Building Precision Fishery Model Cases in the APEC Region with Smart Technology

Policy Report

APEC Policy Partnership on Science, Technology and Innovation

January 2025

Asia-Pacific
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KEY ABBREVIATIONS

Abbreviations	Meaning
AI	Artificial Intelligence
AIS	Automatic Identification Systems
AIMDS	Artificial Intelligence Manufacturing Decision System
APEC	Asia-Pacific Economic Cooperation
CMMs	Conservation and Management Measures
CONCYTEC	National Council for Science, Technology and Technological Innovation
DBSCAN	Density-Based Spatial Clustering
EEZs	Exclusive Economic Zones
HSBI	High Seas Boarding and Inspection
ICT	Information and Communications Technology
IOT	Internet of Things
ISR	Intelligence, Surveillance, and Reconnaissance
ITRI	Industrial Technology Research Institute
IUU	Illegal, unreported and unregulated fishing
LSTM	Long Short-Term Memory
MIRDC	Metal Industries Research & Development Center
NPFC	North Pacific Fisheries Commission
ORP	Oxidation-Reduction Potential
RFMOs	Regional Fisheries Management Organizations
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprises
STI	Science, Technology and Innovation
TAC	Total Allowable Catch
USVs	Unmanned Surface Vehicles
UUVs	Unmanned Underwater Vehicles
VMS	Vessel Monitoring Systems
VR	Virtual reality
VTOL	Vertical Take-Off and Landing

Executive Summary: Final Report on Smart and Sustainable Fisheries

The fisheries and aquaculture sectors are at a critical crossroads, where the challenges of climate change, resource depletion, and global market pressures intersect with the transformative potential of low-carbon smart technologies. This report provides a comprehensive overview of how digital transformation and innovative solutions can drive sustainability, efficiency, and economic resilience in the fisheries industry across APEC economies.

Key Challenges

- Aging Workforce and Labor Shortages: The rising average age of fishers and declining workforce numbers hinder growth and innovation.
- High Carbon Emissions: The fishing industry emits significant CO_2, with traditional methods exacerbating environmental impacts.
- Declining Fish Stocks and Climate Change: Overfishing, warming waters, and disrupted ecosystems lead to reduced seafood production.
- Resistance to Technology Adoption: High costs, knowledge gaps, and cultural resistance slow the adoption of artificial intelligence (AI) and smart technologies.

Smart Technologies Driving Transformation

The report highlights several advancements addressing these challenges:

- AI-Driven Innovations: Precision fisheries leverage AI for route planning, fish detection, and automated processes, reducing waste and enhancing efficiency.
- IoT (Internet of Things) Monitoring Systems: Real-time data collection on water quality, fish behavior, and environmental conditions supports proactive decision-making in aquaculture.
- Low-Carbon Smart Fishing Fleet Systems: AI-equipped drones replace traditional fuel-consuming methods, cutting costs by 65% and achieving zero carbon emissions.
- Digital Twin Systems: Advanced simulations optimize aquaculture operations by integrating water quality monitoring, video surveillance, and feeding records.

Socio-Economic Impacts

Smart technologies are revolutionizing the industry, improving economic outcomes and social inclusivity:

- Cost Savings: Energy-efficient systems and automated operations significantly reduce operational expenses.

- Increased Productivity: Real-time data enhances resource allocation, boosting yields and market alignment.

- Community Empowerment: Digital platforms connect small-scale fishers to markets, increasing income and fostering regional economic development.

Policy and Governance

To maximize the benefits of these innovations, the report emphasizes:

- Policy Harmonization: Aligning regulations across economies to facilitate technology adoption.

- Incentives for Innovation: Providing financial support and training programs to lower barriers to entry.

- Regional Collaboration: Sharing technologies, data, and best practices to address transboundary challenges.

Policy Recommendations

- Invest in research and development for energy-efficient, AI-driven technologies.

- Build capacity through targeted training programs, particularly for women and youth.

