APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for Sustainable Aquaculture in the Asia–Pacific

Summary Report

APEC Ocean and Fisheries Working Group

December 2025

Asia-Pacific
Economic Cooperation

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EXECUTIVE SUMMARY

The APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for Sustainable Aquaculture in the Asia–Pacific was convened from 15 to 16 September 2025 at the Sheraton Hanoi West Hotel, Viet Nam, under the APEC project OFWG 02 2023A, implemented by the Ministry of Foreign Affairs of Viet Nam. The event was supported by the APEC Ocean and Fisheries Working Group (OFWG), with co-sponsorship from Australia; China; Chile; Japan; Peru; Chinese Taipei; Thailand; and Singapore.

The workshop brought together more than 90 delegates from 14 APEC member economies, as well as representatives of regional and international organizations, development agencies, private sector partners, and academic institutions. Participants included senior policymakers, scientists, industry experts, and community leaders working at the intersection of aquaculture, climate change, and sustainable development.

The overall objective of the project was to enhance APEC economies' capacity to adapt to and mitigate the impacts of climate change in aquaculture, a sector vital to regional food security, employment, and trade. Specifically, the workshop aimed to:

- Identify common challenges, knowledge gaps, and practical solutions for climate-resilient aquaculture systems;
- Promote innovation, digitalization, and financing mechanisms that reduce emissions and strengthen adaptation;
- Foster policy coherence, technology transfer, and capacity building through APEC cooperation toward 2030.

The initiative aligns closely with APEC's key strategic frameworks, including the Putrajaya Vision 2040, the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, the OFWG Strategic Plan 2021–2025, and global agendas such as the UN Sustainable Development Goals (SDGs) — particularly Goals 2 (Zero Hunger), 13 (Climate Action), and 14 (Life Below Water).

Workshop Program and Structure

The two-day event was conducted in a hybrid format, combining in-person sessions and online participation. It featured four thematic sessions and one high-level closing segment:

Opening Session: Senior officials from Viet Nam's Ministry of Agriculture and Environment and the APEC Secretariat highlighted the importance of regional collaboration to accelerate green and blue transformation in aquaculture.

- Session I – Aquaculture in the Asia-Pacific in the Face of Climate Change: Focused on assessing vulnerabilities and adaptation pathways.
- Session II – Best Practices in Climate Adaptation and Mitigation: Showcased innovative models and technologies from APEC economies.
- Session III – Regional and International Cooperation: Explored opportunities for policy integration, financing, and partnerships.
- Closing Session: Summarized key messages and outlined next steps for inclusion in the APEC OFWG 2026–2028 Work Plan.

Speakers represented a diverse range of institutions, including the United Nations Industrial Development Organization (UNIDO), National Marine Data and Information Service (NMDIS, China), Singapore Food Agency (SFA), Ministry of Marine Affairs and Fisheries (Indonesia), Subsecretariat for Fisheries and Aquaculture (Chile), Department of Fisheries (Malaysia and Thailand), EnviroStrat Ltd (New Zealand), Grobest Viet Nam, VASEP, COAST Facility, and academic partners from across the region.

Key Themes and Findings

1. Aquaculture and Climate Vulnerability in the Asia-Pacific

Participants recognized that aquaculture is one of the most climate-sensitive food production systems. The region faces increasing exposure to extreme weather events, sea-level rise, salinity intrusion, and temperature variability, which threaten productivity and ecosystem stability. Viet Nam's background study highlighted that climate change could reduce aquaculture yield potential by 10–30% in low-lying coastal areas if no adaptive actions are taken.

Case studies from Chile and Indonesia illustrated how integrated approaches—such as ecosystem-based management, polyculture, and coastal habitat restoration—can simultaneously enhance resilience and reduce carbon footprints.

2. Emerging Technologies and Innovative Practices

- Multiple economies showcased best practices and digital innovations for mitigation and adaptation:
- China's NMDIS presented a marine science data sharing service platform and a sea-level rise monitoring system with potential applications for aquaculture site planning and risk mapping.
- Singapore demonstrated its Aquaculture Sensing Network (ASN) using digital technologies to detect anomalies and manage water quality in real time.
- Thailand and Malaysia shared economy-wide roadmaps on freshwater aquaculture and feed management to reduce emissions.
- Viet Nam's Grobest introduced the GROFARM™ model—a closed-loop, low-emission production system improving feed conversion efficiency and profitability.
- New Zealand and Chinese Taipei presented regenerative aquaculture models, IMTA systems, and low-carbon species management to enhance circularity in production.

3. Policy Integration and Governance Coherence

Discussions underscored that fragmented governance remains a major barrier to scaling climate-smart aquaculture. Participants emphasized the need to integrate aquaculture more systematically into Nationally Determined Contributions (NDCs) and BCG economy strategies. Effective climate action requires inter-ministerial coordination between fisheries, environment, finance, and trade sectors. Policy coherence should also extend to local levels, aligning economy-wide frameworks with coastal community initiatives.

4. Inclusive and Equitable Transformation

Participants highlighted the importance of inclusiveness in resilience building. Women, youth, and micro, small, and medium enterprises (MSMEs) play vital roles in aquaculture innovation, community-based management, and value chain development. Gender-responsive capacity-building programs and community co-management models—such as those piloted by Viet Nam's MCD—were recommended as models for replication.

5. Finance, Investment, and Partnerships

Speakers from UNIDO, COAST Facility, and VASEP emphasized the need for stronger investment mechanisms to sustain green aquaculture transitions. Blue finance tools—

including blue bonds, resilience insurance, and impact investment funds—can help scale innovation and support small producers. Regional partnerships and blended finance are essential to mobilize both public and private capital for aquaculture decarbonization and adaptation.

Outcomes and Recommendations

The workshop generated a set of actionable recommendations to guide APEC's collective efforts for 2026–2030:

- Policy Integration and Alignment: Embed aquaculture adaptation and mitigation priorities into NDCs, BCG, and marine spatial planning frameworks; Develop an APEC Aquaculture Climate Resilience Framework (AqCRF) to guide implementation across economies.
- Technological and Scientific Innovation: Support R&D on digital aquaculture, disease management, low-carbon feed, and blue carbon accounting. Encourage data-driven early warning systems and regional knowledge-sharing platforms.
- Ecosystem and Community Resilience: Scale up nature-based and integrated models such as IMTA, mangrove–shrimp, and rice–shrimp systems; Mainstream gender and social inclusion into economy-wide aquaculture strategies.
- Finance and Investment Mobilization: Establish a regional Blue Finance Fund for aquaculture innovation; Promote public–private partnerships, impact investment, and risk-sharing insurance products.
- APEC Cooperation and Knowledge Exchange: Create an APEC Aquaculture Data and Early Warning Platform to facilitate cross-economy learning; Organize regular technical dialogues, training workshops, and South–South exchange programs.

Conclusion

The workshop reaffirmed APEC's shared commitment to advancing resilient, inclusive, and low-carbon aquaculture across the region. It demonstrated strong consensus among economies that climate adaptation and mitigation in aquaculture are both an environmental necessity and an economic opportunity.

Viet Nam, as the host and project overseer, expressed gratitude to the APEC Secretariat, co-sponsoring economies, and partner organizations for their active contributions. The workshop's results will feed directly into the APEC OFWG Work Plan 2026–2028 and the development of the proposed APEC Aquaculture Climate Resilience Platform—a collaborative mechanism to foster innovation, policy coherence, and sustainable growth for aquaculture under changing climate conditions.

SUMMARY REPORT

APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for Sustainable Aquaculture in the Asia–Pacific

I. INTRODUCTION

1.1. Background and Rationale

Aquaculture is one of the fastest-growing food-production sectors worldwide and a cornerstone of food security, livelihoods, and trade across the APEC region. Asia-Pacific economies account for more than 90 percent of global aquaculture output and supply roughly two-thirds of the fish consumed globally. The sector provides employment and income for tens of millions of coastal and rural households and contributes substantially to GDP, export earnings, and nutrition in many APEC economies.

Yet aquaculture now stands on the frontline of the climate crisis. Rising air and sea temperatures, ocean acidification, sea-level rise, salinity intrusion, and increasingly frequent extreme weather events are already altering aquatic ecosystems and production cycles. These changes disrupt fish growth rates, feed conversion efficiency, reproduction, and disease dynamics, threatening productivity and profitability. At the same time, the sector's own environmental footprint, energy use, nutrient discharge, and land conversion, demands mitigation to ensure long-term ecological balance.

Climate change also intensifies social and economic pressures. Small-scale and family-run aquaculture farms dominate in most APEC economies but often lack access to finance, insurance, and technology. Women and youth, who make up a significant share of the workforce in post-harvest and value-chain activities, face disproportionate vulnerability to shocks and limited participation in decision-making. Strengthening their resilience is essential for inclusive and equitable growth.

The Asia-Pacific region therefore requires collective action that bridges science, policy, and practice. Technological innovations such as recirculating aquaculture systems (RAS), integrated multi-trophic aquaculture (IMTA), precision feeding, and digital monitoring can improve resource efficiency and reduce emissions. Ecosystem-based approaches, mangrove-shrimp integration, seaweed and shellfish farming, and nature-based coastal protection, offer low-carbon solutions that align economic incentives with ecological restoration. Equally critical are cross-economy mechanisms for data sharing, early-warning systems, and coordinated responses to transboundary disease and climate risks.

Recognizing these imperatives, the APEC Ocean and Fisheries Working Group (OFWG) endorsed the project "Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific" (Project Code: OFWG 02 2023A). Implemented by Viet Nam with co-sponsorship from Australia; China; Chile; Japan; Peru; Chinese Taipei; Thailand; and Singapore, the project supports APEC's shared goals of advancing sustainable growth, blue-economy development, and regional food security.

As a core activity of the project, the APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific, held on 15–16 September 2025 in Hanoi, gathered more than 90 delegates from APEC member economies, international organizations, research institutions, and the private sector. The event provided a multi-stakeholder platform to:

- review regional climate impacts and vulnerabilities;
- exchange experiences, innovations, and policy measures;
- promote gender-responsive and inclusive adaptation strategies; and

- identify actionable recommendations for scaling up cooperation under the OFWG framework.

This report summarizes the proceedings and key outcomes of that workshop. It reflects the region's consensus that aquaculture, when guided by science, innovation, and collaboration, can serve not only as a sector at risk but also as a solution to climate change, contributing to a resilient, low-carbon, and inclusive blue economy for the Asia-Pacific.

1.2. Objectives

The project "Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific" was designed to strengthen the collective capacity of APEC economies to respond effectively to the increasing climate risks faced by the aquaculture sector. Building on Viet Nam's initiative and supported by eight co-sponsoring economies, Australia; China; Chile; Japan; Peru; Chinese Taipei; Thailand; and Singapore, the project sought to foster regional dialogue, generate practical knowledge, and formulate policy guidance consistent with APEC's long-term strategic vision.

The overarching goal was to enhance climate resilience and reduce greenhouse-gas emissions in aquaculture through innovation, ecosystem-based management, and inclusive growth. Specifically, the project pursued the following interlinked objectives:

1. Assess regional challenges and vulnerabilities related to climate change impacts on aquaculture systems, including environmental, technical, and socio-economic dimensions.
2. Identify and share best practices in adaptation and mitigation, from ecosystem-based and regenerative models to digital and low-carbon technologies, across APEC member economies.
3. Promote knowledge exchange and policy coherence among governments, research institutions, private enterprises, and community stakeholders, aligning economy-wide strategies with regional and global frameworks.
4. Develop actionable policy recommendations and collaborative mechanisms for incorporation into the APEC Ocean and Fisheries Working Group (OFWG) Work Plan 2026–2028, supporting future capacity-building and investment initiatives.
5. Encourage inclusive and gender-responsive approaches that empower small-scale farmers, women, and youth, ensuring equitable participation and benefits in climate-smart aquaculture development.

Through these objectives, the project aims to create a foundation for sustained cooperation under APEC's blue-economy agenda, linking science, technology, and policy to deliver a resilient, low-carbon, and sustainable aquaculture sector that contributes to regional food security, livelihoods, and shared prosperity.

1.3. Alignment with APEC and Global Agendas

The project *"Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific"* is firmly grounded in the broader strategic frameworks that guide APEC's work on sustainable growth, climate action, and the blue economy. Its objectives and expected outputs directly contribute to the following overarching agendas:

APEC Putrajaya Vision 2040

Adopted by APEC Leaders in 2020, the Putrajaya Vision 2040 calls for an open, dynamic, resilient, and peaceful Asia-Pacific community that delivers prosperity for all. The project supports this vision by promoting innovation-driven, inclusive, and sustainable aquaculture development, helping member economies strengthen food security, environmental stewardship, and economic resilience under the "Innovation and Digitalization for Sustainability" pillar.

Bangkok Goals on the Bio-Circular-Green (BCG) Economy

Endorsed in 2022, the Bangkok Goals emphasize integrating the bio-, circular-, and green-economy approaches into economy-wide and regional strategies. This project operationalizes those goals in the fisheries and aquaculture context by identifying low-carbon production models, advancing circular resource use, and supporting ecosystem-based approaches such as integrated multi-trophic aquaculture and regenerative coastal farming. It highlights aquaculture's potential as both a driver of green growth and a nature-based solution for climate mitigation.

United Nations Sustainable Development Goals (SDGs 2, 13 and 14)

The workshop outcomes contribute directly to:

- SDG 2 – Zero Hunger, by promoting sustainable food production systems;
- SDG 13 – Climate Action, through adaptation, mitigation, and resilience measures; and
- SDG 14 – Life Below Water, by protecting coastal and marine ecosystems and reducing pollution and overexploitation.

These linkages demonstrate the synergy between APEC regional cooperation and the global 2030 Agenda for Sustainable Development.

APEC Ocean and Fisheries Working Group (OFWG) Strategic Plan 2021–2023

The project advances the OFWG's priority areas, sustainable use of marine resources, resilient coastal communities, and the promotion of the blue economy. It provides practical recommendations, technical exchange, and capacity-building pathways that will inform the next OFWG Work Plan (2026–2028). In doing so, the project reinforces APEC's leadership in balancing economic development with ocean and climate stewardship.

1.4 Expected Outputs and Outcomes

The project "Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific" delivers a comprehensive package of knowledge products and cooperative actions designed to strengthen the APEC region's capacity to manage climate risks in aquaculture. Its outputs serve both immediate information needs and longer-term policy planning under the Ocean and Fisheries Working Group (OFWG).

Key Outputs

1. APEC Workshop and Proceedings – The two-day regional workshop held in Hanoi, Viet Nam (15–16 September 2025) convened more than 90 delegates from APEC member economies, international organizations, academia, and industry. It provided a platform for sharing experiences, innovative technologies, and cooperative mechanisms for climate-resilient aquaculture.
2. Summary Report (this document) – A consolidated record of workshop discussions, case studies, and outcomes, including synthesized findings from the Background

Research Paper and participant surveys. The report captures key lessons, thematic insights, and regional recommendations for future action.

