculture 2022. In *The State of World Fisheries and Aquaculture 2022*. Food and Agriculture Organization. https://doi.org/10.4060/cc0461en

FAO. (2024). The State of World Fisheries and Aquaculture 2024 - Blue transformations in action. In *The State of World Fisheries and Aquaculture 2024*. Rome, FAO. https://doi.org/10.4060/cd0683en

Hanh, T. T. H., & Boonstra, W. J. (2019). What prevents small-scale fishing and aquaculture households from engaging in alternative livelihoods? A case study in the Tam Giang lagoon, Viet Nam. *Ocean & Coastal Management*, *182*, 104943. https://doi.org/10.1016/j.ocecoaman.2019.104943

Hicks, C. C., Gephart, J. A., Koehn, J. Z., Nakayama, S., Payne, H. J., Allison, E. H., Belhbib, D., Cao, L., Cohen, P. J., Fanzo, J., Fluet-Chouinard, E., Gelcich, S., Golden, C. D., Gorospe, K. D., Isaacs, M., Kuempel, Caitlin. D., Lee, K. N., MacNeil, M. A., Maire, E., … Naylor, R. L. (2022). Rights and representation support justice across aquatic food systems. *Nature Food*, *3*(10), 851–861. https://doi.org/10.1038/s43016-022-00618-4

Jiang, Q., Bhattarai, N., Pahlow, M., & Xu, Z. (2022). Environmental sustainability and footprints of global aquaculture. *Resources, Conservation and Recycling*, *180*, 106183. https://doi.org/10.1016/j.resconrec.2022.106183

Kamaruddin, R., Samah, R., Soon, J.-J., Musa, R., & Nur Amin, N. A. (2023). Consumers' preference and willingness-to-pay for GAqP-compliant farmed fish produce: Evidence from Malaysia. *Aquaculture*, *568*, 739305. https://doi.org/10.1016/j.aquaculture.2023.739305

Krause, G., Brugere, C., Diedrich, A., Ebeling, M. W., Ferse, S. C. A., Mikkelsen, E., Pérez Agúndez, J. A., Stead, S. M., Stybel, N., & Troell, M. (2015). A revolution without people? Closing the people–policy gap in aquaculture development. *Aquaculture*, *447*, 44–55. https://doi.org/10.1016/j.aquaculture.2015.02.009

Kruijssen, F., McDougall, C. L., & van Asseldonk, I. J. M. (2018). Gender and aquaculture value chains: A review of key issues and implications for research. *Aquaculture*, *493*, 328–337. https://doi.org/10.1016/j.aquaculture.2017.12.038

Kusakake, K., & Thongprasert, S. (2022). Women and men in small-scale fisheries and aquaculture in Asia. *Women and Men in Small-Scale Fisheries and Aquaculture in Asia – Barriers, Constraints and Opportunities towards Equality and Secure Livelihoods. Bangkok, FAO*. https://doi.org/10.4060/cb9527en

Lopez-Ercilla, I., Espinosa-Romero, M. J., Fernandez Rivera-Melo, F. J., Fulton, S., Fernández, R., Torre, J., Acevedo-Rosas, A., Hernández-Velasco, A. J., & Amador, I. (2021). The voice of Mexican small-scale fishers in times of COVID-19: Impacts, responses, and digital divide. *Marine Policy*, *131*, 104606. https://doi.org/10.1016/j.marpol.2021.104606

Love, D. C., Asche, F., Young, R., Nussbaumer, E. M., Anderson, J. L., Botta, R., Conrad, Z., Froehlich, H. E., Garlock, T. M., Gephart, J. A., Ropicki, A., Stoll, J. S., & Thorne-Lyman, A. L. (2022). An Overview of Retail Sales of Seafood in the USA, 2017–2019. *Reviews in Fisheries Science & Aquaculture*, *30*(2), 259–270. https://doi.org/10.1080/23308249.2021.1946481

Lowanshi, A., Jamwal, A., Kant, K., Balasaheb, Y., Konkan, S., Vidypeeth, K., & Singha, S. (2024). Sustainable Aquaculture. In M. B. Katare, H. S. Mogakekar, S. K. Nayak, & S. Swain (Eds.), *Innovations and Ethical Practices for Aquaculture Production*. Elite Publishing House. https://www.researchgate.net/publication/378102983

Macusi, E. D., Geronimo, R. C., & Santos, M. D. (2021). Vulnerability drivers for small pelagics and milkfish aquaculture value chain determined through online participatory approach. *Marine Policy*, *133*, 104710. https://doi.org/10.1016/j.marpol.2021.104710

Marsal, C. J., Jamaludin, M. H., Anwari, A. S., & Chowdhury, A. J. K. (2023). The Potential of Aquaculture Development in Brunei Darussalam. *Agriculture Reports*, *2*(1), 12–21. https://www.multiscipub.com/index.php/AgricultureReports

Michler-Cieluch, T., Krause, G., & Buck, B. H. (2009). Reflections on integrating operation and maintenance activities of offshore wind farms and mariculture. *Ocean & Coastal Management*, *52*(1), 57–68. https://doi.org/10.1016/j.ocecoaman.2008.09.008

Ministerio del Ambiente de Chile [Chilean Ministry of Environment]. (2015). *Plan de adaptación al cambio climático para pesca y acuicultura. [Climate change adaptation plan for fisheries and aquaculture]*. https://mma.gob.cl/wp-content/uploads/2019/08/Plan-Pesca-y-Acuicultura-CMS.pdf

Norambuena, C. R., Soto, D., Nuñez, M. R., & Aguilar-Manjarrez, J. (2024). *Evaluación del estado de avance de políticas y planes de adaptación al cambio climático en la acuicultura en América Latina y El Caribe [Assessment of the progress of policies and plans for adaptation to climate change in aquaculture in Latin America and the Caribbean]*.