- Foster public-private partnerships to support large-scale implementation of digital tools.

- Promote sustainability by aligning initiatives with global frameworks such as the UN Sustainable Development Goals.

Conclusion

Integrating low-carbon smart technologies offers a transformative pathway for fisheries and aquaculture. By addressing environmental, economic, and social challenges, APEC economies can build a sustainable, resilient, and inclusive blue economy. The vision for the future hinges on innovation, collaboration, and strategic policy implementation, ensuring long-term prosperity and environmental stewardship.

Preface

The aim of this project is to integrate smart technology into traditional pelagic fishery/aquaculture methods, with a focus on fostering socio-economic development and ensuring environmental sustainability. By leveraging smart technology, the project seeks to enable precision fishery methods, enhance production efficiency, and address supply chain disruptions arising from the dwindling manpower of fishermen, thereby fostering inclusive growth. Furthermore, developing precision fisheries through smart technology is poised to mitigate adverse impacts on marine ecosystems, facilitating a harmonious balance between environmental preservation and economic activities. Regional stakeholders stand to gain various benefits, including knowledge exchange on smart technology applications, advancements in digital transformation, and the enhanced utilization of AI.

To ensure that representatives of APEC economies, particularly developing economies, can fully exchange ideas and experiences concerning their economies and give feedback, an international forum was held in October 2024 to share building precision fishery model cases in the APEC Region with smart technology. The forum is a 2-day event covering keynote speeches, three main sessions with several topics

Keynote speeches:

- Experience of Promoting Smart Technology on Precision Fishery
- Intelligent Transformation Strategies for Fisheries

Session I. Technology Application and Blue Economy Development

- Japanese Fishery Policy Reform and Global Warming Impacts: Seeking Solutions through New Technologies
- Peru's Experience and Challenges Promoting the Development of Smart Fisheries Technologies in Value Chains

Session II. Building a Sustainable and Resilient Blue Granary with Smart Technologies

- How Al Anchors the Future of Fishing & Charts the Course to Sustainability
- A Decade of Small-Scale Fisheries Management Technology - From the Past and into the Future
- AloT Applications in Pelagic Fisheries
- Precision Aquaculture Environmental Detection with Artificial Intelligence Manufacturing Decision System

Session III. Driving Fishery Innovation through Digital Transformation

- Digital Innovation from the Ocean to the Table

- Smart Aquaculture Innovation under System Simulation
- Smart Fishery Innovation and Transformation

This international forum included on-site visits to fish ponds applying smart technologies and the Industrial Technology Research Institute (ITRI). Female participants from APEC economies are invited to achieve gender equality, including experts and speakers of APEC delegations, policymakers, economic representatives, academia, research institutions, and private company representatives to share information and provide opinions.

Date & Venue

The "APEC Forum on Building Precision Fishery Model Cases in the APEC Region with Smart Technology" was held on 16-17 October 2024 in Taipei. Participants were invited to participate physically in the event at Grand Hyatt Taipei. We have invited 50 speakers and experts from nine economies, including the Indonesia; Japan; Papua New Guinea; Peru; the Philippines; Chinese Taipei; Thailand; United States; and Viet Nam, to participate in this forum for experience sharing and in-depth exchanges.

1. Challenges and Needs for the Development of Smart Fisheries in APEC

1.1. Challenges

The aging workforce and labor shortages

One critical issue is the aging workforce and labor shortages. Between 2000 and 2020 in Chinese Taipei, the average age of farmers rose from 58.6 to 64.4 years, while the agricultural workforce declined by 61,000. This demographic shift underscores the difficulty of attracting younger talent to the industry, further exacerbating labor shortages. Kaohsiung, a major Chinese Taipei fishing port, faces significant challenges in an aging workforce and labor shortages.