3. Compendium of Policy Recommendations – A structured matrix of practical measures and potential collaborations for consideration by the APEC OFWG and inclusion in its 2026–2028 Work Plan. The compendium highlights cross-economy cooperation opportunities, innovation priorities, and financing mechanisms.
4. Knowledge Exchange and Data Platform Concept – A proposed framework for an "APEC Aquaculture Climate Resilience Platform," facilitating information-sharing on climate risks, early-warning systems, and best practices across economies.

Expected Outcomes

- Strengthened Policy Dialogue and Regional Cooperation: Enhanced communication among policymakers, researchers, and industry leaders on adaptation and mitigation strategies.
- Improved Knowledge and Capacity: Greater understanding of technological and ecosystem-based solutions that can be adapted to diverse socio-economic contexts.
- Inclusive and Gender-Responsive Engagement: Broader participation of women, youth, and small-scale farmers in climate-smart aquaculture initiatives.
- Actionable Inputs for Future APEC Work: Concrete recommendations informing APEC's medium-term programming and capacity-building activities under the OFWG and related fora.

Collectively, these deliverables are expected to catalyze continued collaboration among APEC economies, laying the foundation for a resilient, low-carbon, and inclusive aquaculture sector that contributes to regional food security, economic prosperity, and the sustainable blue economy.

II. WORKSHOP OVERVIEW

The APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific was organized under APEC Project OFWG 02 2023A, implemented by Viet Nam with the support of the APEC Secretariat and co-sponsoring economies. The event took place from 15–16 September 2025 at the Sheraton Hanoi West Hotel, Hanoi, Viet Nam, and was delivered in a hybrid format, combining onsite participation with online engagement through APEC's virtual conferencing platform.

2.1. Participation

The Workshop gathered more than 90 delegates from 14 APEC member economies, including Australia; China; Chile; Indonesia; Japan; Malaysia; New Zealand; Peru, the Philippines; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam, as well as representatives from international organizations (UNIDO, SEAFDEC, FAO), academic and research institutions, private-sector enterprises, and civil society groups.

Participants included government policymakers, scientists, entrepreneurs, and technical experts involved in aquaculture, climate adaptation, and blue economy initiatives. The diversity of perspectives reflected the cross-cutting nature of climate change impacts on the sector and the need for multi-stakeholder collaboration in designing effective responses.

2.2. Objectives and Focus

The Workshop aimed to:

- Facilitate technical exchange and regional dialogue on aquaculture adaptation and mitigation in the face of climate change;
- Highlight innovative technologies and policy frameworks that strengthen the sector's resilience;
- Identify opportunities for joint research, investment, and data sharing under APEC cooperation; and
- Develop actionable recommendations for inclusion in the APEC Ocean and Fisheries Working Group (OFWG) Work Plan 2026–2028.

To achieve these goals, the Workshop featured presentations from 18 speakers and experts across member economies, complemented by panel discussions and Q&A sessions that encouraged interactive knowledge sharing and the exchange of good practices.

2.3. Workshop Structure

The two-day program was structured into five main segments:

1. Opening Session – Introduced the objectives, context, and expected deliverables of the project. Welcoming remarks were delivered by senior representatives from the Ministry of Agriculture and Environment (MAE, Viet Nam).
2. Session I – Aquaculture in the Asia-Pacific in the Face of Climate Change – Presented findings from the APEC Background Research Paper and case studies from Chile; Indonesia; Malaysia; New Zealand; and Viet Nam. The session emphasized the sector's vulnerability to climate stressors and showcased policy and technological responses across economies.
3. Session II – Best Practices in Adaptation and Mitigation – Featured technological and policy innovations from China; New Zealand; Singapore; Chinese Taipei; Thailand; and Viet Nam, and, focusing on climate-smart aquaculture models, IoT applications, and regenerative practices.
4. Session III and IV – Regional and International Cooperation – Highlighted cross-economy collaboration, financing mechanisms, and gender-responsive community models through contributions from UNIDO; China; Viet Nam; the United Kingdom (COAST Facility), and regional partners.
5. Closing Session – Summarized outcomes and key recommendations. The Project reaffirmed the commitment of APEC economies to advancing inclusive, low-carbon, and climate-resilient aquaculture, followed by closing remarks from the Ministry of Foreign Affairs (MOFA, Viet Nam).

2.4. Key Features

- Hybrid engagement: Both in-person and remote participants interacted through live presentations and moderated discussions, ensuring broad inclusivity despite geographical constraints.
- Cross-sectoral participation: The workshop linked policy, science, and business communities to encourage the co-design of climate solutions.

- Gender and inclusion lens: Special attention was given to the participation of women experts and small-scale aquaculture representatives in the agenda.
- Knowledge products: Proceedings, background materials, and presentation slides were compiled to form the basis of this Summary Report and the forthcoming Compendium of Recommendations.

The Workshop provided a valuable platform for APEC economies to share lessons learned, identify synergies, and chart a coordinated course toward a climate-smart, sustainable, and inclusive aquaculture future in the Asia-Pacific.

III. OPENING SESSION

The Opening Session of the APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific set the stage for two days of discussion, collaboration, and policy exchange. It reaffirmed APEC's shared commitment to building resilient and low-carbon aquaculture systems that support inclusive and sustainable growth across the region.

The session was chaired by representatives from the Ministry of Agriculture and Environment (MAE) of Viet Nam, in cooperation with the APEC Secretariat, and attended by officials, experts, and delegates from 14 APEC member economies and partner organizations.

3. 1. Welcome Remarks – Ministry of Agriculture and Environment (MAE), Viet Nam

In his opening remarks, Deputy Director-General of the Department of Fisheries and Surveillance, Ministry of Agriculture and Environment, welcomed all APEC delegates and international partners to Hanoi. He highlighted Viet Nam's strong commitment to promoting sustainable aquaculture and deepening cooperation under the APEC framework.

He emphasized that aquaculture plays a strategic role in Viet Nam's economy and food security, accounting for more than half of total fisheries output and supporting millions of livelihoods. However, the sector is increasingly affected by climate-related challenges such as extreme weather, salinity intrusion, and disease outbreaks. These pressures underline the importance of regional collaboration in developing adaptive and sustainable models.

He noted that Viet Nam has adopted the Strategy on Climate Change Adaptation 2021–2030, which promotes low-emission aquaculture and digital transformation. The Government's priorities include developing high-tech farming systems, promoting circular resource use, improving seed quality, and protecting marine ecosystems.

He expressed appreciation for APEC's role as a platform for technical exchange and policy coordination and reaffirmed Viet Nam's willingness to share experiences, learn from partner economies, and contribute to the collective advancement of sustainable aquaculture. He concluded by encouraging all participants to engage actively in discussions and work together toward a climate-resilient, inclusive, and innovative aquaculture sector in the Asia-Pacific.

2. Opening Remarks – Ministry of Foreign Affairs, Viet Nam

The representative from MOFA Viet Nam congratulated this timely and relevant project aligned with APEC's priorities under the Bangkok Goals on the Bio-Circular-Green (BCG) Economy.

He underlined that aquaculture is not only vital for food security and livelihoods but also a critical frontier for achieving low-carbon and sustainable growth. APEC's cross-economy collaboration enables the sharing of innovative technologies, financial mechanisms, and governance models that enhance adaptation and reduce environmental impacts.

He encouraged member economies to use this workshop as a catalyst for scaling up collective action, strengthening knowledge-sharing networks, and developing forward-looking policies that integrate aquaculture into economy-wide climate strategies and NDC commitments.

IV. SESSION I – AQUACULTURE IN THE ASIA-PACIFIC IN THE FACE OF CLIMATE CHANGE

Session I focused on understanding the current and emerging impacts of climate change on aquaculture across APEC economies and identifying regional strategies for adaptation and mitigation. The session featured seven technical presentations representing diverse geographic and thematic perspectives. Collectively, the presentations highlighted both the vulnerabilities and the transformative opportunities of aquaculture as a key driver of food security, employment, and sustainable blue growth in the Asia-Pacific.

4.1. Key Presentations

4.1.1. Viet Nam – Background Research: Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific - Key findings

In the opening presentation of Session I, the presenter introduced the results of the APEC Background Research Paper prepared under Project OFWG 02 2023A, which provides a comprehensive overview of climate change impacts on aquaculture across the Asia–Pacific region and outlines adaptation and mitigation pathways consistent with APEC's sustainability and blue-economy goals. Aquaculture, he noted, has become one of the most dynamic food-producing sectors worldwide, supplying more than half of all aquatic food consumed globally. Within the APEC region, aquaculture accounts for over 90 percent of global output and plays a central role in ensuring food security, livelihoods, and trade. The sector provides employment and income for tens of millions of people, particularly in rural and coastal areas, and supports the economic growth of many member economies through exports and domestic consumption.

However, aquaculture is also among the sectors most affected by climate change. Rising air and water temperatures, ocean acidification, salinity intrusion, and sea-level rise have begun to alter aquatic ecosystems, disrupt production cycles, and increase the frequency of disease outbreaks. More frequent and intense storms and floods are damaging ponds, cages, hatcheries, and supply-chain infrastructure, while prolonged droughts and saltwater intrusion threaten freshwater systems. The cumulative impact of these changes is already visible in several APEC economies, where productivity losses in shrimp, salmon, tilapia, and mollusk farming have been recorded alongside degradation of coastal ecosystems. At the same time, aquaculture itself contributes to greenhouse-gas emissions through energy consumption, feed production, and nutrient discharge. He emphasized that aquaculture must therefore be viewed both as a victim and a contributor to climate change, requiring coordinated action on both adaptation and mitigation fronts.

The study conducted under this project mapped key climate-related vulnerabilities shared among APEC economies. These include temperature fluctuations that affect growth rates and disease resistance, ocean acidification that reduces calcification in shellfish, salinity intrusion in delta regions that threatens brackish and freshwater farms, and the increasing

frequency of harmful algal blooms (HABs) that cause massive economic losses. Small-scale and family-run aquaculture operations, which account for roughly 70 percent of total production, are particularly exposed due to limited access to finance, technology, and insurance. The research also highlighted the socio-economic dimension of vulnerability, noting that women and youth make up a large share of the aquaculture workforce yet often have less access to training and decision-making opportunities.

To respond to these challenges, the presenter presented a portfolio of adaptation and mitigation pathways that APEC economies can apply according to their environmental and institutional contexts. First, ecosystem-based approaches such as mangrove–shrimp, rice–fish, and integrated multi-trophic aquaculture (IMTA) promote resilience by restoring ecological balance and diversifying production. Second, technological innovation, including recirculating aquaculture systems (RAS), biofloc technology, digital monitoring, and IoT-based water-quality sensors, improves feed efficiency, energy use, and environmental control. Third, genetic improvement and selective breeding programs can enhance resistance to heat, salinity, and pathogens, supported by regional biobanks for genetic conservation. Fourth, low-carbon and circular models are emerging through nutrient recycling, feed substitution with algae and insect meal, and the use of renewable energy for aeration and water circulation. Finally, the presenter stressed the importance of institutional and financial innovation, such as the development of blue bonds, carbon-credit mechanisms, and index-based insurance products to protect small-scale farmers and incentivize green investment.

From a policy perspective, the research recommends that APEC economies mainstream aquaculture adaptation and mitigation into economy-wide climate strategies and NDCs (Nationally Determined Contributions), aligning them with the Bangkok Goals on the Bio-Circular-Green Economy. It also advocates the creation of an APEC Aquaculture Climate Resilience Platform, a shared digital space for data exchange, early warning, and technology transfer among member economies. Enhanced regional cooperation could accelerate joint research, pilot demonstrations, and capacity-building activities. The study also calls for a gender-responsive approach that empowers women and youth in aquaculture innovation and governance.

In conclusion, the presenter underscored that climate change, while posing severe challenges, also offers an opportunity to transform aquaculture into a climate-smart and sustainable engine of growth. He urged APEC economies to act collectively to build resilience and reduce emissions, integrating ecological stewardship, technological innovation, and inclusive governance. Three overarching messages were emphasized: first, to act regionally but adapt locally, tailoring measures to economy's conditions while sharing experiences across the region; second, to invest in innovation and inclusion, supporting MSMEs, women, and young entrepreneurs as change agents in the blue economy; and third, to position aquaculture as a pillar of climate action, contributing not only to food security and poverty reduction but also to carbon mitigation and ecosystem restoration.

This presentation set the analytical foundation for the subsequent workshop sessions, framing aquaculture as both a vulnerable and transformative sector within APEC's pursuit of a resilient, low-carbon, and inclusive Asia–Pacific.

4.1.2. Viet Nam – Roles of aquaculture in blue economy development in Viet Nam

In the second presentation of Session I, the presenter emphasized that aquaculture is not only a key component of Viet Nam's food system but also a cornerstone of its emerging blue economy, an economic model that integrates sustainability, technology, and inclusion to maximize the value of marine and aquatic resources. He noted that Viet Nam's aquaculture

sector currently contributes more than 50 percent of total seafood production, accounts for over 4 million jobs, and provides significant export revenue, positioning the economy among the world's top aquaculture producers.

He explained that the Government of Viet Nam has identified aquaculture as one of the priority sectors under its Marine Economy Development Strategy to 2030 and Vision 2045, which aims to build a "strong, sustainable, and prosperous ocean economy." In this vision, aquaculture plays a dual role, ensuring the economy's food security and driving green and digital transformation of the rural and coastal economy. The sector is undergoing rapid structural changes, with an expanding network of intensive shrimp and pangasius farms in the Mekong Delta, seaweed and mollusk cultivation in the northern and central coasts, and new offshore cage farming developments supported by both economy-wide and private investment.

Viet Nam's blue-economy approach prioritizes sustainability and resilience. the presenter highlighted ongoing initiatives to promote circular and eco-efficient production models, including the integration of aquaculture with mangroves, rice, and renewable energy systems. These models reduce environmental impacts while maintaining high productivity and livelihood benefits for local communities. The application of digital technologies, such as remote sensing, IoT-based water-quality monitoring, and AI-assisted feeding systems, has improved efficiency and traceability, aligning Viet Nam's practices with international standards and market requirements.

Another central focus of Viet Nam's strategy is inclusive growth. The presenter stressed that small-scale farmers, cooperatives, and women-led enterprises are increasingly being integrated into formal value chains through training, certification, and access to finance. The Government, through the Ministry of Agriculture and Environment (MAE), is implementing capacity-building programs and promoting partnerships with the private sector and research institutions to upgrade local production systems. These initiatives contribute to rural income diversification, gender empowerment, and sustainable livelihoods.

He underscored that public–private partnerships (PPPs) play a decisive role in scaling innovation and investment. Viet Nam's collaboration with domestic and international partners, including development agencies, universities, and companies, has accelerated the adoption of sustainable aquaculture standards such as ASC, BAP, and VietGAP. The economy's export competitiveness increasingly depends on compliance with environmental and social governance (ESG) criteria, traceability, and low-carbon certification. In this context, building resilience to climate change is both an ecological necessity and an economic opportunity to maintain market access and global leadership in seafood exports.