Obi, C., Manyise, T., Dompreh, E. B., Murshed-e-Jahan, K., & Rossignoli, C. M. (2024). The impact of extension delivery through private local service providers on production outcomes of small-scale aquaculture farmers in Bangladesh. *The Journal of Agricultural Education and Extension*, 1–19. https://doi.org/10.1080/1389224X.2024.2371292

OECD. (2023). *Supporting sustainable fisheries What's the issue?* www.oecd.org/agriculture

Parker, M., Lipton, D., & Harrell, R. M. (2020). Impact financing and aquaculture: Maryland oyster aquaculture profitability. *Journal of the World Aquaculture Society*, *51*(4), 874-895. https://doi.org/10.1111/jwas.12702

Partelow, S., Hadjimichael, M., & Hornidge, A.-K. (2023). *MARE Publication Series 25 Ocean Governance Knowledge systems, Policy Foundations and Thematic Analyses*. Springer - Mare Publication Series. https://doi.org/10.1007/978-3-031-20740-2

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Ramirez, P. J. B., Narvaez, T. A., & Santos-Ramirez, E. J. (2020). Gender-inclusive value chains: the case of seaweed farming in Zamboanga Peninsula, Philippines. *Gender, Technology and Development*, *24*(1), 110–130. https://doi.org/10.1080/09718524.2020.1728810

Ross, G. L., Telfer, T. C., Falconer, L., Soto, D., Aguilar-Manjarrez, J., Asmah, R., Bermúdez, J., Beveridge, M. C. M., Byron, C. J., Clément, A., Corner, R., Costa-Pierce, B. A., Cross, S. F., De Wit, M., Dong, S., Ferreira, J. G., Kapetsky, J. M., Karakassis, I., Leschen, W., … Zhu, C. (2013). Site selection and carrying capacities for inland and coastal aquaculture. In L. G. Ross, D. Soro, T. C. Telfer, & L. Falconer (Eds.), *Site selection and carrying capacities for inland and coastal aquaculture*. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop. 6-8 December 2010. www.fao.org/icatalog/inter-e.htm

Simard, N. S. M., Militz, T. A., Kinch, J., & Southgate, P. C. (2021). From Past to Present: Construction of a Dataset Documenting Mother-of-Pearl Exports From a Pacific Island, Papua New Guinea. *Frontiers in Marine Science*, *8*. https://doi.org/10.3389/fmars.2021.762610

Simard, N. S. M., Militz, T. A., Kinch, J., & Southgate, P. C. (2022). Shocks within a Pacific island fishery: A historic study of events impacting the mother-of-pearl fishery in Papua New Guinea. *Marine Policy*, *143*, 105173. https://doi.org/10.1016/j.marpol.2022.105173

Singh, G. G., Eddy, I. M. S., Halpern, B. S., Neslo, R., Satterfield, T., & Chan, K. M. A. (2020). Mapping cumulative impacts to coastal ecosystem services in British Columbia. *PLOS ONE*, *15*(5), e0220092. https://doi.org/10.1371/journal.pone.0220092

Sumaila, U. R., Ebrahim, N., Schuhbauer, A., Skerritt, D., Li, Y., Kim, H. S., Mallory, T. G., Lam, V. W. L., & Pauly, D. (2019). Updated estimates and analysis of global fisheries subsidies. *Marine Policy*, *109*, 103695. https://doi.org/10.1016/j.marpol.2019.103695

Tidwell, J. H. (2012). *Aquaculture production systems*. Blackwell Publishing.

Troell, M., Costa-Pierce, B., Stead, S., Cottrell, R. S., Brugere, C., Farmery, A. K., Little, D. C., Strand, Å., Pullin, R., Soto, D., Beveridge, M., Salie, K., Dresdner, J., Moraes-Valenti, P., Blanchard, J., James, P., Yossa, R., Allison, E., Devaney, C., & Barg, U. (2023). Perspectives on aquaculture's contribution to the <scp>Sustainable Development Goals</scp> for improved human and planetary health. *Journal of the World Aquaculture Society*, *54*(2), 251–342. https://doi.org/10.1111/jwas.12946

Tucciarone, I., Secci, G., Contiero, B., & Parisi, G. (2024). Sustainable aquaculture over the last 30 years: An analysis of the scientific literature by the Text Mining approach. *Reviews in Aquaculture*, *16*(4), 2064-2076. https://doi.org/10.1111/raq.12950}

Ugalde, S. C., Vu, S. V., Giang, C. T., Ngoc, N. T. H., Tran, T. K. A., Mullen, J. D., Van In, V., & O'Connor, W. (2023). Status, supply chain, challenges, and opportunities to advance oyster aquaculture in northern Viet Nam. *Aquaculture*, *572*, 739548. https://doi.org/10.1016/j.aquaculture.2023.739548

Valenti, W. C., Kimpara, J. M., Preto, B. de L., & Moraes-Valenti, P. (2018). Indicators of sustainability to assess aquaculture systems. *Ecological Indicators*, *88*, 402–413. https://doi.org/10.1016/j.ecolind.2017.12.068

Valenti, W. C., Kimpara, J. M., & Preto, B. L. (2011). Measuring aquaculture sustainability. *World Aquaculture*, *42*(3), 26–30.

Ward, M., Spalding, A. K., Levine, A., & Wolters, E. A. (2022). California shellfish farmers: Perceptions of changing ocean conditions and strategies for adaptive capacity. *Ocean & Coastal Management*, *225*, 106155. https://doi.org/10.1016/j.ocecoaman.2022.106155

White, T. H., Bickley, P., Brown, C., Busch, D. E., Dutson, G., Freifeld, H., Krofta, D., Lawlor, S., Polhemus, D., & Rounds, R. (2021). Quantifying Threats to Biodiversity and Prioritizing Responses: An Example from Papua New Guinea. *Diversity*, *13*(6), 248. https://doi.org/10.3390/d13060248

Xuan, B. B. (2021). Consumer preference for eco-labelled aquaculture products in Viet Nam. *Aquaculture*, *532*, 736111. https://doi.org/10.1016/j.aquaculture.2020.736111

ANNEXES

Annex 1: Methodology

The methodology employed in the preparation of this report is outlined briefly below. Quantitative and qualitative data were gathered to assess the sustainability status of aquaculture in the APEC region, with a particular focus on SSA systems. Next, data on initiatives supporting the sustainable development of SSA were collected. Information was sourced from all 21 APEC economies using both primary and secondary sources.

Primary sources

The primary sources were composed of two main instruments: a digital questionnaire and a virtual interview. Initially, a questionnaire with 23 structured questions and 3 open questions was designed to collect information from government officials or regulators of the aquaculture sector in APEC economies. The questions were designed using the FAO guideline: "Using questionnaires based on the Code of Conduct for Responsible Fisheries as diagnostic tools in support of fisheries management". The questionnaire was disseminated via email through official channels and responses were obtained from 14 June 2024 to 07 February 2025. The questionnaire applied can be seen in Annex 2. Eight official responses were obtained, **representing 38.1% of APEC economies**. Each economy had one government official respond, with each individual response being considered representative of the entire economy. The following economies responded to the questionnaire:

1. Brunei Darussalam
2. Chile
3. New Zealand
4. Papua New Guinea
5. Peru
6. the Philippines
7. Chinese Taipei
8. Thailand

For the second instrument, in-depth virtual interviews with various aquaculture stakeholders, including government officials, representatives of intergovernmental organizations, academics and scientists, were performed and the responses included representatives from Australia; Chile; Malaysia; Mexico; Philippines and Peru. The interviews consisted of 7-8 semi-structured questions; questions differed between experts to match their area of expertise. Each interview lasted approximately 0.5–1 hour, and were all recorded, transcribed, anonymized, and translated when needed. The complete list of respondents for both instruments is shown in Annex 3.