Big carbon emission of the fishery industry

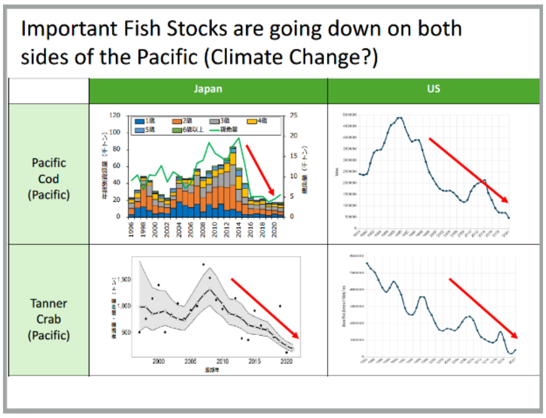
Fishing activities emit a large amount of CO_2. It is cited that in an NHK documentary last year, the trawl fisheries worldwide are estimated to emit 1 G ton of CO_2 annually.

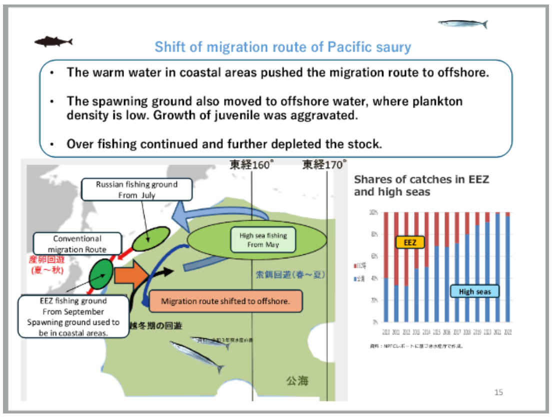
Global population growth and increase in seafood demand

The global population is expected to exceed 10 billion by 2050, and the demand for food protein will reach 500 million metric tons, representing a 38% increase over the current supply. Seafood is anticipated to be crucial in meeting this demand, as land-based protein production has limitations. Four conditions are essential for increasing seafood supply: eliminating overfishing, promoting sustainable aquaculture, revolutionizing feed for mariculture, and shifting consumer demand from meat to seafood.

Rapid decline in seafood production

It is found that the fish stock on both sides of the Pacific – Japan and the US is declining, this could be a result of climate change. Japan's total fish production dropped from 12.8 million metric tons in 1984 to 4.2 million metric tons in 2021, with distant water fishing now contributing only 6.6% of the total catch. Major fish stocks, such as Pacific saury, squid, and salmon, have significantly declined.





Climate change impact on marine resources and aquaculture species

In Japan, seawater warming caused the shift of migration route of Pacific saury, which resulted in a decrease in the fish stock. In Peru, change phenomena like El Niño and La Niña disrupt key species such as giant squid. In Chiayi, Chinese Taipei, the number of days with temperatures exceeding 35°C increased dramatically from 6.9 in 2000 to 26.2 in 2022. These rising temperatures not only disrupt marine ecosystems but also impact the viability of aquaculture operations.

Challenges in new technology adoption

For the application of AI, high initial costs, slow return on investment, and a knowledge gap about available tools and their legitimacy deter many organizations. There is resistance from workers who fear AI might replace their jobs, although evidence suggests AI enhances rather than eliminates roles by automating repetitive tasks. Elderly fishermen hesitate to use smart technologies, though they use smartphones. Specifically, there's resistance to applying smart tracking systems to manage catch amounts.

International Collaboration needs to be reinforced

International organizations such as the North Pacific Fisheries Commission (NPFC) aim to work for regional cooperation. However, there's a need for broader international collaboration to ensure the sustainability of global fish stocks. Sharing technologies, data, and best practices across borders is essential for addressing the industry's environmental and economic challenges.

Overfishing, Illegal, Unreported and Unregulated Fishing (IUU)

Global trends in fisheries management emphasize the need for sustainability. Regional Fisheries Management Organizations (RFMOs) have implemented quota management systems for key species such as tuna, billfish, and shark. These measures aim to conserve marine resources and impose additional regulatory pressures on the industry.