He also pointed out that while the sector's contribution to GDP and exports is substantial, challenges remain. Climate change, disease risks, input cost volatility, and fragmented governance continue to threaten sustainability. He called for enhanced coordination between economy-wide agencies, local governments, and private stakeholders to harmonize planning, research, and investment. Strengthening legal frameworks on spatial planning, environmental protection, and innovation incentives will be essential to achieve Viet Nam's blue-economy objectives.

In conclusion, the presenter reaffirmed that aquaculture is a strategic driver of Viet Nam's blue economy, enabling economic growth, climate resilience, and social inclusiveness. By adopting a "green and digital" transformation pathway, anchored in science, technology, and regional cooperation, Viet Nam aims to position its aquaculture sector as a model for sustainable development in the Asia–Pacific. He emphasized that this transformation cannot be achieved in isolation and requires continued support from APEC partners through knowledge exchange, investment facilitation, and joint initiatives under the Ocean and Fisheries Working Group (OFWG).

4.1.3. Viet Nam – Climate Change Impacts on Health and Disease in Aquaculture in Viet Nam: Challenges and Solutions for Adaptation and Mitigation

In the third presentation of Session I, presenter analyzed the growing impact of climate change on aquatic animal health and disease dynamics, emphasizing that climate variability has become one of the most serious challenges to sustainable aquaculture in Viet Nam and across the Asia–Pacific. He explained that rising water temperatures, changing rainfall patterns, and increasing salinity fluctuations are altering the delicate balance between hosts, pathogens, and the aquatic environment, creating conditions favorable for disease outbreaks. These disruptions threaten not only farm productivity but also food security and export competitiveness.

He presented evidence from recent studies showing that diseases such as Acute Hepatopancreatic Necrosis Disease (AHPND) and Early Mortality Syndrome (EMS) in shrimp, as well as Streptococcus and Aeromonas infections in fish, have become more frequent and severe under climate-stressed conditions. In many provinces of the Mekong Delta, temperature spikes and sudden salinity changes have coincided with massive shrimp mortality events, causing significant economic losses to smallholders. These incidents underscore the urgent need for integrated approaches that combine disease prevention, environmental management, and adaptive farming techniques.

To address these challenges, the presenter highlighted polyculture systems, the practice of culturing multiple compatible species in the same environment, as an effective and nature-based solution. By introducing species that occupy different ecological niches, polyculture enhances nutrient utilization, stabilizes the pond ecosystem, and reduces the proliferation of pathogens. For example, combining shrimp with tilapia or filter-feeding mollusks allows the latter to consume organic waste and algae, improving water quality and minimizing the accumulation of harmful bacteria. Trials conducted in the Mekong Delta have shown that polyculture systems can increase productivity by 20–30 percent, reduce chemical and antibiotic use, and improve profit margins while maintaining environmental balance.

He emphasized that the adoption of polyculture aligns closely with Viet Nam's broader policy on climate-smart and circular aquaculture. By improving ecosystem resilience, these models contribute to both adaptation and mitigation outcomes, reducing greenhouse-gas emissions, enhancing resource efficiency, and supporting biodiversity. However, he also cautioned that successful implementation requires strong biosecurity measures, consistent monitoring of water parameters, and technical training for farmers to manage interspecies interactions effectively.

He further called for the establishment of an economy-wide disease surveillance network linked to regional and international systems under APEC. Such a network would improve the early detection and reporting of transboundary aquatic diseases, facilitating coordinated responses and minimizing economic losses. Dr. Van also proposed that APEC economies collaborate in selective breeding programs to develop and share genetic strains of fish and shrimp resistant to thermal stress and pathogens, supported by the creation of regional biobanks and diagnostic laboratories.

Beyond technical measures, he underscored the importance of institutional support and farmer engagement. Small-scale producers, who make up the majority of Viet Nam's aquaculture sector, often lack access to reliable information, veterinary services, and insurance. Strengthening extension systems and farmer cooperatives, along with integrating women and youth in disease management programs, would enhance social resilience and knowledge dissemination.

In his concluding remarks, the presenter reaffirmed that the future of aquaculture health management under climate change lies in an ecosystem-based and preventive approach, rather than reactive disease control. Polyculture, he argued, embodies the principles of sustainability, efficiency, and adaptation that APEC promotes under its Blue Economy and Bio-Circular-Green frameworks. By reducing vulnerability, improving resource use, and diversifying income, this model not only mitigates risks but also strengthens the long-term resilience of aquaculture communities in the Asia–Pacific.

4.1.4. Indonesia – Aligning aquaculture adaptation measures with APEC's food security and blue economy agendas

The presentation focused on Indonesia's Blue Economy 2045 Vision, a long-term economy-wide strategy that integrates sustainable resource use, climate resilience, and inclusive growth. The presenter emphasized that as one of the world's largest archipelagic economies with vast marine resources, Indonesia considers aquaculture a cornerstone of its blue economy and a critical pathway to achieving food security, poverty reduction, and environmental sustainability. The government's target is to increase aquaculture production by 70 percent by 2045 while minimizing environmental degradation and improving socio-economic equity across coastal communities.

The presenter outlined that Indonesia's aquaculture sector is diverse and rapidly growing, producing shrimp, tilapia, milkfish, seaweed, grouper, and lobster for both domestic and export markets. However, the sector faces growing challenges from climate change, including rising sea surface temperatures, increased frequency of flooding and drought, and the spread of aquatic diseases. These issues threaten production stability, rural employment, and export competitiveness. In response, Indonesia has developed a comprehensive policy framework that combines adaptation and mitigation actions to promote climate-smart aquaculture (CSA) and strengthen ecosystem resilience.

At the heart of this framework is the Aquaculture Village Program, an economy-wide initiative that promotes community-based aquaculture clusters designed to balance production, environmental protection, and social inclusion. Each aquaculture village integrates local knowledge with modern technology to improve productivity, reduce waste, and enhance adaptive capacity. The program encourages ecosystem-based management, supporting mangrove rehabilitation, polyculture systems, and water-quality monitoring. It also provides training, certification, and financial access to farmers, particularly women and youth, to ensure equitable participation in the blue economy.

The presenter explained that Indonesia is investing heavily in digital transformation through the development of the Digital Climate-Smart Aquaculture Platform (DCAP). This platform integrates real-time environmental monitoring, remote sensing, and predictive analytics to provide farmers with early warnings of temperature anomalies, harmful algal blooms, and disease risks. Pilot programs using this platform in shrimp-farming regions have demonstrated significant improvements in feed efficiency, survival rates, and profitability. The government aims to scale the system to cover all major aquaculture provinces by 2030.

Feed innovation and circular economy principles are also key pillars of Indonesia's approach. The Ministry of Marine Affairs and Fisheries has promoted the use of alternative feed ingredients, such as microalgae and insect protein, to reduce dependence on fishmeal and lower the sector's carbon footprint. Waste from aquaculture and fish processing is being repurposed into organic fertilizer and bioenergy, creating additional income streams for small enterprises. These efforts align with the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, ensuring that economic expansion occurs alongside environmental restoration.

To ensure long-term sustainability, Indonesia is pursuing low-emission aquaculture development zones, integrating renewable energy into production systems and applying green certification standards. The government is also expanding climate finance through Blue Carbon Partnerships and cooperation with multilateral development banks to support adaptation and innovation at scale.

In his concluding remarks, the presenter emphasized that regional collaboration is critical for achieving the goals of the Blue Economy 2045 Vision. He called for APEC economies to strengthen cooperation on technology transfer, joint research, and policy harmonization in areas such as digital aquaculture management, low-carbon feed production, and climate insurance for small-scale farmers. Indonesia's experience demonstrates that with the right combination of community empowerment, innovation, and regional partnerships, aquaculture can become both a climate solution and a driver of sustainable blue growth.

4.1.5. Chile – Strengthening the Resilience of Chile's Aquaculture Sector in the Face of Climate Change

The presenter presented Chile's Sectoral Adaptation Plan for Fisheries and Aquaculture (2025–2029), developed in accordance with the economy's Law on Climate Change (2022) and aligned with Chile's Nationally Determined Contributions (NDCs). He explained that Chile is among the world's leading aquaculture producers, particularly of salmon, mussels, and seaweed, but its coastal ecosystems are increasingly vulnerable to climate change. Rising sea temperatures, shifts in ocean currents, acidification, and harmful algal blooms (HABs) have already caused severe environmental and economic losses in recent years. These risks threaten not only productivity but also the livelihoods of thousands of workers in southern Chile's aquaculture zones.

To address these challenges, the Government of Chile has adopted a forward-looking and evidence-based adaptation framework grounded in science, spatial analysis, and stakeholder participation. Central to this effort is the Atlas de Riesgo Climático (ARCLIM), a digital tool that compiles and visualizes large-scale oceanographic, climatic, and socio-economic data. ARCLIM enables decision-makers to identify the most vulnerable production areas, model future scenarios, and plan risk reduction measures at both the economy-wide and local levels. The Atlas incorporates climate projections for temperature, pH, oxygen concentration, and extreme weather frequency, along with socio-economic indicators such as employment dependence and infrastructure exposure.

The presenter emphasized that ARCLIM is not only a research product but a policy instrument guiding investment, monitoring, and spatial planning for sustainable aquaculture. Its outputs are used to prioritize adaptation actions, allocate resources, and inform the private sector about long-term risks. The tool has already influenced zoning decisions for aquaculture concessions and helped shape the Sectoral Adaptation Plan for Fisheries and Aquaculture (2025–2029), which contains 11 strategic measures and 29 concrete actions. These include the development of ecosystem-based management plans, reinforcement of biosecurity and early-warning systems, conservation of genetic resources, rehabilitation of degraded habitats, and strengthening of insurance mechanisms for climate-induced losses.

A notable feature of Chile's adaptation plan is its emphasis on multi-stakeholder participation. Local communities, industry representatives, scientists, and civil society organizations contributed to designing and validating the proposed measures. This participatory approach ensures that adaptation is socially inclusive, technically sound, and economically feasible. The plan also integrates gender equality and community empowerment as cross-cutting principles, recognizing that women and small-scale

producers are often the most affected by climate variability but can play transformative roles in implementing adaptive practices.

He stressed that Chile's approach embodies three key dimensions: science-based policymaking, ecosystem resilience, and social inclusion. He underscored that climate adaptation in aquaculture cannot rely solely on technological fixes but must be embedded within long-term governance reforms and regional cooperation frameworks. Through active engagement in APEC's Ocean and Fisheries Working Group (OFWG), Chile aims to share its methodological experience and collaborate on developing region-wide risk mapping, data-sharing protocols, and blue-finance instruments to support adaptation investments.

In closing, he emphasized that Chile's Climate Risk Atlas and the 2025–2029 Adaptation Plan together provide a practical model for other APEC economies: combining spatial intelligence, participatory planning, and policy coherence to strengthen resilience in fisheries and aquaculture. This integrated approach demonstrates how an economy with complex marine ecosystems can balance economic competitiveness with environmental stewardship, contributing to the collective goal of a climate-resilient and sustainable aquaculture sector across the Asia–Pacific.

4.1.6. Malaysia – Malaysia's Policies and Strategies to Address Climate Change Challenges in Aquaculture

In her presentation, the presenter outlined Malaysia's Agro-Food Policy 2021–2030 (NAP 2.0), which provides a comprehensive roadmap for ensuring sustainable, resilient, and inclusive food systems in the face of climate change. She explained that aquaculture has become one of the economy's fastest-growing and most strategic agricultural sub-sectors, contributing significantly to domestic consumption, export earnings, and rural livelihoods. However, the sector is increasingly exposed to climate-related risks such as temperature rise, drought, flooding, salinity intrusion, and disease outbreaks, threats that could undermine economy-wide food security and the government's long-term growth objectives.

The NAP 2.0, launched by the Ministry of Agriculture and Food Security, integrates climate adaptation and environmental sustainability as cross-cutting priorities. Its vision is to transform Malaysia's agri-food sector into a high-tech, high-income, and low-carbon industry that enhances productivity while maintaining ecological balance. Within this framework, aquaculture is identified as a key pillar for sustainable growth and a major contributor to economy-wide food sovereignty. Ms. Yahaya emphasized that the policy explicitly links aquaculture development to Malaysia's Nationally Determined Contributions (NDCs) under the Paris Agreement and to the economy's Twelfth Malaysia Plan (2021–2025), which calls for strengthening resilience to climate and market shocks.

To operationalize these commitments, Malaysia is implementing a suite of climate adaptation measures focused on digital transformation, green technology, and community empowerment. The Department of Fisheries has developed a National Aquaculture Data Centre (NADC) to centralize information on water quality, disease outbreaks, and production performance, enabling evidence-based planning and rapid response to environmental changes. Malaysia is also expanding the adoption of Recirculating Aquaculture Systems (RAS) and biosecure hatcheries, which allow for more efficient water use and better control of disease and temperature fluctuations.

Another important component of Malaysia's adaptation strategy is the promotion of low-emission and circular aquaculture practices. Farmers are being encouraged to adopt renewable energy systems, waste recycling, and green certification schemes to reduce carbon footprints. Pilot projects integrating solar power into shrimp farms and using probiotic-based feeds have demonstrated both environmental and economic benefits.

These initiatives are supported through public–private partnerships that mobilize investment from domestic enterprises and international collaborators.

The presenter also highlighted Malaysia's efforts to foster inclusive and community-based adaptation. Training and capacity-building programs have been introduced to support small-scale farmers, cooperatives, and women entrepreneurs in adopting digital tools and sustainable production methods. The Smart Aquaculture Programme, for example, provides farmers with mobile applications to monitor dissolved oxygen, pH, and temperature levels in real time, improving decision-making and reducing losses. The government's extension services are being restructured to deliver on-site technical support, ensuring that the benefits of innovation reach vulnerable groups.

She acknowledged that while Malaysia has made substantial progress, several challenges remain. These include high initial investment costs for advanced technologies, limited awareness of climate risks among smallholders, and the need for more robust coordination between government agencies. To address these gaps, the policy emphasizes integrated planning and multi-stakeholder collaboration, involving ministries, universities, private companies, and civil society organizations.

In conclusion, the presenter reaffirmed that Malaysia's Agro-Food Policy 2021–2030 represents a transformative agenda for achieving climate-smart, sustainable, and inclusive aquaculture. By aligning economy-wide objectives with the APEC Putrajaya Vision 2040 and the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, Malaysia is positioning itself as a regional leader in digital and low-carbon aquaculture innovation. She emphasized that continued cooperation under APEC's Ocean and Fisheries Working Group (OFWG) will be crucial for sharing knowledge, scaling technologies, and mobilizing finance to support resilient aquaculture systems across the Asia–Pacific.

4.1.7. New Zealand – Developing regenerative ocean farming ventures in New Zealand

The presenter introduced New Zealand's pioneering experience in regenerative ocean farming, a model that merges commercial aquaculture with ecosystem restoration and climate mitigation. His presentation underscored that aquaculture can serve as a powerful instrument for both environmental recovery and sustainable economic growth when guided by science, innovation, and community partnership.