Secondary sources

Additionally, a systematic scientific review approach was used to complement the information provided by the government officials and experts. Scientific articles, reports, technical publications, gray literature from official governmental or inter-governmental sources (including FAO, UN, OECD, INFOFISH, WorldFish, SEAFDEC, OFWG and USDA), official press releases and newspaper articles were used as secondary sources.

The data was obtained from the main academic databases including:

A. Google
B. Google Scholar
C. ScienceDirect
D. Web of Sciences
E. Wiley
F. Scopus

The inclusion criteria for the selection of documents were:

- Documents in English or Spanish.

- Published between 1 January 2019 and 07 February 2025 (covering a five year period). Some exceptions were made for specific concepts for which articles older than 5 years were necessary.
- The search strategy employed various keywords: aquaculture, sustainable, sustainability, small-scale, and the operators ‘AND’ and ‘OR’ to broaden the scope.
- Publications with a global or regional (Asia, the Americas, and Oceania) perspective on the topic were included, as well as documents with information on one or more of the 21 APEC economies.

The exclusion criteria for the selection of documents were:

- Publications from economies outside the APEC region.
- Publications with focus only on fisheries and not aquaculture.
- Publications in other languages than English and Spanish.

Annex 2: Digital questionnaire

Please respond to this form in the provided hyperlink: https://ee.kobotoolbox.org/x/y7rc2bWe, this document is for verification purposes only.

1. Please indicate your full name (Names will not be disclosed in public in any form).

2. Please indicate the APEC economy that you represent.

3. Please specify the institution you represent and your position within that institution.

4. Please indicate your gender.
   A) Female
   B) Male
   C) Prefer not to answer.

5. How does your economy define the concept of small-scale aquaculture?

6. Can you estimate the number and percentage distribution of producers/enterprises in the aquaculture sector in your economy across small-scale, medium-scale, and large-scale categories? (For example, small-scale aquaculture 300 producers - 30%, medium-scale aquaculture 500 producers - 50%, large-scale aquaculture 200 producers - 20%)

7. Please rate the following statement based on the provided scale: “The government's current efforts in my economy adequately cover the economic, social and cultural sustainability needs of small-scale aquaculture producers”.
   A. Totally agree
   B. Agree
   C. Neutral
   D. Disagree
   E. Totally disagree

8. Has your economy implemented any type of subsidy specifically targeted at small-scale aquaculture farmers? Please select one or more of the following options:
   A) Yes, direct financial subsidies (e.g., farmer's assistance).
   B) Yes, subsidies for input (e.g., feed, fuel, equipment).
   C) Yes, subsidies for infrastructure development (e.g., ponds, hatcheries).
   D) Yes, capacity-enhancing subsidies.
   E) Yes, subsidies for research and development.
   F) Yes, other type.
   G) No, there are no subsidies specifically targeted at small-scale aquaculture farmers.

9. How would you characterize your government's investment in research, development, and innovation specifically for small-scale aquaculture?
   A. Very High
   B. High
   C. Moderate
   D. Low

10. How receptive are small-scale aquaculture farmers in your economy to innovation and technology adoption?
    A) Highly receptive.
    B) Open to innovation.
    C) Neutral.
    D) Cautious towards innovation.
    E) Resistant to innovation.

11. To what extent has your economy implemented wide-spread and fully operational extension services and training networks for small-scale aquaculture farmers?
    A. Fully implemented.

B. Largely implemented.
C. Partially implemented.
D. Plans in development but not yet implemented.
E. Not developed or implemented.

12. Please indicate the level of associativity of small-scale aquaculture farmers (cooperative associations or farmer groups) in your economy.
    A) Very High
    B) High
    C) Moderate
    D) Low
    E) Not sure / Prefer not to answer

13. To what extent has your economy implemented or supported certification programs or systems that specifically promote socially responsible aquaculture for small-scale farmers?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans in development but not yet implemented.
    E. Not developed or implemented.

14. To what extent have gender-inclusive policies been developed and implemented to support and empower women in the small-scale aquaculture sector?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans are currently in development but have not yet been implemented.
    E. Not developed or implemented.

15. To what extent has your economy implemented sufficient stakeholder consultation in the formulation of aquaculture policies for the small-scale sector?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans in development but not yet implemented.
    E. Not developed or implemented.

16. Has your economy implemented legal regimes to ensure water rights to indigenous people for the development of aquaculture/fishery enterprises?
    A. Yes, comprehensive legal regimes are in place.
    B. Yes, some legal provisions exist, but they are limited.
    C. No, there are no specific legal regimes addressing water rights for indigenous people.
    D. Not applicable in my economy.
    E. Not sure / Prefer not to answer.

17. Please rate the suspected impacts of the following measures for the economic and social sustainable development of small-scale aquaculture in your economy. *Rate each measure as "highly effective, moderately effective, slightly effective or not effective".*

    A) Sector specific subsidies or tax incentives.
    B) Access to sector specific credits loans and grants.
    C) Promotion of innovative technologies.
    D) Promotion of diversification of their operations.
    E) Technical assistance and extension programs.
    F) Promotion of association among farmers.
    G) Support for the access to new markets.

18. Please rate the following statement based on the provided scale: "The government's current efforts in my economy adequately cover the environmental and ecological sustainability needs of small-scale aquaculture producers".

A. Totally agree.
B. Agree.
C. Neutral.
D. Disagree.
E. Totally disagree.

19. To what extent has your economy implemented a comprehensive regulation regime for the management of effluents of small-scale aquaculture sites?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans in development but not yet implemented.
    E. Not developed or implemented.

20. To what extent has your economy adopted a robust incentive system for aquaculture farmers, including financial subsidies, technical support, or recognition programs, to encourage the restoration or rehabilitation of water resources?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans in development but not yet implemented.
    E. Not developed or implemented.

21. To what extent has your economy implemented economy-wide available eco-labeling schemes or certifications to verify that small-scale aquaculture products meet environmental sustainability standards?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans are currently in development but have not yet been implemented.
    E. Not developed or implemented.

22. To what extent has your economy adopted emergency plans to respond to natural disasters or climate change impacts specifically affecting the aquaculture sector?
    A. Fully implemented.
    B. Largely implemented.
    C. Partially implemented.
    D. Plans in development but not yet implemented.
    E. Not developed or implemented.

23. To what extent have insurance programs been implemented to support small-scale aquaculture farmers in your economy in the event of natural disasters?
A. Fully implemented.
B. Largely implemented.
C. Partially implemented.
D. Plans in development but not yet implemented.
E. Not developed or implemented.

24. Identify the main challenges hindering the achievement of economic, social, and environmental sustainability in your economy's small-scale aquaculture sector. This may encompass issues like market accessibility, financial limitations, social inequality, labor conditions, or any other pertinent factors. Please provide your response in the space provided below.