1.2. Needs for Blue Economy

Digital transformation

Enhancing information literacy is critical for promoting data-driven decision-making. Digitalization, research, and development efforts aim to integrate energy-efficient technologies, labor-saving machinery, and environmental innovations, such as precision aquaculture systems, to improve sustainability and productivity.

Low-carbon Smart Technology

The Smart Fishing Fleet System developed by ITRI and the Metal Industries Research & Development Center (MIRDC) replaces traditional fuel-consuming helicopters with AI-equipped drones. These vertical take-off and landing (VTOL) drones support low-carbon fishing through enhanced efficiency, digital management, and reduced environmental impact. They enable cost savings and safety improvements by facilitating rapid deployment and precise data collection.

Precision fishery systems

AI-driven innovations for route planning, fish detection, and automated processes, enhancing operational efficiency and reducing reliance on manual labor. AI has significantly transformed various aspects of the fishing industry. For instance, smart nets equipped with AI can scan and analyze fish to ensure the right species, size, and age are caught, reducing bycatch and waste. Additionally, AI-powered video recognition technology enables real-time tracking of fish populations, while satellite and GPS data help monitor fishing vessels and detect illegal activities. Furthermore, AI aids in waste management at processing plants, exploring innovative uses for fish byproducts, such as incorporating them into sustainable battery production.

Strategy on digitalization

Digitalization plays a central role in transforming fisheries and aquaculture. Systems need to be implemented for managing vessel information, catch data, and aquaculture operations to improve transparency, efficiency, and decision-making.

Strategy on research

Research and development for creating innovative solutions such as labor-saving machinery, energy-efficient equipment, environmentally friendly technologies, and precision aquaculture tools. These advancements aim to reduce costs, improve productivity, and minimize the environmental impact of fisheries and aquaculture.

Strategy on skill development

Skill development for both soft and hard skills within the industry. This includes improving information literacy and infrastructure proficiency to facilitate the adoption of new technologies. Tools such as intelligent fishing lights, precision feeding systems, and 24/7 fisheries monitoring platforms to ensure that technological innovations are effectively applied to enable research in intelligent fisheries to benefit the entire industry.

Data collection, management, and sharing among economies

Real-time data collection from fishing vessels and marketing systems is essential for effective management. Tools must be user-friendly and facilitate rapid data sharing and analysis. Massive data integration, including satellite observations, can enhance scientific research, but insufficient budgets hinder technological adoption.

Science, Technology, and Innovation in Fisheries

CONCYTEC (National Council for Science, Technology and Technological Innovation), as Peru's principal entity for promoting Science, technology and innovation (STI), focuses on long-term perspectives for fish and aquaculture stocks. The organization emphasizes the need to strengthen technology and innovation capacities, develop human resources, and facilitate better funding and articulation among institutions. Establishing a cohesive domestic STI framework and policy is a critical step to improving the sector's technological capabilities.

Policy reform for sustainability

In response to these challenges, Japan enacted a fundamental policy reform in 2018. The objectives of this reform include rebuilding fish stocks, improving fishery management through science-based approaches, and increasing income and workforce diversity within the industry. Peru’s policy is to develop STI policies, fostering collaboration between industry and academia, and promoting technology transfer

International cooperation

International cooperation is essential for ensuring the sustainability of fish stocks. In the case of Pacific saury, the Total Allowable Catch (TAC) remains excessively high at 225,000 tons, nearly double the actual catch of 120,000 tons in 2023. Current measures, such as Vessel Registry, Vessel Monitoring Systems (VMS), High Seas Boarding and Inspection (HSBI), and transshipment reporting, are inadequate to address overfishing. The slow response of RFMOs highlights the urgent need for stronger, more unified international efforts to manage fish stocks effectively.