He began by describing the concept of regenerative aquaculture as an evolution beyond traditional sustainability. Instead of merely reducing environmental harm, it actively restores ocean health and biodiversity while providing livelihoods and food. New Zealand's coastal ecosystems, once abundant in kelp forests, shellfish beds, and coral-like biogenic structures, have been degraded by overfishing, sedimentation, and warming seas. Regenerative farming seeks to reverse these losses through integrated, nature-based solutions that enhance the ocean's capacity to sequester carbon, filter water, and support marine life.

The presenter presented two flagship initiatives: GreenWave Aotearoa and Save Our Scallops, both led by EnviroStrat Ltd in partnership with local iwi (Indigenous communities), scientists, and impact investors. GreenWave Aotearoa promotes co-cultivation of seaweed and shellfish within Integrated Multi-Trophic Aquaculture (IMTA) systems. By co-locating species that absorb nutrients and carbon at different levels of the marine food web, these farms help to reduce ocean acidification, improve water quality, and restore ecological balance. The project also quantifies blue-carbon sequestration, generating scientifically verified data that can underpin future carbon-credit markets.

The Save Our Scallops program, meanwhile, focuses on restoring New Zealand's depleted scallop beds through a combination of hatchery-based stock enhancement and ecosystem management. The project employs adaptive farming techniques, including temperature-resilient broodstock breeding, biobank development, and strategic site selection guided by environmental modelling. Farmed scallops are released to reseed wild beds, simultaneously supporting ecosystem recovery and small-scale livelihoods. This approach demonstrates how aquaculture can move from extraction toward regeneration, creating positive feedback loops between production and conservation.

The presenter explained that climate change has intensified the urgency of such approaches. Rising sea temperatures, increased sediment runoff, and periodic marine heatwaves have stressed coastal ecosystems and jeopardized aquaculture productivity. By developing offshore aquaculture systems located in cooler, high-energy waters, New Zealand is adapting its industry to changing environmental conditions while diversifying economic opportunities for coastal communities. Offshore systems are more resilient to storms and biofouling and can accommodate multi-species cultivation, including kelp, mussels, and oysters, which together provide valuable ecosystem services.

A major focus of his presentation was on innovation and finance. The presenter highlighted that regenerative aquaculture requires blended funding models that combine public support, private investment, and impact-finance instruments. EnviroStrat has mobilized investments through blue-economy ventures that measure both ecological and financial returns, ensuring accountability to investors and communities alike. He noted that the emerging blue-carbon credit framework offers a significant opportunity for APEC economies to attract investment in nature-based aquaculture and coastal restoration.

The New Zealand experience also illustrates the importance of inclusive governance. Indigenous Māori communities play a central role as co-owners and stewards of regenerative farming sites, embedding traditional knowledge within contemporary science. This collaboration ensures that aquaculture expansion respects cultural values and delivers tangible social benefits, including job creation, food supply, and youth engagement in marine careers.

The presenter emphasized that regenerative aquaculture aligns directly with the APEC Putrajaya Vision 2040 and the Bangkok Goals on the Bio-Circular-Green Economy by combining low-carbon innovation with ecosystem regeneration and inclusive growth. He called for regional collaboration to replicate these models across the Asia–Pacific, particularly in economies with similar coastal conditions such as Chile; Indonesia; the Philippines; and Viet Nam. Joint research on seaweed genetics, carbon accounting, and ecosystem-service valuation could accelerate the development of a regional Blue Carbon Partnership under the APEC Ocean and Fisheries Working Group (OFWG).

In closing, the presenter concluded that regenerative ocean farming demonstrates how aquaculture can evolve from a sector perceived as environmentally intensive to one that actively heals ecosystems while feeding communities. Through technology, finance, and collaboration, APEC economies can transform aquaculture into a cornerstone of climate adaptation and ocean recovery, proving that economic prosperity and environmental restoration can, and must, advance together in the twenty-first-century blue economy.

4.2. Discussion and Key issues

The discussions following the seven technical presentations in Session I revealed both the diversity of challenges facing aquaculture across the Asia–Pacific and the convergence of priorities among APEC economies in responding to climate change. Participants agreed that the sector occupies a pivotal position in the region's food systems, providing nutrition, employment, and export income, yet remains highly exposed to environmental stressors.

Climate change has become an undeniable driver of transformation, pushing economies to reimagine aquaculture as a climate-smart, inclusive, and innovation-led industry.

A central theme emerging from the session was the recognition of shared vulnerabilities. Rising water temperatures, salinity fluctuations, ocean acidification, and the increasing frequency of extreme weather events were reported across all economies, affecting productivity, farm infrastructure, and ecosystem health. Disease outbreaks linked to environmental changes, such as shrimp diseases in Southeast Asia, salmon mortality in Chile, and HAB events in temperate zones, were identified as common threats with transboundary implications. Participants emphasized the urgent need to strengthen regional surveillance networks, early-warning systems, and coordinated biosecurity measures through APEC mechanisms.

At the same time, the session showcased a wide range of adaptive and regenerative solutions being developed across economies. Indonesia; Malaysia; and Viet Nam demonstrated the potential of ecosystem-based and circular models, such as mangrove-shrimp integration, rice-fish systems, and IMTA, to enhance resilience while maintaining productivity. Chile's Climate Risk Atlas (ARCLIM) illustrated how spatial and climate modelling tools can support science-based policymaking, while New Zealand's regenerative ocean farming approach showed how aquaculture can actively restore marine ecosystems and contribute to blue-carbon sequestration. Collectively, these experiences highlighted a portfolio approach to climate adaptation that combines traditional knowledge, ecosystem restoration, and technological innovation.

Participants also emphasized the growing importance of digital transformation and technology adoption. Economies such as Indonesia; Malaysia; and Singapore are leveraging IoT sensors, remote sensing, and big-data platforms to monitor water quality, predict disease risks, and optimize feed management. Such technologies improve resource efficiency and reduce emissions, but they also require strong data governance, interoperability, and access for smallholders. Several delegates proposed that APEC establish a Regional Aquaculture Data and Innovation Platform to facilitate the sharing of real-time environmental information, research outputs, and digital tools.

Another recurrent theme was the critical role of finance and inclusion. Many small-scale and family-run aquaculture enterprises lack access to affordable credit, insurance, and investment needed to adopt climate-smart technologies. Delegates called for the expansion of blue finance instruments, including blue bonds, climate-adaptation funds, and index-based insurance, to support innovation at the grassroots level. Public–private partnerships and blended financing were viewed as essential mechanisms for scaling up climate-resilient models and fostering entrepreneurship among women and youth.

The session also reaffirmed the need for policy coherence and governance reform. Participants noted that aquaculture policies in many economies remain fragmented across ministries of fisheries, environment, and trade, leading to gaps in implementation and monitoring. Integrating aquaculture into Nationally Determined Contributions (NDCs), coastal management frameworks, and biodiversity strategies would ensure greater consistency with global and regional commitments. APEC's Ocean and Fisheries Working Group (OFWG) was encouraged to play a stronger role in harmonizing guidelines, promoting cross-economy collaboration, and linking science with policy.

Gender equality and community participation were highlighted as indispensable components of resilience. Women constitute a significant share of the aquaculture workforce, especially in post-harvest and processing activities, yet often face barriers to training, finance, and leadership. Inclusive governance and capacity-building programs, such as Malaysia's Smart Aquaculture Programme and Indonesia's Aquaculture Village

initiative, demonstrate effective pathways for empowering women and smallholders while strengthening local adaptation capacity.

In summary, the discussions in Session I underscored that while the impacts of climate change on aquaculture are profound and widespread, they also present a unique opportunity for innovation, cooperation, and transformation. The collective experience of APEC economies shows that by integrating ecosystem-based models, technological advances, and inclusive financing, the region can build an aquaculture sector that is not only resilient to climate risks but also contributes actively to carbon mitigation, biodiversity conservation, and equitable blue-economy growth. This session laid the foundation for subsequent discussions on best practices (Session II) and regional cooperation mechanisms (Session III), advancing APEC's shared vision of a sustainable and climate-resilient aquaculture future.

V. SESSION II – BEST PRACTICES IN CLIMATE ADAPTATION AND MITIGATION

Session II focused on practical experiences and innovations in climate adaptation and mitigation across APEC economies. The session demonstrated how governments, research institutions, and private companies are leveraging technology, ecosystem restoration, and inclusive finance to strengthen aquaculture resilience. Presentations from China; New Zealand; Singapore; Chinese Taipei; Thailand; and Viet Nam provided a diverse portfolio of solutions, from big-data platforms and IoT-based monitoring systems to regenerative aquaculture and low-carbon biotechnologies. The session was moderated by the delegate from Viet Nam.

5.1. Key Presentations

5.1.1. China – Sea Level Rise Adaptation: NMDIS's efforts in monitoring, assessment, and public service

The presenter presented China's efforts in developing a comprehensive system to monitor, assess, and respond to the impacts of climate change, particularly sea-level rise, on coastal ecosystems and aquaculture. She explained that the National Marine Data and Information Service (NMDIS) operates as China's central agency for marine environmental observation data collection and analysis, supporting economy-wide policy formulation and providing data-driven services to the fisheries and aquaculture sectors.

Over the past decade, NMDIS has built a domestic 3D ocean observation system and a cumulative database exceeding 300 billion records. These include real-time measurements of sea temperature, salinity, currents, sea-level variation, and ocean chemistry, combined with satellite remote-sensing data. The system enables multi-scale climate analysis, ranging from daily forecasts to multi-decadal projections, thereby providing a scientific foundation for risk management and adaptation planning.

The presenter introduced two of NMDIS's flagship annual publications: the China Sea Level Bulletin and the Blue Book on Marine Climate Change in China, which synthesize economy-wide data on ocean conditions and trends. These publications serve as authoritative references for policymakers, researchers, and coastal planners, providing timely insights into the physical and ecological impacts of climate change. The data reveal that China's coastal sea level has risen at an average rate of 3.5 millimeters per year over the past four decades, slightly higher than the global average, with pronounced implications for low-lying aquaculture zones such as the Yangtze Delta, Beibu Gulf, and Bohai Bay.

To enhance predictive capability, NMDIS has developed the China Global Ocean Fusion Dataset (CGOF 1.0), a high-resolution dataset powered by AI and advanced computing

infrastructure. CGOF 1.0 integrates multi-source data and numerical models to generate three-dimensional data of 10 Essential Ocean Variables. These data and information underpin early-warning services for coastal flooding, storm surges, and harmful algal blooms (HABs), all of which directly affect aquaculture productivity and biosecurity.

The presenter emphasized that NMDIS's marine big-data infrastructure not only enhances economy-wide resilience but also holds immense value for regional cooperation. Climate change impacts on the marine environment are inherently transboundary, influencing shared ecosystems, migration patterns, and disease dynamics across APEC economies. She noted that the gaps in data interoperability, early-warning coverage, and capacity building across the region limit the ability of economies to coordinate responses to extreme events and long-term oceanic changes.

In response, she proposed to jointly build an APEC Marine Climate Change Adaptation and Knowledge Platform under the Ocean and Fisheries Working Group (OFWG). This platform would connect APEC economies through a shared data interface, standardized monitoring protocols, and collaborative research projects. It would facilitate:

1. Data sharing and interoperability, linking economy-wide ocean observation networks and enabling comparative analysis of climate trends;
2. Joint scientific research and modelling, supporting region-wide assessments of sea-level rise, ocean warming, and acidification;
3. Capacity-building and technical training, focusing on data analytics, forecasting, and decision-support applications; and
4. Policy dialogue and best-practice exchange, helping member economies integrate climate information into aquaculture and coastal management planning.

The presenter highlighted that this proposed APEC platform aligns closely with the APEC Putrajaya Vision 2040, the Bangkok Goals on the Bio-Circular-Green Economy, and the UN Sustainable Development Goals (SDGs 13 and 14) by promoting innovation, environmental stewardship, and inclusive growth. It also complements existing APEC initiatives on marine debris management, ecosystem-based coastal planning, and digital transformation.

In conclusion, she underlined that data-driven collaboration is fundamental to building climate-resilient aquaculture and coastal economies. She invited APEC economies to join in exploring partnerships for the design and operation of the proposed platform, sharing lessons learned from NMDIS's experience, and contributing to a collective knowledge base for the Asia–Pacific. By transforming data into actionable insights, the region can better anticipate climate risks, safeguard livelihoods, and advance sustainable blue-economy development for future generations.

5.1.2. Singapore – Aquaculture Sensing Network

In her presentation, the presenter introduced Singapore's experience in integrating digital technologies for sustainable intensification and aquaculture management through the Aquaculture Sensing Network (ASN), an internet-based platform designed to strengthen early warning, enhance productivity, and improve climate resilience in the economy's aquaculture sector. As a small, densely populated island with limited land and water resources, Singapore has prioritized innovation and technology to increase local food production for as part of its food security strategies. Aquaculture plays a vital role in achieving this objective, particularly as climate variability, sea-level rise, and urban development pressures increase the complexity of coastal resource management.

The Aquaculture Sensing Network (ASN) was developed and managed by the Singapore Food Agency (SFA). This project involved close collaboration between agencies, technology companies, and local farmers. The ASN connects a series of real-time monitoring stations strategically located across marine farming areas, to capture any upstream environmental trends. Each ASN node is equipped with multi-parameter sensors that measure dissolved oxygen, temperature, pH, salinity, turbidity, and chlorophyll-a at five-minute intervals. These data are transmitted wirelessly to a central cloud-based system, where they are analyzed to detect anomalies and generate warnings. When critical thresholds are exceeded, such as low oxygen levels, alerts are sent to enable rapid intervention to prevent fish mortality and minimize losses. The ASN model demonstrates how digital technologies can help to provide for early warning, to assist aquaculture players in their operations.

The presenter explained that the ASN is one of the components of the Singapore Aquaculture Plan that was launched in 2024, which seeks to transition from traditional, labor-intensive practices towards higher intensity and data driven aquaculture system. The platform's data analytics capabilities enable the identification of long-term environmental trends, seasonal patterns, and potential early indicators of harmful algal blooms (HABs). The system also supports Singapore's vision for sustainable aquaculture practices to monitor for environmental changes in the farming environment, and in turn improve farming practices. During low dissolved oxygen events, SFA could use the data and alerts sent by the ASN to inform farms to take early action, such as providing aeration to mitigate the situation. In the long run, it also supports adaptive management by allowing farmers and regulators to make data-based decisions on feeding rates, stocking densities, and harvest planning. By providing a shared information ecosystem, the ASN helps to provide a verified information source to farms, contributing to a more collaborative, resilient aquaculture sector.

In conclusion, the presenter shared that the ASN is an example of how Singapore is demonstrating the use of sensors and digital platforms to facilitate the adoption of data-driven, adaptive, and sustainable aquaculture.

5.1.3. Thailand – Advancing Adaptation and Mitigation of Climate Change Impacts through Thailand's Leadership Role in Sustainable Aquaculture

The presenter presented Thailand's Freshwater Aquaculture Development Plan 2022–2027, an economy-wide roadmap designed to promote sustainable, climate-resilient, and inclusive aquaculture through technological innovation and ecosystem-based management. He emphasized that the plan represents a core element of Thailand's broader Bio-Circular-Green (BCG) Economy Model, which seeks to balance productivity and environmental integrity while improving the livelihoods of rural communities.