25. Please share any success stories or examples of initiatives in your economy that have significantly benefited small-scale aquaculture through innovative practices or research and development initiatives aimed at ensuring the sustainability of the sector. Please provide your answer in the space below.

26. Would you be willing to participate in a brief virtual interview to provide further insights on small-scale aquaculture sustainability initiatives in your economy? If yes, please provide an email for contact. Rest assured, any communication will be conducted in a highly professional manner. (Optional question).

Annex 3: List of respondents to the questionnaire and interviews

Names have been removed from the list to protect personal information. Each specialist's listed economy represents the geographic area pertinent to the questions they responded to.

Economy	Relevant position
QUESTIONNAIRE	
Brunei Darussalam	Department of Fisheries, Brunei Darussalam
Chile	Chilean Fisheries and Aquaculture Service (SERNAPESCA) - Official of the Aquaculture Inspection Management Department of the Aquaculture Sub-directorate
New Zealand	OFWG Lead, Policy Analyst Ministry for Primary Industries
Papua New Guinea	Fisheries Authority of Papua New Guinea
Peru	Scientist, Sea Institute of Peru
The Philippines	Department of Agriculture - Bureau of Fisheries and Aquatic Resources, Regional Director
Chinese Taipei	Fisheries Agency, Ministry of Agriculture
Thailand	Department of Fisheries, Thailand
INTERVIEWS	
Australia	Scientist, Institute for Marine and Antarctic Studies, College of Sciences and Engineering, University of Tasmania
Chile	Official of the Aquaculture Inspection Management Department of the Aquaculture Sub-directorate, Chilean Fisheries and Aquaculture Service (SERNAPESCA)
Malaysia	Scientist, WorldFish
Mexico	Department of Nutrition and Aquaculture Health, Mexican Institute for Sustainable Fisheries and Aquaculture Research (IMIPAS)
Peru	Scientist, Sea Institute of Peru (IMARPE) General Direction of Aquaculture, Ministry of Production of Peru (PRODUCE)
the Philippines	Professor for Environment and Society Earth, Energy, and Sustainability, Global Challenges Program, Leiden University, The Netherlands

Annex 4: Indicators of the workshop

Data from the Zoom meeting reports and online surveys applied at the end of each session of the event were used to analyze the performance of the workshop. For this, different quantitative and qualitative indicators were prepared, which are presented and discussed in this section.

Number of participants and APEC economies represented in the workshop.

In total participants from nine different APEC economies (9/21) joined either Session I or II from the event, which represents 42.9% of APEC economies; these economies were considered as participants from the event since at least one participant from both sessions came from such regions. The participating economies were Brunei Darussalam; Chile; Indonesia; Japan; Malaysia; Mexico; Peru; the Philippines and Thailand.

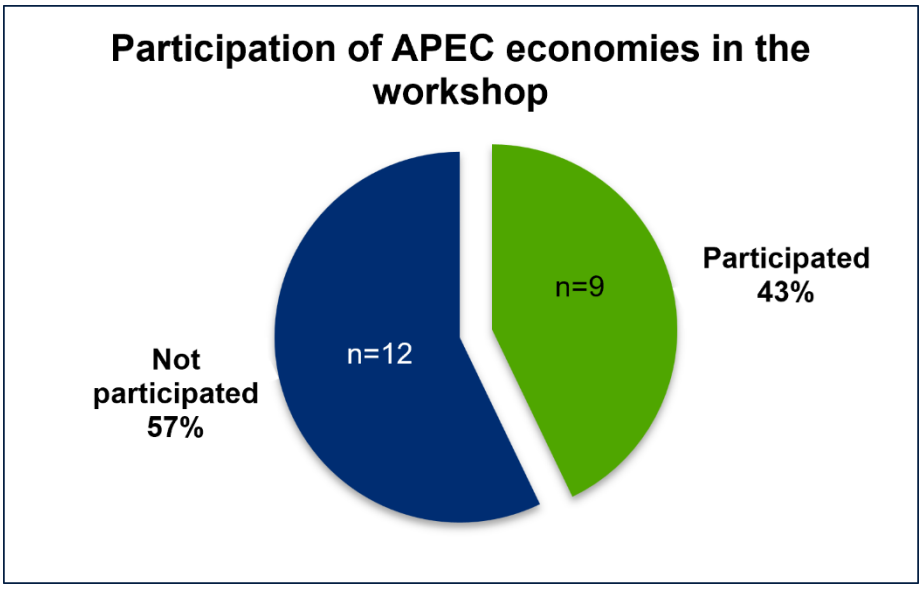


Figure 11. *Participation of APEC economies in the two-day workshop.*

The virtual Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies was held in two sessions on consecutive days (24 and 25 October 2024). Session I of the Workshop accumulated 67 participants, while Session II had 59 participants (Fig. 12). The project had the goal of achieving at least 100 participants on both days of the workshop, this goal was achieved since the total number of participants on both sessions was 126.

The first session had both the maximum number of participants and the greater number of representatives from eight different APEC economies: Brunei Darussalam; Chile; Japan; Malaysia; Mexico; Peru; the Philippines and Thailand. Meanwhile, the second session had representatives from six different APEC economies: Brunei Darussalam; Chile; Indonesia; Mexico; Peru and Thailand. The differences between the number of participants and the diversity of the origin of the attendees can be explained due to the fact that the first session started on 24 October 2024 from 18:00-22:00 (24h format, UMT-5 time zone, Lima, Peru), this time allowed more participants from Asia to join the event. Meanwhile, the second session was developed on 25 October 2024 from 8:00-11:30 (24h format, UMT-5 time zone, Lima, Peru), a time that was more suitable for participants in the Americas. Since the event was held by the Ministry of Production of Peru, this economy accumulated most of the participants in both sessions.

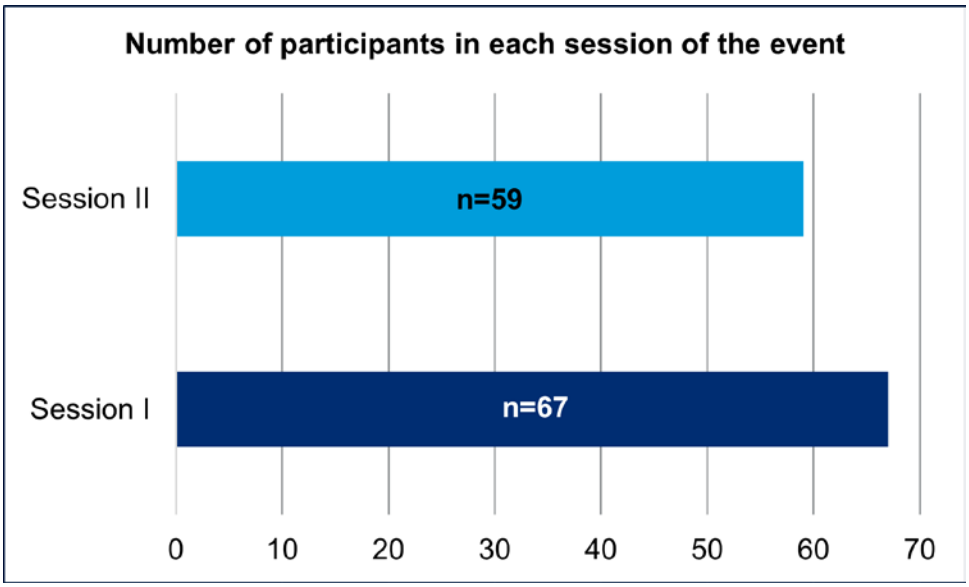


Figure 12. *Total number of attendees to both sessions of the virtual Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies.*