The Japanese squid faces severe depletion. This species migrates across multiple Exclusive Economic Zones (EEZs), with spawning grounds in Japan’s waters. The absence of a cooperative framework has led to uncontrolled catches, leaving the stock heavily depleted and unlikely to recover. These examples demonstrate that without coordinated international action, achieving sustainable management of fish stocks is impossible.

EX. 1 NPFC and Pacific saury: this stock was overfished heavily.

- TAC of Pacific saury is still 1.9 times higher than the actual catch amount. (TAC=225 thousand tons whereas the total catch in 2023 is 120 thousand tons.)
- Only minimum MSC measures are in place (Vessel Registry, VMS, HSBI, transshipment reporting), but more stringent MSC measures are necessary.

RFMOs tend to be too slow to take measures to ensure sustainability of fish stocks.

EX. 2 Japanese common squid

- This squid migrate in Japanese and all other economies’ EEZs while its spawning ground is in Japanese EEZ.
- No cooperation was made to control the catches among coastal economies’
- As a result, this stock is heavily depleted. No future recovery can be expected.

Without a cooperation framework, fish sustainability cannot be achieved.

2. The Impact of the Development of Low-Carbon Smart Technology on the Fisheries Industry

The fisheries industry is one of the most critical sectors for ensuring global food security, economic development, and environmental sustainability. However, it faces mounting challenges, including climate change, overfishing, habitat degradation, and high carbon emissions. The development and adoption of low-carbon smart technologies have emerged as transformative solutions. These technologies integrate AI, renewable energy, and data-driven systems to optimize operations, reduce environmental impacts, and improve economic outcomes.

2.1. Role of Low-Carbon Smart Technology

Low-carbon smart technology integrates AI, IoT, and drones to enhance operational efficiency and environmental sustainability. AI algorithms analyze large datasets from sensors and satellite imagery to optimize fishing routes, predict fish behavior, and monitor environmental changes. These insights reduce fuel consumption and improve the efficiency of fishing operations. IoT devices collect real-time data on water quality, fish health, and weather conditions, enabling precise interventions in aquaculture and reducing waste.

In addition, renewable Energy Systems are solar panels, wind turbines, and hybrid systems that power aquaculture operations and fishing vessels, drastically reducing reliance on fossil fuels and cutting emissions.

Low-Carbon Smart Fishing Fleet System

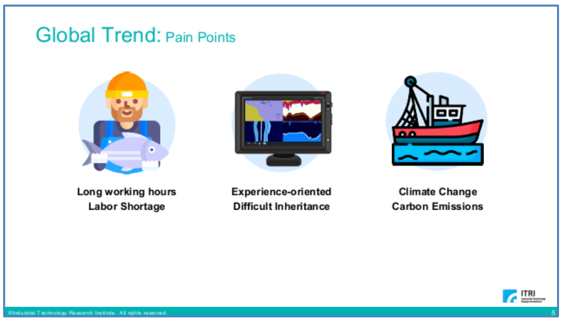
In aquaculture, AI-driven systems optimize feeding schedules and monitor water quality, ensuring precise resource use and healthier fish stocks. IoT sensors collect real-time data on parameters like temperature and oxygen levels, enabling farmers to respond proactively to environmental changes. Drones equipped with thermal imaging and environmental sensors have also proven effective in monitoring large aquaculture areas.

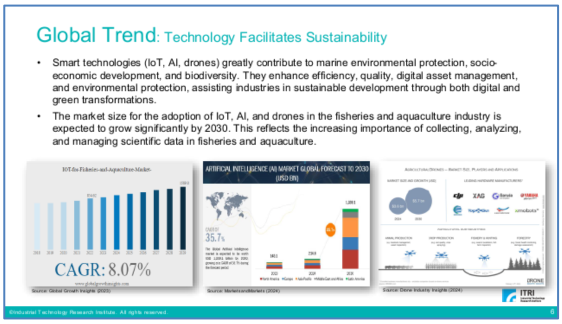
Smart Water Quality Sensing System

It automates water monitoring and management. AI-powered drones conduct autonomous sampling, cleaning, and disinfection, requiring minimal human intervention. The system provides real-time analysis of water quality parameters and AI-driven fish feeding analysis, significantly reducing the manual effort needed to maintain optimal conditions in multiple ponds. These technologies save labor, increase operational precision, and reduce errors.