The freshwater aquaculture sector in Thailand contributes significantly to economy-wide food security and export earnings, producing key species such as Nile tilapia, catfish, barbs, and freshwater prawns. However, the sector faces mounting challenges from climate variability, water scarcity, and disease outbreaks. Changes in temperature and rainfall patterns have affected water availability, pond stability, and breeding success, while increased nutrient loading has led to eutrophication in several production zones. He noted that these challenges have underscored the need for an integrated and adaptive strategy combining innovation, governance reform, and farmer participation.

Thailand's Freshwater Aquaculture Development Plan 2022–2027 is structured around four strategic pillars. The first focuses on climate-tolerant species and genetic improvement, promoting selective breeding programs for resilient strains of tilapia, barbs, and hybrid

catfish capable of withstanding temperature and salinity fluctuations. The second centers on Recirculating Aquaculture Systems (RAS), which enable efficient water use, energy conservation, and improved biosecurity. These systems have been successfully piloted in northern and central provinces, reducing water consumption by up to 70 percent while maintaining stable yields.

The third pillar advances Integrated Multi-Trophic Aquaculture (IMTA), combining species with complementary ecological roles to recycle nutrients and reduce waste. Thailand has introduced IMTA models that pair filter feeders (e.g., mussels or clams) with finfish or aquatic plants to maintain ecological balance and enhance farm profitability. The final pillar emphasizes capacity building and service delivery, particularly through the deployment of mobile hatchery units, a distinctive innovation of Thailand's program. These mobile units bring seed production, training, and extension services directly to remote farming communities, ensuring that high-quality fingerlings and technical guidance are accessible economy-wide.

He highlighted that the plan also integrates digital tools and data management systems to support decision-making and traceability. The Department of Fisheries is developing a centralized database linking hatcheries, farms, and markets, allowing for better monitoring of production trends and disease outbreaks. Moreover, Thailand is expanding partnerships with universities and private-sector companies to promote research and the commercialization of new technologies, such as low-cost water sensors and climate forecasting applications.

Another major focus of the plan is inclusive development. The government aims to empower smallholder farmers and community cooperatives, particularly those led by women and youth, through microfinance programs, cooperative marketing schemes, and green certification initiatives. These mechanisms help ensure that the benefits of innovation and market access are distributed equitably, supporting social resilience alongside environmental and economic goals.

The presenter underscored that successful adaptation requires not only technology but also education and leadership. The Department of Fisheries has expanded its network of regional training centers to enhance technical skills, promote sustainable feed management, and strengthen farmers' understanding of climate risks. Thailand's extension strategy now prioritizes hands-on learning, peer-to-peer mentorship, and continuous professional development.

In conclusion, the presenter reaffirmed Thailand's commitment to advancing aquaculture as a climate-resilient and low-carbon growth sector consistent with APEC's priorities and the Bangkok Goals on the Bio-Circular-Green (BCG) Economy. The Freshwater Aquaculture Development Plan 2022–2027 demonstrates how economy-wide strategies can integrate ecosystem-based practices, high technology, and inclusive community engagement into a single coherent framework. He emphasized that regional cooperation under APEC's Ocean and Fisheries Working Group (OFWG) will be vital for sharing knowledge, harmonizing standards, and scaling up innovation across the Asia–Pacific.

5.1.4. Viet Nam – Optimization of Nutritional Program Solution to Reduce Production Costs and Environmental Impacts of Shrimp Farming through the GROFARM™ Model

The presenter introduced the GROFARM™ model, an innovative aquaculture management system developed by Grobest Viet Nam to enhance production efficiency, improve water quality, and reduce the environmental footprint of shrimp farming. His presentation illustrated how private-sector innovation can play a transformative role in achieving climate

adaptation and mitigation goals, while simultaneously strengthening economic performance and farmer livelihoods.

Grobest Viet Nam, a major regional feed and aquaculture technology company, developed the GROFARM™ program to respond to three interrelated challenges: the rising cost of feed and inputs, increasing vulnerability to disease and environmental stress, and the urgent need to reduce carbon and nutrient emissions. The model combines precision feeding technology, smart farm design, and AI-based water-quality monitoring to optimize the entire production cycle, from pond preparation and stocking to harvest and waste management.

The presenter explained that GROFARM™ is built on three core principles: efficiency, sustainability, and traceability. By integrating advanced sensors and data analytics, farmers can monitor key water parameters in real time and adjust feed and aeration accordingly. The system's data platform analyzes feeding behavior, oxygen levels, and temperature to determine the optimal feeding schedule, reducing waste and improving feed conversion ratios (FCR). As a result, participating farms have recorded a 7 percent reduction in FCR, a 23 percent decrease in nitrogen and phosphorus discharge, and a 22 percent reduction in total water use. These efficiency gains translate into lower operating costs and improved environmental outcomes.

At the production level, the GROFARM™ model has demonstrated remarkable economic and ecological results. Participating shrimp farms reported an average 27 percent increase in yield and a 21 percent higher return on investment (ROI) compared to conventional systems. Additionally, improved biosecurity and pond management have reduced disease incidence, minimizing the need for antibiotics and chemical treatments. These outcomes contribute directly to Viet Nam's economy-wide priorities on antibiotic-free aquaculture, resource efficiency, and low-carbon growth as outlined in the Climate Change Adaptation Plan 2021–2030.

The presenter emphasized that the success of GROFARM™ is not limited to technology, it depends equally on capacity building and farmer partnership. The company provides comprehensive technical training and on-site advisory services through its GROFARM™ Partner Network, which connects experts, farmers, and suppliers across multiple provinces. This participatory model ensures that farmers can effectively apply data-driven management tools while understanding the environmental rationale behind them. Many small and medium-scale producers have adopted the system, achieving both cost savings and compliance with sustainability standards such as the Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP).

Beyond farm-level outcomes, the GROFARM™ model supports broader climate mitigation objectives by reducing greenhouse-gas emissions from energy and feed use. The optimization of feed and aeration lowers electricity consumption, while reduced water exchange minimizes the discharge of organic matter and methane from pond sediments. Preliminary assessments suggest that each hectare of GROFARM™ ponds can reduce emissions by several tons of CO_2-equivalent per production cycle compared with traditional practices. The company is now collaborating with economy-wide research institutions to quantify these impacts and explore integration with blue-carbon crediting schemes.

The presenter also stressed the importance of public–private collaboration in scaling up low-carbon innovation. He highlighted that the private sector has a unique capacity to develop, pilot, and deploy technologies rapidly, while governments play an essential role in establishing supportive policies, infrastructure, and financing mechanisms. Through partnerships with the Ministry of Agriculture and Environment (MAE) and local cooperatives, Grobest is expanding the GROFARM™ program economy-wide and exploring its adaptation for other species such as pangasius and tilapia.

In conclusion, the presenter affirmed that Viet Nam's GROFARM™ model demonstrates how technological innovation and business leadership can drive tangible progress toward sustainable and climate-smart aquaculture. By reducing costs, emissions, and disease risks simultaneously, the program delivers triple dividends, economic profitability, environmental protection, and social inclusion. He encouraged APEC economies to replicate similar private-sector partnership models and integrate them into regional initiatives under the APEC Ocean and Fisheries Working Group (OFWG), supporting the collective goal of a low-carbon and resilient aquaculture industry across the Asia–Pacific.

5.1.5. New Zealand – Regenerative aquaculture in New Zealand: adapting to a changing climate

The presenter presented New Zealand's innovative experience in regenerative aquaculture, emphasizing the integration of commercial production with ecosystem restoration and climate adaptation. He explained that New Zealand's aquaculture industry, centered on mussels, oysters, and seaweed, faces increasing environmental pressures from ocean warming, acidification, sedimentation, and periodic marine heatwaves. Rather than focusing solely on mitigation, the economy's emerging strategy is to transform aquaculture into a regenerative, nature-positive activity that restores marine ecosystems while supporting livelihoods and economic growth.

At the forefront of this approach are a series of regenerative ventures led by EnviroStrat Ltd, including GreenWave Aotearoa and Save Our Scallops. These initiatives apply Integrated Multi-Trophic Aquaculture (IMTA) systems that co-cultivate complementary species such as kelp and shellfish to recycle nutrients, enhance biodiversity, and absorb carbon. In IMTA farms, seaweed removes excess nutrients from finfish and shellfish operations, improving water quality and mitigating eutrophication. The cultivation of seaweed also contributes to blue-carbon sequestration, positioning regenerative aquaculture as a contributor to economy-wide climate targets and coastal ecosystem recovery.

The presenter highlighted that these ventures are underpinned by the establishment of biobanks for resilient broodstock, which preserve genetic diversity and provide seed for climate-tolerant strains of mussels, oysters, and macroalgae. The biobanks enable selective breeding for temperature and pH resilience, reducing vulnerability to ocean acidification and supporting stock restoration programs in degraded habitats. This genetic safeguarding strategy ensures the continuity of key aquaculture species while strengthening the adaptive capacity of coastal ecosystems.

An equally important dimension of New Zealand's model is the linkage between impact investment and ecosystem outcomes. EnviroStrat has mobilized private capital through blue-economy funds and blended-finance partnerships that reward both environmental performance and financial returns. By quantifying carbon capture, water-filtration benefits, and biodiversity restoration, regenerative ventures attract investors interested in blue-carbon credits and sustainable-finance products. This approach demonstrates how private finance can complement public policy in scaling climate-positive aquaculture models.

The presenter also stressed the role of inclusive governance and Indigenous partnership. Māori communities are co-owners and active managers of many regenerative farms, contributing traditional ecological knowledge and ensuring cultural and social values are reflected in project design. These collaborations create employment, strengthen food sovereignty, and embed stewardship ethics in the aquaculture value chain.

He explained that regenerative aquaculture directly supports the goals of the APEC Putrajaya Vision 2040 and the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, demonstrating how innovation can reconcile productivity, climate mitigation, and biodiversity

enhancement. By advancing IMTA systems, genetic biobanks, and blue-finance mechanisms, New Zealand is positioning itself as a regional hub for science-based, low-carbon aquaculture solutions.

In closing, the presenter emphasized that the principles of regenerative aquaculture are widely transferable across APEC economies, particularly those with similar coastal conditions such as Chile; Indonesia; the Philippines; and Viet Nam. He encouraged APEC members to collaborate on developing regional standards for blue-carbon accounting, co-invest in regenerative pilots, and integrate such models into future APEC OFWG initiatives. By shifting from extractive production to ecosystem restoration, aquaculture can become a driver of climate resilience and sustainable prosperity for the entire Asia–Pacific region.

5.1.6. Chinese Taipei – The sustainable management of low-carbon aquaculture applications onto the disease control of fourfinger threadfin

The presenter shared Chinese Taipei's innovative achievements in developing low-carbon aquaculture systems that simultaneously improve productivity, enhance animal health, and mitigate environmental impacts. His presentation focused on the application of Complex Photosynthetic Bacteria (CPSB) technology in the culture of four-finger threadfin (Eleutheronema tetradactylum), a high-value marine species widely farmed along Chinese Taipei's southern coast.

He explained that climate change has increasingly disrupted marine aquaculture operations in the region through rising water temperatures, unstable salinity, and more frequent extreme weather events. These conditions have accelerated disease outbreaks, degraded water quality, and reduced overall productivity. In response, researchers and farmers have collaborated to develop the CPSB system, a microbial-based biotechnological solution that leverages photosynthetic bacteria to stabilize pond ecology, enhance nutrient recycling, and reduce dependence on chemical inputs.

The CPSB technology functions by promoting beneficial microbial populations that consume organic waste, convert ammonia and nitrite into harmless compounds, and generate oxygen through photosynthetic processes. This creates a self-regulating aquatic environment that improves both water quality and animal health. The bacteria also produce natural bioactive compounds that inhibit pathogenic microorganisms, reducing the risk of bacterial infections without antibiotics.

The presenter presented empirical results from field trials demonstrating the significant ecological and economic advantages of CPSB application. Compared with conventional systems, CPSB farms achieved a 26 percent reduction in Streptococcus infections, a 50 percent decline in Vibrio outbreaks, and a 19 percent shorter culture cycle, resulting in higher turnover and better profitability. The survival rate of cultured four-finger threadfin increased by 13 percent, and net economic benefits reached approximately USD 12,000 per hectare per production cycle. In addition to these operational gains, the system reduced overall CO_2-equivalent emissions by more than 1.1 million kilograms through lower energy use and minimized water exchange.

The presenter emphasized that the CPSB model exemplifies the principles of climate-smart aquaculture, as it integrates adaptation, mitigation, and efficiency within a single framework. The system enhances resilience by buffering environmental fluctuations, lowers greenhouse-gas emissions by optimizing resource use, and promotes sustainable intensification through better disease control and water management. It also improves social outcomes by reducing farmers' production risks and increasing income stability, particularly for small and medium-scale enterprises that dominate the aquaculture sector in Chinese Taipei.

He further noted that CPSB technology aligns closely with economy-wide and regional climate objectives, supporting the APEC Bangkok Goals on the Bio-Circular-Green (BCG) Economy and the Sustainable Development Goals (SDGs 2, 13, and 14). Its microbial recycling process embodies circular-economy principles, transforming waste into bio-nutrients and minimizing environmental discharge. In parallel, the approach contributes to food safety and traceability, as the system reduces chemical residues and ensures cleaner aquaculture products.

The presenter underscored the importance of collaboration among academia, government, and industry in driving the success of this innovation. The CPSB program is supported by the Fisheries Agency, local cooperatives, and private-sector partners who provide technical and financial assistance to farmers adopting the system. Training and demonstration centers have been established to scale up adoption economy-wide, coupled with ongoing research to adapt CPSB for other cultured species such as grouper, milkfish, and shrimp.

In conclusion, he emphasized that the CPSB model illustrates how low-carbon and bio-based technologies can transform aquaculture into a sustainable solution to climate challenges. By integrating microbial biotechnology, precision management, and community participation, Chinese Taipei is demonstrating a practical pathway toward greener and more resilient aquaculture systems. He encouraged APEC economies to explore joint research and pilot projects on microbial-based and circular aquaculture technologies, noting that cross-economy cooperation under the APEC Ocean and Fisheries Working Group (OFWG) could accelerate the deployment of such innovations across the region.

2. Discussion and Cross-Cutting Insights

The six presentations in Session II revealed a broad spectrum of technological and policy innovations that are reshaping aquaculture in the Asia–Pacific toward greater resilience, efficiency, and sustainability. While each economy showcased unique economy-wide approaches, several cross-cutting themes emerged that underscore APEC's collective direction in climate adaptation and mitigation for aquaculture.

First, the session highlighted the central role of technological innovation as a driver of resilience. From China's Marine Big Data System and Singapore's Aquaculture Sensing Network to Viet Nam's GROFARM™ model and Chinese Taipei's CPSB microbial technology, the adoption of digital tools, sensors, and bio-based systems is transforming aquaculture management across the region. These innovations are enabling early warning, precision feeding, disease prevention, and emission reduction, core elements of climate-smart aquaculture. Participants observed that technology not only enhances productivity but also provides the analytical foundation for risk assessment, supporting data-driven decision-making by farmers and policymakers alike.