For the first session Peru had 37 participants, Thailand (8), Malaysia (7), Mexico (6), Chile (5), the Philippines (2), Brunei Darussalam (1) and Japan (1) (Fig. 13).

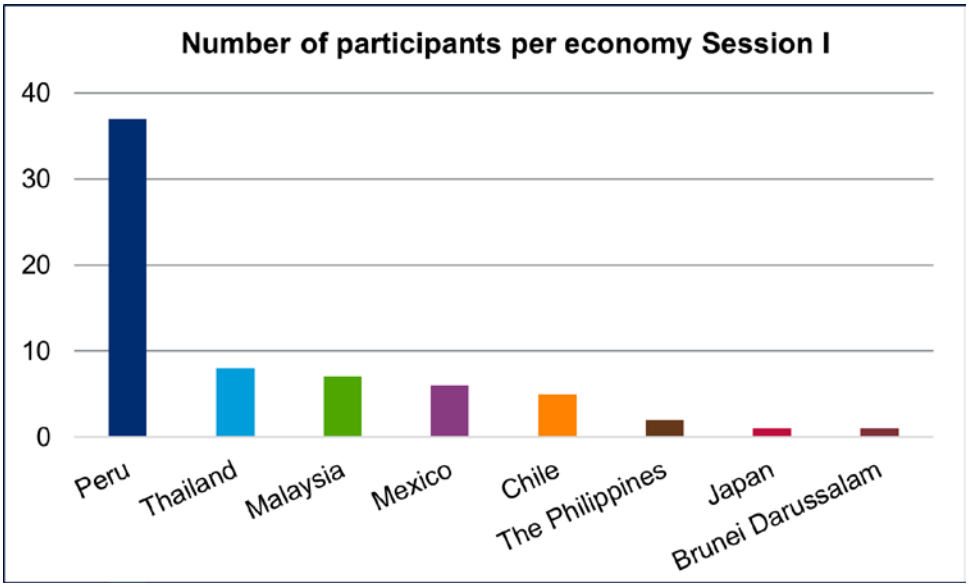


Figure 13. *Total number of attendees per economy to Session I of the virtual Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies.*

For Session II of the workshop Peru accumulated 42 participants, Chile (6), Mexico (5), Thailand (3), Brunei Darussalam (1), Indonesia (1). Additionally, there was one speaker from Italy (Fig. 14).

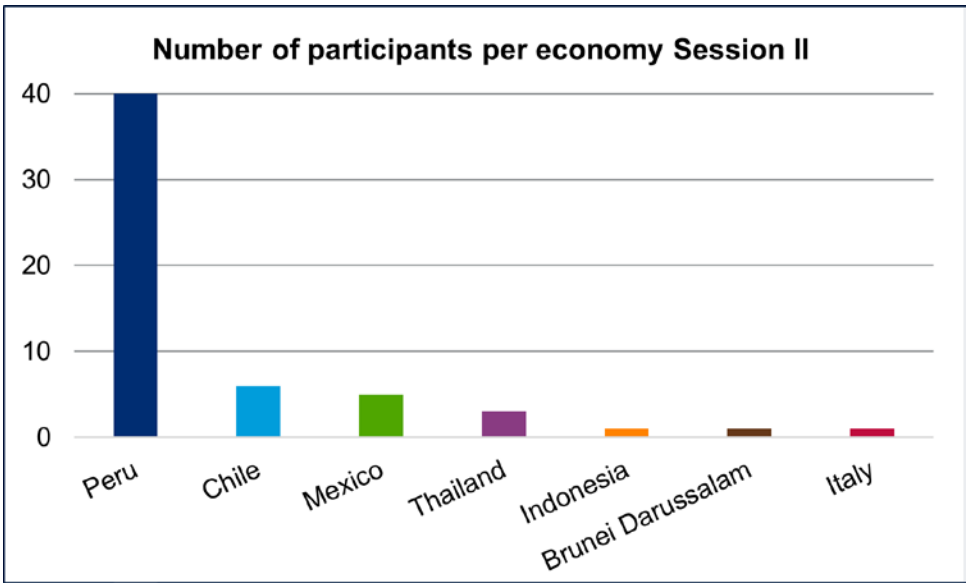
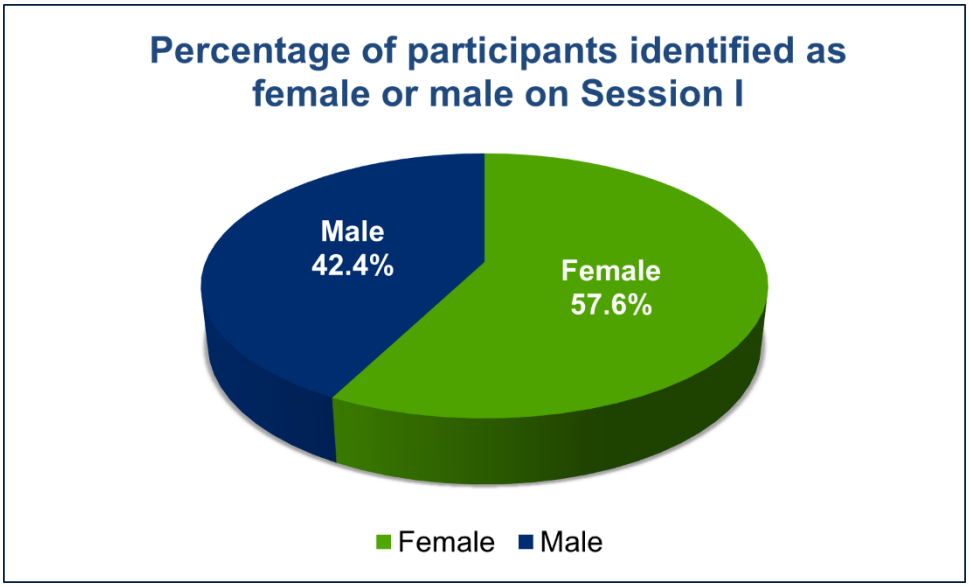


Figure 14. *Total number of attendees per economy to Session II of the virtual Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies.*

Indicators of gender

From the 68 attendees to Session I of the workshop, 38 participants identified themselves as female, 28 identified as males, while one participant preferred not to declare their gender (Fig. 15). Correcting the data for those that responded to either of the two categories, 57.6% participants identified as females and 42.4% as males on the first session. Session II of the workshop had 59 participants from which 31 (52.5%) identified as females and 28 (47.5%) as males. Regarding the female participation as speakers for the event, there were 12 speakers from which four identified as females (33.3%) and eight as males (66.7%). The speakers for the event came from different APEC economies such as Chile; Japan; Mexico; Peru; Thailand and one came from a non-APEC economy: Italy.