Regional Implementation

Economies across the globe are adopting low-carbon smart technology in innovative ways. In Chinese Taipei, developing the Low-Carbon Smart Fishing Fleet System and AI-driven aquaculture technologies has led to significant cost reductions and enhanced productivity. These systems have achieved a 65% reduction in operational costs, a threefold increase in efficiency, and zero carbon emissions.





2.2. Examples of Low-Carbon Smart Technology

2.2.1. Digital Twin Systems: These systems integrate water quality monitoring, video surveillance, and feeding records to support decision-making in aquaculture. They are used for managing white-leg shrimp and sea bass farms, providing early warnings and improving operational management.

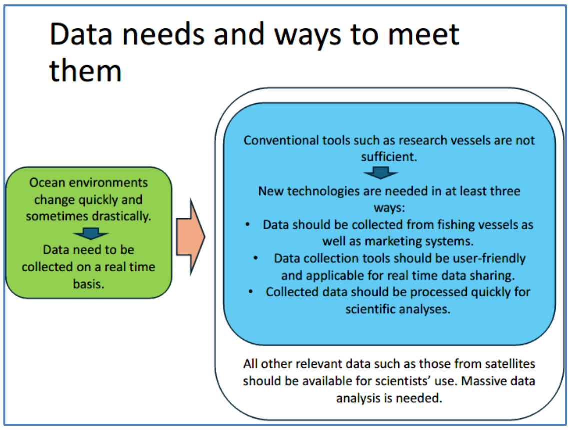
2.2.2. 24/7 Fisheries Monitoring Center: This center consolidates data from AIS, VDR, and other sources to enhance administrative efficiency and reduce costs. It supports the distinction between navigation and fishing activities and improves resource allocation.

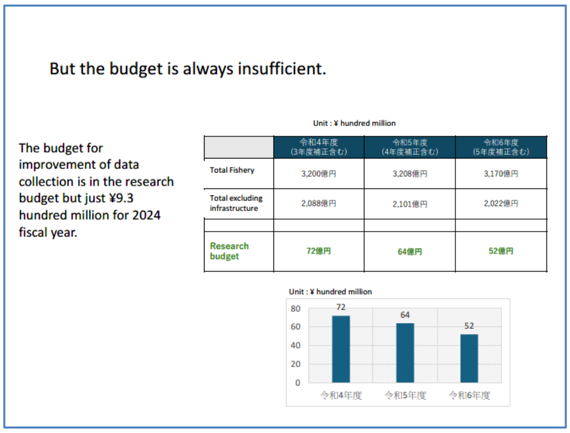
2.2.3. Intelligent LED Fish-Gathering Lamps: These lamps reduce fuel consumption by 25-30%, extend operational lifespan, and optimize spare parts management for saury and squid vessels.

2.2.4. Smart Feeding Systems: Using AI and photography, these systems optimize feeding amounts, reduce waste, and prevent water pollution, improving fish growth and operational efficiency.

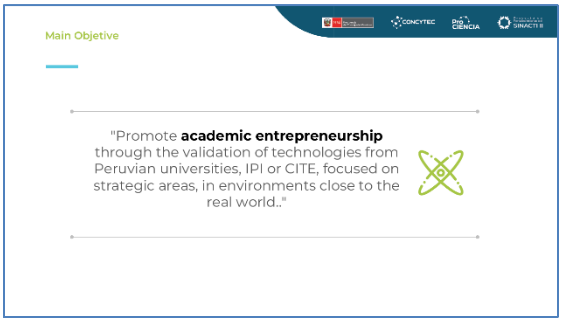
2.2.5. Cage Culture Estimation and Feeding Systems: These systems use underwater imaging to monitor fish growth and quality, enabling precise feeding and reducing fish stress during harvest.