Second, economies are converging around ecosystem-based and circular production models that restore rather than deplete natural resources. Thailand's integration of RAS and IMTA systems, New Zealand's regenerative aquaculture ventures, and China's big-data-enabled coastal adaptation planning exemplify how nature-based solutions can complement high-tech systems. These models demonstrate that ecosystem restoration, blue-carbon sequestration, and water reuse can coexist with commercial aquaculture, delivering co-benefits for biodiversity and livelihoods. The concept of regenerative aquaculture, where farming contributes directly to ecosystem health, was widely recognized as a promising paradigm for future APEC collaboration.

Third, the discussions reinforced the importance of public–private partnerships as a catalyst for innovation and scale. The GROFARM™ program in Viet Nam and New Zealand's regenerative ventures both illustrate how private enterprises can lead technological

advancement and investment while aligning with economy-wide sustainability goals. Participants agreed that mobilizing private capital through blue-finance mechanisms, impact investment, and carbon-credit frameworks is critical to accelerating the transition toward low-carbon aquaculture. Governments, in turn, play a vital role in establishing enabling policies, infrastructure, and certification systems that reduce investment risks and ensure equitable benefits for smallholders.

A fourth theme centered on data sharing, interoperability, and capacity building. Presentations from China and Singapore demonstrated the value of integrating oceanographic and farm-level data into real-time monitoring systems, while participants noted the need for region-wide cooperation in this area. An APEC-level Aquaculture Climate Resilience and Knowledge Platform, could serve as a foundation for harmonized standards, training, and joint research, facilitating the exchange of information on disease surveillance, water quality, and emission accounting.

Fifth, participants emphasized inclusion and gender equity as essential dimensions of sustainable aquaculture. Across the region, women, youth, and small-scale farmers play critical roles in production and value-chain management but often face limited access to technology, finance, and training. Economies such as Malaysia and Thailand are making deliberate efforts to integrate these groups through mobile hatchery programs, digital literacy training, and cooperative business models. Ensuring equitable access to innovation will strengthen both social and environmental resilience.

Overall, Session II underscored that effective climate adaptation and mitigation in aquaculture require an integrated portfolio approach, combining ecosystem-based solutions, digital transformation, financial innovation, and inclusive participation. The region's collective experience demonstrates that sustainable aquaculture is achievable not through isolated interventions but through coordinated actions linking science, policy, and enterprise.

Participants concluded that APEC economies are well-positioned to lead global progress toward low-carbon, resilient, and regenerative aquaculture. Building on the innovations shared in this session, future cooperation under the APEC Ocean and Fisheries Working Group (OFWG) should focus on scaling proven models, harmonizing data and monitoring standards, and expanding capacity-building networks. Through these joint efforts, APEC can transform aquaculture into a cornerstone of the blue economy, delivering climate, economic, and social benefits for the entire Asia–Pacific region.

VI. SESSION III – REGIONAL AND INTERNATIONAL COOPERATION

Sessions III and IV focused on fostering regional and international cooperation to strengthen climate adaptation and mitigation in aquaculture across the Asia–Pacific. The discussions showcased a wide array of multilateral initiatives, cross-economy partnerships, and community-based models led by governments, international organizations, research institutions, and private actors. The session highlighted that achieving sustainable and resilient aquaculture is a shared regional challenge that requires coordinated action in science, policy, finance, and capacity building.

6.1. Key presentations

6.1.1. UNIDO – Regional and international programs and initiatives to support sustainable aquaculture in the face of climate change

The presenter presented the United Nations Industrial Development Organization's (UNIDO) current and emerging initiatives supporting Blue Economy development and

climate-resilient aquaculture across Asia and the Pacific. She emphasized that UNIDO's work in this field seeks to bridge technology, policy, and enterprise development to help coastal and island economies adapt to climate change while generating sustainable livelihoods and environmental co-benefits.

The presenter began by outlining the central challenge: many developing economies in the region rely heavily on aquaculture for food security and employment but face increasing climate and market pressures. Rising sea temperatures, salinity intrusion, and habitat degradation threaten productivity, while smallholders often lack access to finance, green technologies, and formal markets. UNIDO's Blue Economy initiatives aim to address these challenges through integrated approaches that combine innovation, capacity building, and value-chain upgrading.

She highlighted three interlinked programs that demonstrate UNIDO's strategy.

- The first is the Integrated Mangrove–Aquaculture Restoration Program, which promotes ecosystem-based adaptation by rehabilitating mangrove forests while improving aquaculture productivity. Implemented in partnership with economy-wide governments and local communities, the program has restored more than 4,000 hectares of mangroves in Southeast Asia, introducing low-intensity, organic shrimp–mangrove systems that sequester carbon and protect coastlines from erosion. The model has proven successful in increasing farm resilience to storm surges and disease while enhancing biodiversity and carbon capture.
- The second initiative focuses on Ulva seaweed value chains, targeting the transformation of the green macroalgae Ulva into high-value products such as feed additives, fertilizers, and bioplastics. The program supports circular-economy development by converting waste nutrients into biomass through seaweed cultivation. These projects, implemented in collaboration with the Global Environment Facility (GEF) and local private-sector partners, are generating new income opportunities for women and coastal cooperatives while contributing to nutrient recycling and blue-carbon sequestration.
- The third program, the Southeast Asia Climate Resilience Program, provides technical assistance and policy support to strengthen the adaptive capacity of small-scale aquaculture producers. The program assists economy-wide authorities in developing low-emission aquaculture guidelines, pilot testing renewable energy systems for hatcheries, and establishing certification schemes aligned with international standards. Through targeted interventions, UNIDO helps governments embed aquaculture within economy-wide adaptation plans and Nationally Determined Contributions (NDCs), aligning local practices with global climate commitments.

She emphasized that these programs share a common foundation: innovation, inclusion, and institutional partnership. UNIDO's approach ensures that technology transfer goes hand in hand with local capacity building. Training programs equip farmers, especially women and youth, with the skills to manage ecosystem-based and digital aquaculture systems. The organization also facilitates access to finance through public–private partnerships and impact investment channels, supporting the scaling up of green business models.

She highlighted the potential for collaboration between UNIDO and APEC in advancing regional knowledge exchange, noting that both frameworks share complementary goals under the Bangkok Goals on the Bio-Circular-Green (BCG) Economy and the APEC Putrajaya Vision 2040. Specifically, UNIDO expressed its readiness to work with APEC's Ocean and Fisheries Working Group (OFWG) in three priority areas:

1. Developing a Regional Blue Finance Facility to mobilize capital for sustainable aquaculture and blue innovation;

2. Conducting joint training and policy dialogues on low-emission and circular aquaculture systems; and
3. Establishing pilot demonstration projects that integrate mangrove restoration, seaweed farming, and aquaculture diversification under the APEC cooperation umbrella.

In conclusion, the presenter underscored that UNIDO's Blue Economy programs demonstrate the value of connecting environmental restoration with inclusive economic development. By integrating mangrove rehabilitation, seaweed utilization, and green enterprise support, these initiatives provide tangible models for climate adaptation, mitigation, and sustainable growth. She reaffirmed UNIDO's commitment to continue partnering with APEC economies, offering technical expertise and capacity-building support to help the region advance toward a resilient and inclusive blue economy.

6.1.2. China – Practices of Island Regions for Climate Change Response in China

The presenter presented China's efforts in island restoration and blue-carbon development, highlighting how digital innovation, spatial planning, and ecosystem-based management are being integrated to create zero-carbon and climate-resilient island models. He explained that as a coastal economy with more than 14,000 islands, China has prioritized the restoration and sustainable management of its island ecosystems as part of its broader strategy to achieve carbon neutrality and enhance marine ecological security.

At the core of this strategy is the Zero-Carbon Island Initiative, launched by the Ministry of Natural Resources in collaboration with the Chinese Academy of Sciences and several coastal provinces. The initiative combines renewable energy systems, ecosystem restoration, and sustainable aquaculture to reduce emissions and enhance resilience in vulnerable island communities. Through pilot projects in Hainan, Zhoushan, and Sansha Islands, China has established living laboratories where integrated offshore aquaculture, seaweed and shellfish farming, and mangrove rehabilitation are managed in synergy with solar, wind, and tidal energy generation. These sites demonstrate how multiple forms of blue and green energy can coexist with productive aquaculture while maintaining ecosystem health.

The presenter explained that the Zero-Carbon Island Initiative is supported by advanced digital tools developed by the China Institute of Remote Sensing and Digital Earth (RADI). The institute has established a Coastal Ecosystem Observation Network that uses satellite imagery, drones, and real-time sensors to monitor environmental indicators such as sea-surface temperature, chlorophyll concentration, turbidity, and coastal erosion. The data are integrated into a Geographic Information System (GIS) platform for marine spatial planning and decision support. This system helps identify suitable sites for aquaculture and energy development, optimize resource use, and minimize ecological conflicts.

A key output of this initiative has been the development of China's Marine Blue-Carbon Accounting Framework, which quantifies carbon sequestration from seaweed, seagrass, and mangrove ecosystems. This framework has laid the foundation for emerging blue-carbon crediting mechanisms, linking ecosystem restoration with climate finance. He noted that the approach has gained international attention and provides a replicable model for APEC economies interested in integrating carbon accounting into aquaculture and coastal management.

In addition, China has strengthened international cooperation through the China–Pacific Islands Cooperation Platform, supporting small island developing economies (SIDS) in the Pacific to build capacity in digital monitoring, blue-carbon assessment, and sustainable

aquaculture. Through joint research programs, Chinese experts have assisted local governments in developing early-warning systems for sea-level rise and coral reef degradation, while facilitating training workshops on the use of remote-sensing data for marine spatial planning. These initiatives aim to build scientific capacity, share digital infrastructure, and promote inclusive knowledge exchange among APEC economies.

The presenter emphasized that the Zero-Carbon Island Initiative contributes directly to China's commitment to the APEC Putrajaya Vision 2040, the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, and the UN Sustainable Development Goals (SDGs 13 and 14). It demonstrates how technological innovation, ecosystem restoration, and financial instruments can be combined to achieve a low-carbon, resilient, and inclusive blue economy.

He proposed that APEC economies collaborate on developing standardized blue-carbon methodologies, coastal digital twin systems, and regional databases for aquaculture zoning and climate monitoring. These collaborative tools could form the basis of a future APEC Blue-Carbon Partnership, aligning carbon sequestration efforts with the sustainable expansion of aquaculture.

In conclusion, he stressed that island ecosystems are among the most vulnerable yet most valuable frontiers in the fight against climate change. Through innovation and cooperation, they can become models of sustainability and self-sufficiency. He invited APEC members to join China in advancing the Zero-Carbon Island Alliance, fostering joint research, data exchange, and capacity-building initiatives that integrate renewable energy, aquaculture, and ecosystem restoration into coherent frameworks for climate adaptation and mitigation across the Asia–Pacific.

6.1.3. Viet Nam – International Cooperation in Aquaculture: Perspectives & implementation in Vietnamese Associations

The presenter presented the perspective of the seafood industry, highlighting how Viet Nam's private sector is mobilizing innovation, partnerships, and responsible trade practices to promote sustainable aquaculture and climate resilience. Representing more than 500 enterprises, the Viet Nam Association of Seafood Exporters and Producers (VASEP) has played a pivotal role in linking producers, processors, and exporters with international markets, while aligning business operations with environmental and social sustainability standards.

He noted that aquaculture is the backbone of Viet Nam's seafood industry, accounting for over 70 percent of total fisheries output and generating approximately USD 9 billion in export earnings in 2024. The sector provides livelihoods for millions of rural households and contributes substantially to economy-wide food security and foreign exchange. However, the industry faces multiple challenges, including rising production costs, environmental degradation, and increasing international requirements for sustainability, traceability, and low-carbon certification.

In response, VASEP has implemented a comprehensive strategy centered on public–private partnership (PPP), innovation, and market transformation. Mr. Nam described the Sustainable Shrimp Alliance, a flagship program initiated by VASEP in collaboration with the Ministry of Agriculture and Environment (MAE), international organizations, and the private sector. The initiative promotes the adoption of good aquaculture practices (GAP), digital traceability systems, and efficient water and energy management technologies. Through the alliance, farms are supported in achieving international certifications such as Aquaculture Stewardship Council (ASC) and Best Aquaculture Practices (BAP), improving both environmental performance and market access.

VASEP's approach combines technical assistance with policy advocacy. It supports the government in formulating regulations that incentivize sustainable production, such as tax reductions for certified farms and preferential credit for low-emission technologies. He explained that aligning economy-wide policies with global market standards helps ensure the competitiveness of Viet Nam's seafood exports in key destinations such as the European Union; Japan; and the United States, where buyers increasingly demand verifiable sustainability credentials.

Digital transformation is another central pillar of VASEP's strategy. The organization has launched a Seafood Digital Traceability Platform, integrating blockchain technology to document production history, environmental data, and supply-chain transactions. This transparency not only enhances consumer confidence but also helps enterprises monitor their carbon footprints and demonstrate compliance with environmental and labor standards. VASEP is also exploring the use of artificial intelligence and satellite data to verify the sustainability of farming zones and assess vulnerability to climate impacts.

In addition to environmental objectives, VASEP has prioritized social sustainability and labor responsibility. In partnership with the International Labour Organization (ILO) and USAID, the association has developed training programs on occupational safety, gender equality, and responsible recruitment, benefiting thousands of workers in aquaculture processing plants. Mr. Nam noted that strengthening social safeguards enhances the industry's reputation and ensures compliance with international trade regulations.

He emphasized that sustainable aquaculture must be both climate-resilient and market-oriented. As global buyers increasingly link procurement to carbon accounting and environmental performance, integrating adaptation measures with trade competitiveness becomes a strategic necessity. VASEP's long-term objective is to transition Viet Nam's aquaculture sector toward a green and circular value chain, minimizing waste and emissions while maximizing efficiency and inclusiveness.

To achieve these goals, VASEP is working closely with APEC partners and global institutions to explore blue-finance opportunities, including credit guarantees and impact investment funds for small and medium enterprises. These financial instruments can support the wider adoption of low-carbon technologies, renewable energy, and ecosystem-based production systems.

In his concluding remarks, he stressed that public–private partnership is the cornerstone of Viet Nam's success in sustainable aquaculture. He called on APEC economies to facilitate regional dialogue between industry and policymakers to harmonize sustainability standards, mutual recognition of eco-certifications, and carbon-labelling schemes. Strengthening cooperation in these areas would not only improve trade transparency but also position APEC as a leader in shaping global standards for sustainable seafood.

The presenter concluded by reaffirming VASEP's commitment to contributing to APEC's collective vision of a low-carbon, inclusive, and competitive aquaculture sector, where climate action and responsible trade reinforce one another as mutually beneficial pillars of regional growth.

6.1.4. Viet Nam – Sustainable Rice-Shrimp Farming for Climate Change Adaptation in the Mekong Delta, Viet Nam

The presenter presented Viet Nam's successful experience in promoting community-based climate adaptation through integrated rice–shrimp farming systems in the Mekong Delta. The initiative, led by the Marine Conservation and Development Organization (MCD),

demonstrates how smallholder farmers can adapt to climate change while sustaining livelihoods, enhancing gender equity, and contributing to global sustainability goals.