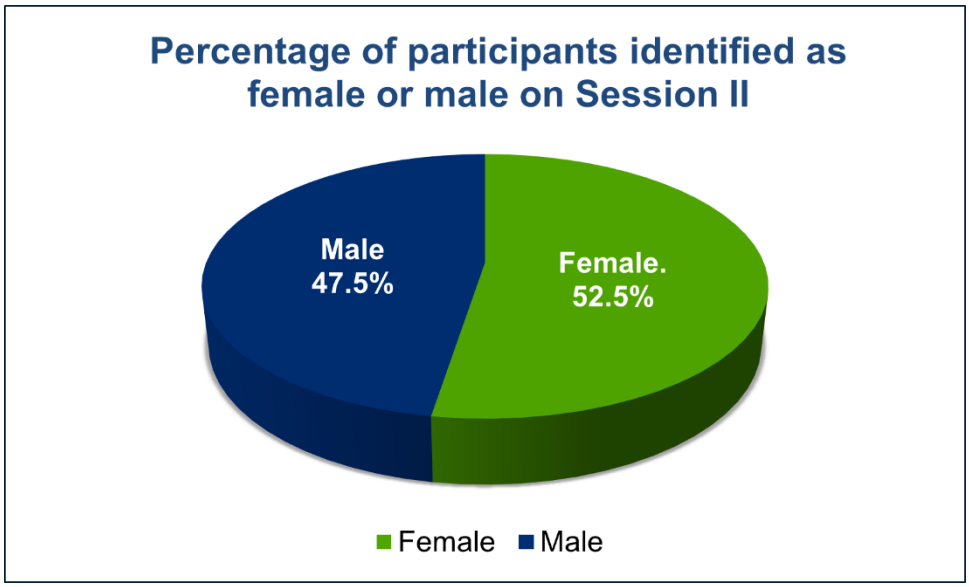


Figure 15. *Percentages of female and male participants on both sessions of the virtual Workshop on Development of Sustainable Ventures in Small-Scale Aquaculture in APEC Economies.*

Relevance of the information

First, participants were consulted about the usefulness and applicability of the topics addressed in each session, for this, participants were consulted about their agreement with the following statement: "*The topics covered in Session I were useful and applicable to my professional experience*". For Session I, 92.6% of participants responded positively, 40.7% totally agreed and 51.9% agreed with the statement, while only 7.4% of participants did not agree nor disagree with the statement. For Session II, a similar figure could be seen with 95.7% of attendees responding positively, 56.5% totally agree and 39.1% agree with the same statement. At both sessions, none of the participants disagreed or totally disagreed with the statement regarding the practical application of the topics covered in the event (Fig. 16).

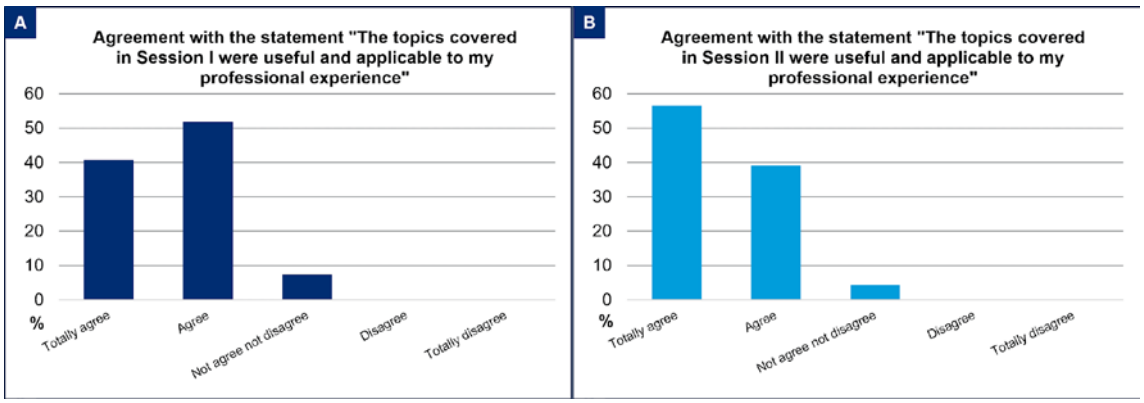


Figure 16. *Participant agreement on the practical application of topics covered in Sessions I and II.*

Fitness of time allotted for each presentation

Moreover, attendees were consulted about the time allotted for each presentation, for this, the agreement with the following statement was assessed: "*The time available for the topics addressed in Session I/II was sufficient to provide a general view of them*". For Session I, 85.2% of participants either totally agreed (25.9%) or agreed (59.3%) with such a statement. Only 7.4% responded that they did not agree or disagree with the fact that the time given to each presentation was sufficient to provide a general view of the topic, while also 7.4% disagree with the statement,

suggesting time was probably insufficient for them and no one totally disagrees. For Session II, 95.7% of attendees considered that the duration of the plenaries was sufficient (43.5% totally agree and 52.2% agree), meanwhile only 4.3% did not agree nor disagree with such a statement (Fig. 17). Overall, we consider this indicator as satisfactory since more than 80% of attendees agree that the time allotted for each presentation was adequate (on both sessions), and less than 15% of participants considered that the time was somehow insufficient, this valid option could be explained since the minor presentations on the event had a maximum time of 20 minutes so the event did not become tedious, longer presentation times would have increased considerably the duration of the event.