The Mekong Delta, Viet Nam's most productive aquaculture and rice-growing region, is facing severe climate-induced challenges, including sea-level rise, saltwater intrusion, droughts, and unstable rainfall patterns. These changes have significantly reduced the viability of traditional rice monoculture systems. In response, farmers and local authorities have adopted the rice–shrimp model, a nature-based, adaptive farming practice that alternates rice cultivation during the wet season with shrimp farming during the dry season when salinity levels increase. This rotation reduces input costs, improves soil and water quality, and stabilizes income by diversifying production.

The presenter explained that MCD, in partnership with provincial governments and international donors, has implemented a multi-year program to strengthen the sustainability and inclusiveness of the rice–shrimp model. The program provides technical support for sustainable water management, organic farming methods, and disease control while promoting certification schemes to improve market access. By coordinating with the Aquaculture Stewardship Council (ASC) and Naturland, MCD has helped over 2,500 hectares of rice–shrimp farms achieve certification, enabling smallholders to sell premium-quality products to international markets.

A key success factor of the model is its emphasis on community participation and women's empowerment. MCD has established farmer field schools and cooperatives that bring together men and women farmers to share experiences, adopt good aquaculture practices (GAP), and collectively manage water resources. Women, who often play leading roles in post-harvest processing and marketing, are increasingly represented in cooperative leadership positions. This inclusive governance structure ensures that adaptation decisions reflect diverse perspectives and community priorities.

The presenter highlighted several measurable outcomes. Certified farms have reported income increases of 15–25 percent compared to conventional systems, along with reductions in chemical fertilizer and pesticide use by up to 70 percent. These improvements have contributed to healthier ecosystems and reduced greenhouse-gas emissions from rice cultivation. Furthermore, improved water governance among community members has led to more equitable sharing of resources during drought periods, reducing social conflict and enhancing local resilience.

The rice–shrimp system also supports broader climate mitigation and biodiversity conservation goals. Mangrove buffers and vegetative strips are being planted along irrigation channels to stabilize embankments, filter effluents, and provide habitat for aquatic species. MCD's collaboration with local authorities has resulted in the inclusion of these practices in provincial climate adaptation plans, institutionalizing community-based solutions within the policy framework.

The presenter emphasized that the model's success lies in its integration of environmental, social, and economic objectives. By aligning farm-level innovation with local governance and market incentives, the program has created a virtuous cycle of adaptation and empowerment. However, she noted that scaling up requires access to finance and stronger linkages between community models and economy-wide or regional policy platforms.

She proposed three recommendations for APEC economies:

1. Scale up nature-based community models such as rice–shrimp, mangrove–shrimp, and polyculture systems through technical cooperation and shared financing mechanisms;

2. Strengthen regional exchange programs to connect farmers' organizations, women's groups, and cooperatives across APEC economies for peer learning; and
3. Integrate community-based adaptation into APEC's policy dialogue and OFWG agenda, ensuring that local voices inform regional strategies on aquaculture resilience.

In conclusion, the presenter reaffirmed that the rice–shrimp model embodies the principles of resilience, inclusivity, and circularity central to the Bangkok Goals on the Bio-Circular-Green (BCG) Economy. It illustrates how grassroots innovation, when supported by science, policy, and markets, can contribute directly to APEC's collective effort to build a climate-smart and equitable blue economy.

6.1.5. COAST Facility – Sustainable Coasts and Resilient Communities: Scaling Sustainable Aquaculture through the COAST Facility

The presenter presented the Coastal Adaptation and Sustainable Transformation (COAST) Facility, a United Kingdom–based initiative designed to mobilize inclusive blue finance for climate adaptation, coastal resilience, and sustainable aquaculture across the Asia–Pacific. Her presentation highlighted how innovative financial instruments and public–private partnerships can bridge the gap between climate ambition and real-world investment, ensuring that small-scale producers, women, and vulnerable communities can access resources to build resilience and prosperity.

She began by noting that coastal and aquaculture-dependent communities are among the most vulnerable to climate change. Rising sea levels, ocean acidification, and increasingly frequent extreme weather events threaten livelihoods, infrastructure, and food security. Yet, despite these risks, access to affordable finance for adaptation remains limited, particularly for small and medium enterprises (SMEs) and local cooperatives that lack credit history or collateral. The COAST Facility addresses this gap by designing blended-finance mechanisms that combine concessional public funding with private investment to de-risk projects and make them bankable.

The presenter explained that COAST operates through a three-pronged approach: (i) providing technical assistance to governments and local partners to prepare and evaluate climate-resilient aquaculture projects; (ii) structuring innovative financial instruments such as blue bonds, micro-insurance, and revolving credit schemes; and (iii) building capacity among financial institutions to assess and manage blue-economy investments. These activities ensure that capital flows effectively to where it is most needed, supporting adaptation, biodiversity restoration, and inclusive economic development.

She presented several case studies demonstrating how COAST's model has been implemented in collaboration with APEC economies. In Southeast Asia, the Facility supported the development of microcredit and insurance schemes for small-scale shrimp and shellfish farmers affected by flooding and disease. Through partnerships with local banks and cooperatives, COAST helped design parametric insurance products that provide rapid payouts based on weather or temperature triggers, reducing farmers' financial vulnerability after extreme events. These pilot projects enabled farmers to reinvest quickly and adopt adaptive technologies such as solar-powered aeration, recirculating aquaculture systems (RAS), and biofloc ponds.

In the Pacific region, COAST has worked with governments to establish blue investment pipelines, collections of pre-screened projects in areas such as coastal habitat restoration, aquaculture modernization, and eco-tourism. By improving transparency and providing feasibility assessments, these pipelines attract investors interested in measurable

environmental and social returns. The approach has proven effective in reducing transaction costs and scaling up small projects into regional programs suitable for blended-finance structures.

She emphasized that the COAST Facility places strong emphasis on social inclusion and gender equity. Women and youth are key stakeholders in the aquaculture value chain but often face disproportionate barriers to finance and training. COAST addresses these gaps through gender-responsive financing guidelines and mentorship programs that connect women entrepreneurs with investors and technical experts. These interventions not only empower women economically but also enhance the resilience of entire communities by diversifying income and leadership roles.

She noted that COAST's methodologies are fully aligned with the Bangkok Goals on the Bio-Circular-Green (BCG) Economy and the APEC Putrajaya Vision 2040, particularly under the pillars of sustainability and inclusiveness. The Facility's Blue Finance Toolkit, developed in consultation with financial institutions and regional governments, provides guidance on project selection, risk assessment, and impact measurement. This toolkit is being adapted for use by APEC member economies to support the design of economy-wide blue-finance strategies and aquaculture investment programs.

The presenter proposed that APEC economies consider establishing a Regional Blue Finance Partnership under the Ocean and Fisheries Working Group (OFWG), leveraging COAST's technical expertise and financing models. Such a partnership could facilitate the scaling of pilot initiatives, support regional capacity building, and develop standardized frameworks for evaluating climate-aligned aquaculture investments.

In conclusion, she underscored that finance is the linchpin of sustainable transformation. Without accessible and inclusive investment mechanisms, climate adaptation will remain beyond the reach of the communities most affected by change. Through innovative finance, capacity building, and public–private collaboration, the COAST Facility demonstrates that resilient aquaculture and coastal adaptation are not only feasible but also financially viable. She reaffirmed COAST's commitment to continuing its collaboration with APEC economies to unlock blue capital, promote equity, and build coastal resilience for a sustainable Asia–Pacific.

6.1.6. Viet Nam – Scaling-Up APEC Cooperation on Climate-Resilient Aquaculture and Sustainable Development in the Region: Challenges and Opportunities

In the concluding presentation of Sessions III and IV, the presenter synthesized the lessons and strategic priorities emerging from the APEC Workshop, emphasizing the urgent need for regional cooperation and integrated action to strengthen climate adaptation and mitigation in aquaculture. Drawing on insights from the Background Research Paper and discussions among participants, he argued that while many APEC economies have made significant progress at the economy-wide level, the magnitude and transboundary nature of climate impacts demand collective regional mechanisms to sustain progress and share innovation.

He began by outlining key challenges common across APEC economies: fragmented data systems, limited access to finance for small-scale producers, and uneven capacity to deploy advanced technologies for climate-smart aquaculture. He noted that climate stressors, rising sea temperatures, salinity intrusion, ocean acidification, and disease outbreaks, are not confined by borders, and therefore require coordinated monitoring, research, and policy responses. APEC, with its well-established frameworks for economic cooperation and sustainable development, provides an ideal platform to align economy-wide efforts into a cohesive regional strategy.

To this end, the presenter proposed the establishment of an APEC Aquaculture Climate Resilience Platform, a long-term cooperative mechanism to connect economies, institutions, and enterprises in addressing shared climate challenges. The proposed platform would consist of three key pillars:

1. Data and Knowledge Sharing: creation of an APEC-wide digital portal integrating marine, climate, and aquaculture data from member economies. This would facilitate early-warning systems, promote transparency, and enable cross-economy comparisons for risk assessment and decision support.
2. Capacity Building and Technology Exchange: organization of joint training programs, study tours, and innovation incubators focusing on ecosystem-based aquaculture, blue-carbon accounting, IoT systems, and disease management. Such activities would build technical capacity and foster youth and gender inclusion in aquaculture innovation.
3. Financing and Partnership Mechanisms: establishment of a multi-stakeholder partnership framework linking governments, development banks, and private investors. This would mobilize resources for pilot projects, scaling of regenerative aquaculture systems, and the adoption of low-emission technologies.

He noted that these three pillars directly support APEC's strategic commitments under the Putrajaya Vision 2040, the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, and the Ocean and Fisheries Working Group (OFWG) Strategic Plan 2021–2025. By embedding aquaculture into APEC's climate and blue-economy agenda, member economies can transform the sector from one of high vulnerability into a key contributor to regional sustainability and food security.

The presenter also proposed the creation of a network of regional demonstration sites to serve as innovation hubs for climate-smart aquaculture. Each site would showcase practical applications of technology and policy, such as integrated mangrove–shrimp systems, regenerative seaweed farms, and AI-based monitoring platforms, and facilitate peer learning among farmers, scientists, and policymakers. These hubs could operate under a coordinated framework supported by the APEC Secretariat, ensuring the exchange of standardized methodologies and lessons learned.

He further stressed the importance of blue-finance mobilization to implement these initiatives. Many economies, he noted, have strong technical knowledge but lack financial mechanisms to scale climate-smart practices. Building on the proposals from COAST Facility and UNIDO, Dr. Nghia encouraged APEC to explore the development of a Regional Blue Finance Facility dedicated to sustainable aquaculture. This facility would provide concessional loans, credit guarantees, and impact-investment instruments to de-risk innovation and attract private-sector participation.

Throughout his presentation, he emphasized inclusivity and gender equity as foundational principles of regional cooperation. He urged that future APEC activities actively engage women, youth, and small-scale producers as co-creators of solutions, not merely beneficiaries. Empowering these groups with knowledge, finance, and leadership roles will ensure that aquaculture growth remains both equitable and resilient.

In closing, the presenter reaffirmed that APEC economies possess the collective capacity, expertise, and institutional frameworks to lead global progress toward climate-smart, low-carbon, and regenerative aquaculture. He called upon the APEC Ocean and Fisheries Working Group (OFWG) to adopt a long-term vision that integrates science, finance, and policy into a unified regional roadmap. By institutionalizing collaboration through the proposed platform, APEC can ensure that aquaculture continues to provide sustainable food, livelihoods, and ecosystem benefits for future generations.

2. Discussion and Key issues

The discussions in Sessions III and IV demonstrated that achieving climate-resilient and low-carbon aquaculture in the Asia–Pacific requires collective action across governance, finance, capacity building, and knowledge systems. While economies differ in scale, structure, and technological readiness, participants agreed on four overarching themes that should guide APEC's future cooperation under the Ocean and Fisheries Working Group (OFWG) and related fora.

Governance Integration and Policy Coherence:

Speakers emphasized that policy coherence and cross-sectoral coordination are the foundation of effective climate adaptation in aquaculture. Many economies face fragmentation across ministries responsible for fisheries, environment, industry, and finance, leading to inefficiencies and inconsistent implementation. Participants called for integrated governance mechanisms that link aquaculture development with climate policy, biodiversity protection, and blue-economy planning.

The case studies presented by China, VASEP, and MCD demonstrated how inclusive, multi-stakeholder coordination, bridging government, academia, and the private sector, can accelerate adaptation. Delegates proposed that APEC economies strengthen institutional mechanisms for policy harmonization, ensuring that economy-wide aquaculture strategies align with Nationally Determined Contributions (NDCs) and with the Bangkok Goals on the Bio-Circular-Green (BCG) Economy.

APEC's OFWG was encouraged to facilitate inter-fora coordination and joint policy dialogues among fisheries, environment, and finance ministries to promote governance integration, accountability, and long-term coherence in regional aquaculture management.

Regional Finance Mechanisms (Blue Bonds, Insurance, and Impact Investment)

Finance was recognized as a key enabler of transformation. Presentations by UNIDO, COAST Facility, and VASEP highlighted that while technologies for low-carbon and adaptive aquaculture exist, access to affordable finance remains limited, especially for smallholders, women entrepreneurs, and MSMEs.

Participants called for the development of regional blue finance mechanisms, including blue bonds, blended-finance funds, and climate insurance schemes, to de-risk investment and unlock private-sector participation. The COAST Facility's models on microcredit, weather-index insurance, and revolving funds showcased how innovative finance can empower communities while ensuring social inclusion.

Delegates supported the establishment of an APEC Blue Finance Partnership or Regional Blue Finance Facility, bringing together governments, development banks, and investors to mobilize capital for regenerative aquaculture, digital infrastructure, and climate innovation. This mechanism would complement the policy work of the OFWG and support pilot programs across member economies.

Inclusive Capacity Building for MSMEs, Women, and Youth

Throughout the sessions, participants underscored that inclusion and equity are critical to long-term resilience. MSMEs, women, and youth play vital roles across aquaculture value chains but often lack the skills, finance, and technology needed to adapt to a changing climate. The MCD's rice–shrimp program and COAST's gender-responsive finance model

illustrated how community-based adaptation and women's leadership strengthen both social and ecological resilience.

Delegates recommended that APEC economies mainstream inclusive capacity-building initiatives, including training on digital tools, biosecurity, blue finance, and business management, targeting underrepresented groups. Establishing an APEC-wide capacity-building and mentorship network would help coordinate programs, facilitate exchange visits, and create regional "champions" for innovation and inclusion.

This approach aligns with APEC's broader goals of inclusive growth, women's economic empowerment, and youth engagement, ensuring that climate-smart aquaculture contributes to equitable socio-economic development.

Knowledge Sharing and Joint R&D Networks (APEC Aquaculture Resilience Platform)

A recurring theme across all presentations was the urgent need for structured regional cooperation in research, data, and innovation. Participants highlighted the fragmentation of climate and aquaculture data systems across economies and the limited interoperability of existing databases.