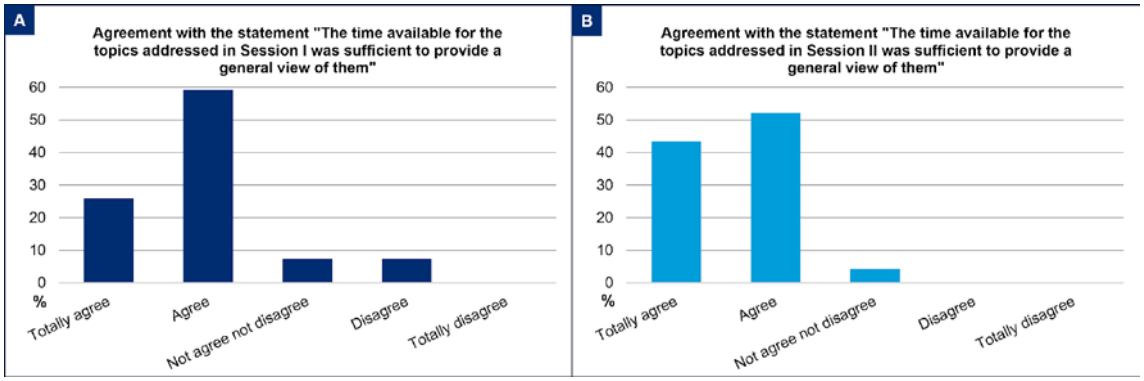


Figure 17. *Participant agreement on the fitness of time allotted for each presentation in Sessions I and II.*

Organization of the workshop

The participants were consulted about their agreement with the following statement: “The organization of the Session I/II was appropriate and allowed the event to flow smoothly”. For Session I, the general appreciation of the organization of the workshop was that 100% totally agree or agree with that statement, 48.1% totally agree and 51.9% agree. A similar situation was found for Session II, 100% of participants agree that the event was well organized, with 73.9% that totally agree with the statement and 26.1% that agree (Fig. 18). No participant responded that they did not agree nor disagree, neither disagree nor totally disagree for any of the sessions.

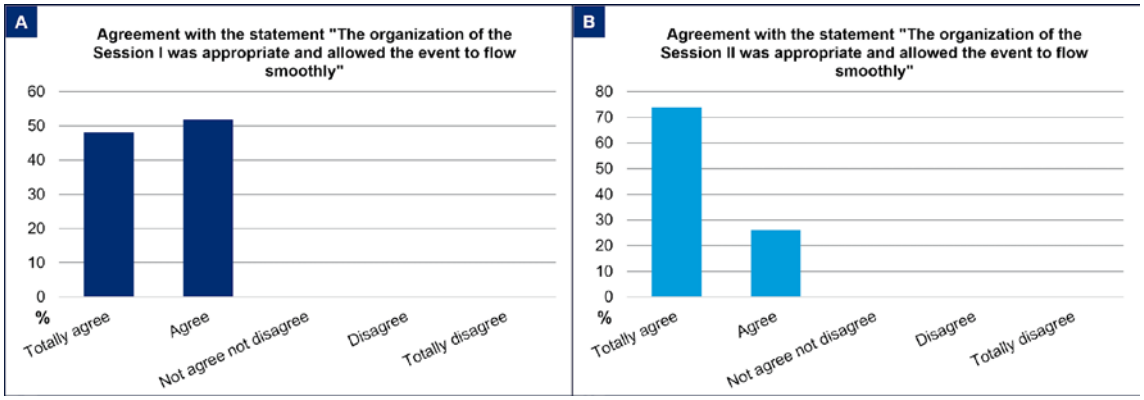


Figure 18. *Participant agreement on the level of organization in Sessions I and II.*

Finally, participants were consulted about the final conclusions of each session. In the first session, 96.3% of participants totally agree (37%) or agree (59.3%) with the following statement: “The conclusions at the end of Session I were appropriate and consistent with the topics discussed”, only 3.7% of participants did not agree or disagree. In the second session, 91.3% of attendees agreed with the statement and only 4.3% did not agree or disagree with and 4.3% disagreed. The high level of agreement on both sessions highlights that the discussions developed on the workshop remained relevant and appropriate for the challenges that they try to cover (Fig. 19).

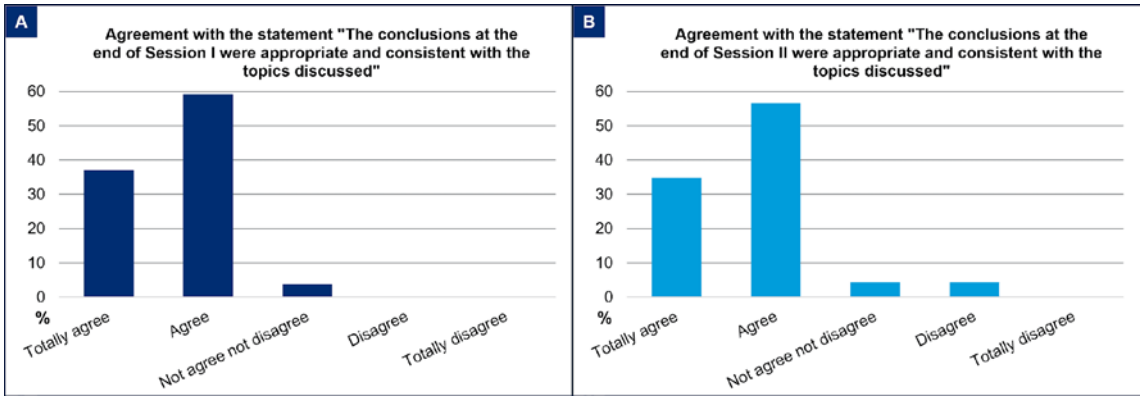
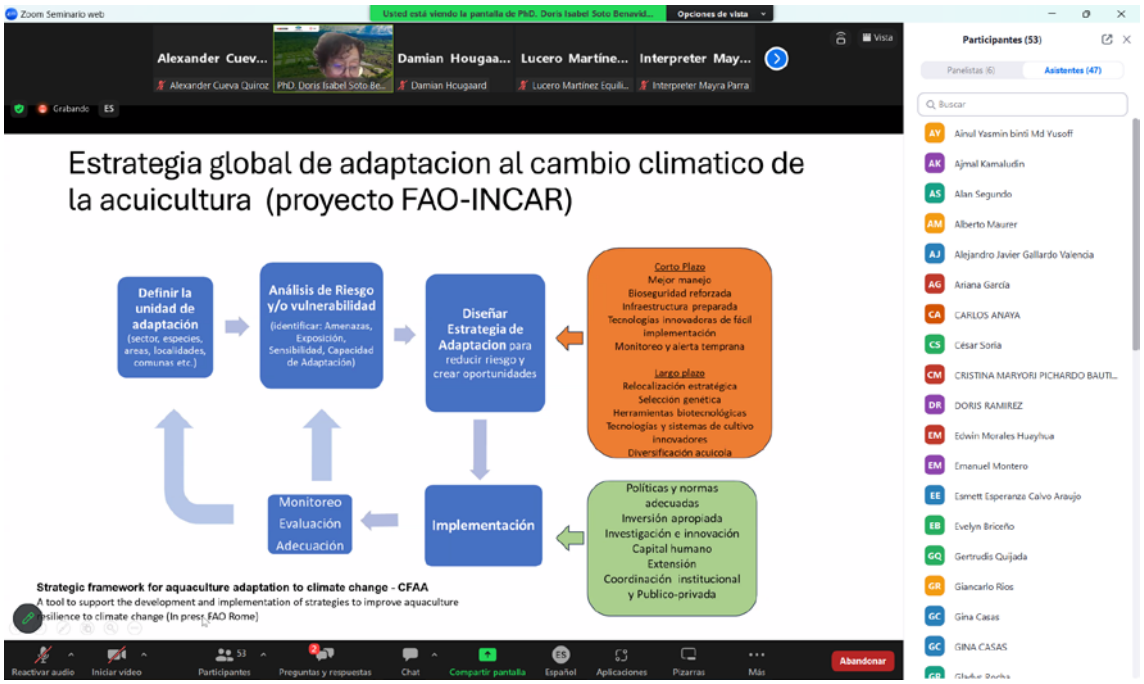