Building on proposals by China (NMDIS) and Viet Nam (VNUA), delegates endorsed the creation of an APEC Aquaculture Climate Resilience Platform, a digital and institutional mechanism to coordinate data sharing, joint research, and innovation. The platform would link APEC economies, universities, and international partners (UNIDO, SEAFDEC, COAST Facility, FAO) in co-developing tools for blue-carbon accounting, ocean monitoring, disease forecasting, and digital farm management.

This initiative would also serve as a hub for training, policy dialogues, and demonstration projects, fostering evidence-based decision-making and harmonization of standards. By institutionalizing regional R&D collaboration, APEC can accelerate technology transfer and build collective capacity to address shared challenges in aquaculture sustainability and climate resilience.

These four themes, governance integration, finance innovation, inclusive capacity building, and regional knowledge networks, represent interconnected pillars of APEC's cooperative framework for the next phase of the OFWG Work Plan (2026–2028). Together, they provide a clear strategic direction: to transform aquaculture into a climate-smart, inclusive, and regenerative blue-economy sector that sustains livelihoods, ensures food security, and contributes to the region's collective climate goals.

VII. CLOSING SESSION

The Workshop concluded with closing remarks delivered by representatives from the Ministry of Foreign Affairs (MOFA) of Viet Nam, who commended the active participation of delegates, experts, and partners from across the Asia–Pacific.

In his closing remarks, the representative of MOFA (Viet Nam) emphasized that the workshop had fulfilled its objectives of strengthening regional dialogue, promoting cooperation, and sharing best practices in climate adaptation and mitigation for sustainable aquaculture. He noted that the event's outcomes reflected Viet Nam's strong commitment to advancing the APEC Putrajaya Vision 2040 and the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, and reaffirmed the government's dedication to supporting continued collaboration under the APEC Ocean and Fisheries Working Group (OFWG).

He congratulated Viet Nam and the organizing institutions for the successful delivery of the project. He highlighted that the workshop had brought together a diverse network of

stakeholders, including policymakers, scientists, private enterprises, and civil society, to build a common understanding of the region's priorities for climate-smart aquaculture. He underlined that the recommendations and proposals generated during the workshop would contribute directly to the formulation of the OFWG Work Plan 2026–2028, particularly in strengthening the linkages between innovation, investment, and inclusive growth.

Both speakers expressed appreciation to the co-sponsoring economies, Australia; China; Chile; Japan; Peru; Chinese Taipei; Thailand; and Singapore, for their substantive contributions and ongoing partnership. Acknowledgment was also given to collaborating organizations including UNIDO, COAST Facility, SEAFDEC, MCD, VASEP, and VNUA, whose technical expertise and case studies enriched the discussions and outcomes.

The host economy extended sincere thanks to all delegates for their active engagement and constructive exchange of experiences, noting that the workshop had laid a strong foundation for sustained cooperation across APEC economies. The closing remarks concluded with a shared vision: to continue building momentum toward a resilient, low-carbon, and inclusive aquaculture sector that ensures food security, economic opportunity, and healthy oceans for future generations.

VIII. KEY FINDINGS AND RECOMMENDATIONS

The workshop's deliberations generated a strong consensus on the priority actions needed to accelerate climate adaptation and mitigation in aquaculture across the APEC region. Building on the outcomes of the background research, expert presentations, and multi-economy discussions, participants identified five interlinked areas for collective action that should inform the APEC Ocean and Fisheries Working Group (OFWG) Work Plan 2026–2028. These recommendations aim to align aquaculture development with the APEC Putrajaya Vision 2040, the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, and the UN Sustainable Development Goals (SDGs 2, 13, and 14).

8.1. Policy Integration

Participants agreed that effective climate action in aquaculture requires strong policy integration across environmental, agricultural, trade, and financial sectors. Many economies are already embedding aquaculture within economy-wide climate strategies, but further progress is needed to ensure coherence with Nationally Determined Contributions (NDCs) and BCG strategies.

Delegates recommended that APEC economies develop an APEC Aquaculture Climate Resilience Framework (2026–2030) to guide collective action, harmonize economy-wide policies, and track progress in adaptation and mitigation. The framework should define shared principles, measurable indicators, and policy benchmarks for low-carbon and ecosystem-based aquaculture, while ensuring inclusiveness and cross-sectoral alignment.

By integrating aquaculture into economy-wide climate policies and coastal development plans, APEC economies can ensure that adaptation contributes directly to food security, employment, and biodiversity conservation, reinforcing the triple goals of economic growth, environmental protection, and social well-being.

8.2. Technological Innovation

The workshop underscored that technology and innovation are the driving forces behind modern aquaculture transformation. Economies such as China; Singapore; and Viet Nam showcased the potential of digital and precision aquaculture, where IoT sensors, artificial

intelligence, and big-data analytics optimize water use, feeding efficiency, and disease prevention.

Participants called for expanded research and development (R&D) cooperation under the APEC framework to accelerate innovation in key areas:

- Low-carbon feed formulations, including insect protein, algae, and microbial-based alternatives;
- Disease control and biosecurity, through vaccine research, early-warning systems, and genetic improvement;
- Blue-carbon metrics and ecosystem services accounting, to quantify the climate mitigation value of seaweed, shellfish, and mangrove-based systems.

Regional innovation networks and technology transfer hubs should be supported to ensure that these advances are accessible to all economies, particularly developing and small island members.

8.3. Ecosystem and Community Resilience

Participants reaffirmed that ecosystem restoration and community inclusion are central to sustainable aquaculture. Nature-based solutions, such as Integrated Multi-Trophic Aquaculture (IMTA), mangrove–shrimp, and rice–shrimp systems, have proven effective in reducing environmental impacts, diversifying income, and enhancing climate resilience.

Delegates recommended that APEC scale up these models through joint demonstration sites, technical cooperation, and integration into economy-wide adaptation plans. They also emphasized the need to mainstream gender equality and community participation in aquaculture development, recognizing the leadership of women and youth in innovation, processing, and entrepreneurship.

By embedding social inclusion and gender equity into all aquaculture policies and projects, APEC economies can ensure that resilience is both ecological and societal, empowering coastal communities to become active agents of change rather than passive beneficiaries.

8.4. Finance and Investment

A recurring theme throughout the workshop was the need to mobilize finance for innovation and adaptation. Participants called for the creation of an APEC Blue Finance Fund to provide concessional loans, blended finance, and grants for low-emission and regenerative aquaculture. The fund could complement economy-wide and multilateral programs by supporting priority investments in climate-smart infrastructure, renewable energy, and ecosystem restoration.

Delegates also encouraged the expansion of insurance mechanisms, including weather-index and parametric insurance, to protect farmers from climate-related losses. In parallel, APEC should promote public–private partnerships (PPPs) and impact investment models that attract private capital into sustainable aquaculture while ensuring transparency and social responsibility.

These mechanisms will be essential to unlocking innovation and de-risking investments, ensuring that both small-scale producers and enterprises can transition toward low-carbon, resilient production systems.

8.5. Cooperation and Knowledge Sharing

Participants agreed that long-term progress depends on sustained regional cooperation. Building on proposals from China (NMDIS) and Viet Nam (VNUA), delegates supported the establishment of an APEC Aquaculture Data and Early Warning Platform to integrate environmental, oceanographic, and aquaculture datasets. This platform would facilitate real-time monitoring, improve early-warning capacity, and enable joint research and policy coordination across economies.

Complementing this, APEC should facilitate joint training programs and South–South learning exchanges to accelerate technology transfer, promote inclusive innovation, and harmonize best practices in climate-smart aquaculture. These initiatives would not only strengthen institutional capacity but also deepen trust, solidarity, and shared accountability among APEC members.

Collectively, these recommendations provide a roadmap for the next phase of regional collaboration under the APEC Ocean and Fisheries Working Group. By aligning policy integration, technological innovation, ecosystem resilience, financial mobilization, and knowledge exchange, APEC economies can transform aquaculture into a climate-smart, inclusive, and regenerative engine of sustainable blue growth.

The workshop outcomes reaffirmed that cooperation, not competition, will define the region's success in achieving resilience and sustainability. Through continued dialogue, joint research, and coordinated investment, APEC can lead the global transition toward a low-carbon aquaculture future that benefits people, economies, and the ocean ecosystems they depend upon.

IX. CONCLUSION

The APEC Workshop on Enhancing Adaptation and Mitigation to Climate Change for Sustainable Aquaculture in the Asia–Pacific concluded with a reaffirmation of the region's collective commitment to building a resilient, inclusive, and low-carbon aquaculture sector. Across two days of presentations and discussions, delegates from APEC economies, international organizations, research institutions, and private-sector partners shared a unified vision: that aquaculture must evolve from a climate-vulnerable industry into a driver of innovation, food security, and blue-economy transformation.

Participants agreed that the transition toward climate-smart aquaculture will require sustained policy integration, investment in technological innovation, and strengthened regional partnerships. The workshop underscored that resilience cannot be achieved in isolation, ecosystems, communities, and markets are interdependent. Hence, effective adaptation and mitigation must be pursued through cross-sectoral governance, inclusive finance, and knowledge exchange, supported by a strong enabling environment at both economy-wide and regional levels.

The workshop outcomes align directly with the APEC Putrajaya Vision 2040, which calls for an open, dynamic, resilient, and peaceful Asia–Pacific community by promoting sustainability and innovation. They also advance the Bangkok Goals on the Bio-Circular-Green (BCG) Economy, translating its principles of resource efficiency, circular production, and ecosystem restoration into practical actions for aquaculture. By integrating science, technology, and community-based solutions, APEC economies are demonstrating leadership in operationalizing the BCG approach through tangible, measurable outcomes.

Moving forward, the workshop participants proposed that these findings form the foundation for follow-up projects under the APEC Ocean and Fisheries Working Group (OFWG) Work Plan 2026–2028. Priority areas include the establishment of an APEC Aquaculture Climate

Resilience Platform, a Regional Blue Finance Facility, and coordinated demonstration projects showcasing digital, regenerative, and inclusive aquaculture systems. These initiatives will sustain the momentum generated through this workshop and ensure that APEC remains at the forefront of innovation and collaboration in the global blue economy.

In closing, the workshop reaffirmed that APEC's collective strength lies in its unity of purpose and diversity of expertise. By continuing to work together, sharing data, financing solutions, and practical models, the economies of the Asia–Pacific can lead the transformation toward aquaculture systems that are not only economically competitive, but also socially inclusive and environmentally restorative.

X. ANNEXES

Full Workshop Agenda

TENTATIVE AGENDA
APEC WORKSHOP ON ENHANCING ADAPTATION AND MITIGATION TO CLIMATE CHANGE FOR THE SUSTAINABLE AQUACULTURE OF THE ASIA-PACIFIC
(Sheraton Hanoi West Hotel, Ha Noi, 15 – 16 September, 2025)

Sponsoring economy: Viet Nam
Co-sponsoring economies: Australia; China; Chile; Japan; Peru; Chinese Taipei; Thailand; Singapore

15/9/2025	
08.00 – 09.15	Registration and Test run
09.15 – 09.30	**OPENING SESSION**
	• **Opening Remarks**
09.30 – 09.35	Photo session
09.35 – 09.45	Break
09.45 – 11.45	**SESSION I: AQUACULTURE IN THE ASIA-PACIFIC IN THE FACE OF CLIMATE CHANGE** Moderator: Speakers: - **Background Research: Enhancing Adaptation and Mitigation to Climate Change for the Sustainable Aquaculture of the Asia-Pacific - Key findings** - **Roles of aquaculture in blue economy development in Viet Nam** - **Climate Change Impacts on Health and Disease in Aquaculture in Viet Nam: Challenges and Solutions for Adaptation and Mitigation** - **Aligning aquaculture adaptation measures with APEC's food security and blue economy agendas** - **Strengthening the Resilience of Chile's Aquaculture Sector in the Face of Climate Change** - **Malaysia's Policies and Strategies to Address Climate Change Challenges in Aquaculture** - **Developing regenerative ocean farming ventures in New Zealand** Suggested topics: - Role of the aquaculture sector in economic growth and sustainable development in the Asia - Pacific - Overview of climate change impacts on aquaculture productivity and ecosystems - Challenges to sustainable aquaculture under changing climatic conditions

	- Socio-economic implications for coastal and rural communities dependent on aquaculture **DISCUSSION**
11.45 – 13.30	Break
13.30 – 16.00	**SESSION II: BEST PRACTICES IN CLIMATE CHANGE ADAPTATION AND MITIGATION FOR SUSTAINABLE AQUACULTURE – FOCUS ON APEC ECONOMIES** Moderator: Speakers: - **Sea Level Rise Adaptation: NMDIS's efforts in monitoring, assessment, and public service** - **Aquaculture Sensing Network** - **Advancing Adaptation and Mitigation of Climate Change Impacts through Thailand's Leadership Role in Sustainable Aquaculture** - **Optimization of Nutritional Program Solution to Reduce Production Costs and Environmental Impacts of Shrimp Farming through the GROFARM™ Model** - **Regenerative aquaculture in New Zealand: adapting to a changing climate** - **The sustainable management of low-carbon aquaculture applications onto the disease control of fourfinger threadfin** Suggested topics: - Best practices from APEC economies on climate change adaptation and mitigation in sustainable aquaculture - Successful government policies and initiatives to support aquaculture farmers, co-operatives and businesses, including technical assistance, green finance, early warning systems - Public–private partnerships to enhance sustainability and innovation in the aquaculture sector - Case studies of climate-smart aquaculture models, including ecosystem-based approaches, innovative breeding methods, technology applications, water quality management, disease prevention **DISCUSSION**
16/9/2025	
08.30 – 09.30	Registration and Test run
09.30 – 11.30	**SESSION III: BEST PRACTICES IN CLIMATE CHANGE ADAPTATION AND MITIGATION FOR SUSTAINABLE AQUACULTURE - FOCUS ON REGIONAL AND INTERNATIONAL COOPERATION** Moderator: Speakers: - **Regional and international programs and initiatives to support sustainable aquaculture in the face of climate change** - **Practices of Island Regions for Climate Change Response in China** - **International Cooperation in Aquaculture: Perspectives & implementation in Vietnamese Associations**

	- **Sustainable Rice-Shrimp Farming for Climate Change Adaptation in the Mekong Delta, Viet Nam** - **Sustainable Coasts and Resilient Communities: Scaling Sustainable Aquaculture through the COAST Facility** - **Scaling-Up APEC Cooperation on Climate-Resilient Aquaculture and Sustainable Development in the Region: Challenges and Opportunities** <u>Suggested topics:</u> - Regional and international programs and initiatives to support sustainable aquaculture in the face of climate change, including knowledge sharing, capacity building, technology transfer, green finance - Experiences in mobilizing and utilizing resources from regional and international organizations for climate actions - Case studies of climate-smart aquaculture models, including ecosystem-based approaches, innovative breeding methods, technology applications, water quality management, disease prevention - Recommendations on enhancing APEC's future work, regional and global collaboration for climate-resilient aquaculture and sustainable development in the region **DISCUSSION**
11.30 – 11.40	● **Concluding Remarks**