Figure 19. *Participant agreement on the appropriateness of conclusions in Sessions I and II.*

Annex 5: Graphical resume of the event

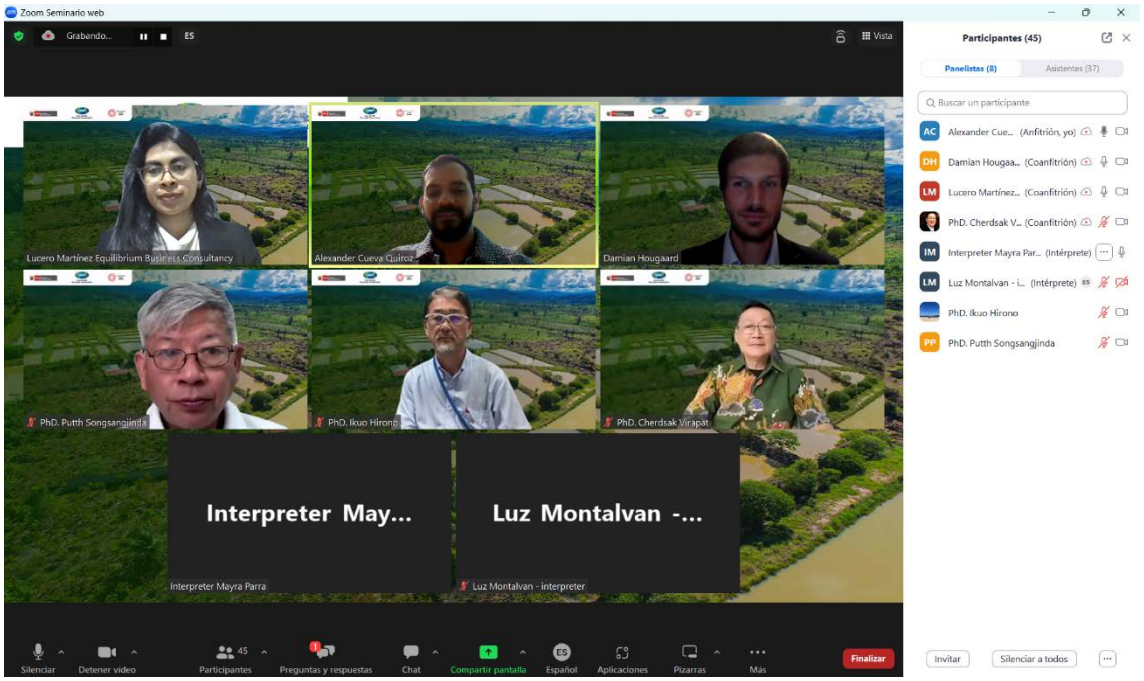
Presentation by PhD. Doris Soto Benavides



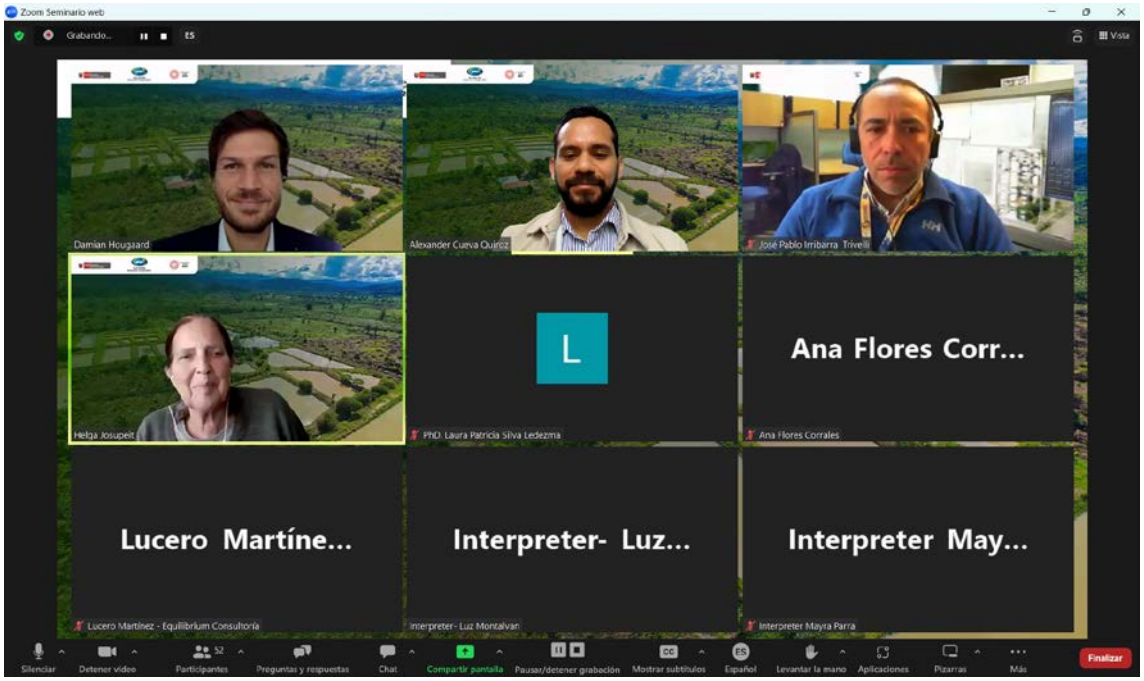
Presentation by PhD. Jefferson Yunis Aguinaga

Presentation by PhD. Eva Coronado Castro

Final discussion from Session II of the workshop with participation of the speakers: PhD. Cherdsak Virapat, PhD. Puth Songsangjinda PhD. Ikuo Hirono and Mr. Victor Alexander Cueva Quiroz.



Presentation by PhD. Helga Josupeit



Final discussion from Session II of the workshop with participation of the speakers: Mr. Edgard Fabricio Flores, Ysla, PhD. Laura Silva Ledezma, Mr. Alejandro Javier Gallardo Valencia, Mr. José Pablo Irribarra Trivelli and Ms. Ana Flores Corraales.