Japan has implemented system simulation to optimize aquaculture operations. These tools allow for precisely modeling environmental conditions and operational adjustments, reducing waste, and improving resource use. New technologies are needed to cope with all the issues.





Peru has implemented various initiatives, such as developing STI policies, fostering collaboration between industry and academia, and promoting technology transfer. A pilot value chain project focused on shrimp aquaculture exemplifies these efforts, integrating industry, academia, and government stakeholders to establish sustainable practices and improve competitiveness. The project emphasizes using Information and Communications Technology (ICT), data monitoring, and circular economy practices to create a more transparent and efficient value chain. Efforts include enhancing R&D capabilities, supporting academic entrepreneurship, and validating technologies in real-world environments to ensure their applicability to industry needs.



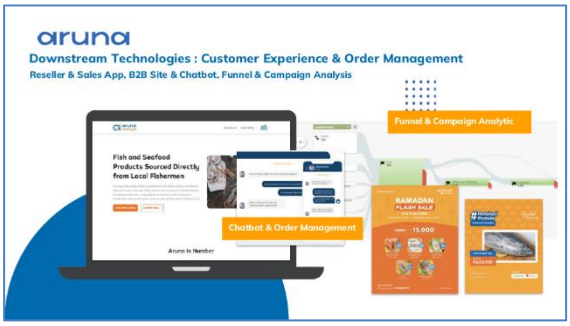
Technology application in Aruna, Indonesia

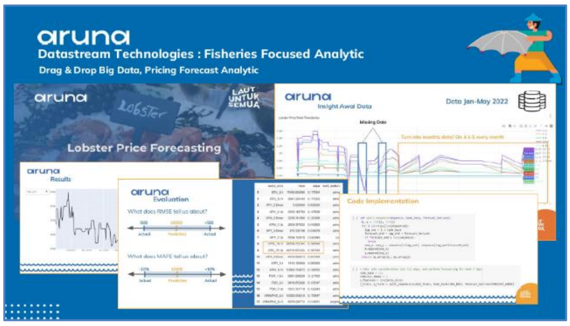
Aruna employs technology to support fishermen across various stages of the supply chain. Upstream technologies focus on enhancing fishing operations and ensuring traceability. Tools like the Aruna Heroes App and Nelayan App provide fishers with platforms to record activities and maintain detailed traceability data for their catches. Boat tracker devices improve the safety and efficiency of fishing by enabling real-time monitoring of boats. Additionally, loyalty programs encourage fishers to adopt sustainable practices and stay engaged with the platform.

Midstream technologies are designed to support small and medium enterprises (SMEs) in seafood processing and manufacturing. The Aruna Mitra SME Platform simplifies operations and helps coastal communities process and add value to seafood products effectively.

Downstream technologies enhance customer interactions and streamline order management. Apps for resellers and sales, along with a B2B website and chatbots, make it easier for customers to place and manage orders. Marketing tools, including funnel and campaign analytics, improve outreach and drive sales growth by optimizing customer engagement.

Data stream technologies provide valuable insights into fisheries operations. Big data systems and pricing forecast analytics help fishers and businesses understand market trends, optimize pricing, and make informed decisions. These technological solutions collectively empower fishermen, increase their incomes, improve safety, and promote sustainable practices, while also creating a more efficient and transparent supply chain from the ocean to the table.





2.3. Low-Carbon Smart Technology for the Economy

The economic benefits of adopting low-carbon smart technologies are multifaceted. One of the most significant advantages is cost savings. Fishing operations can lower their operational expenses by reducing fuel consumption through renewable energy systems and AI-driven optimizations. For instance, the VTOL drones equipped with AI replace traditional scouting methods, saving both time and resources while improving catch efficiency. The adoption of low-carbon smart technologies in the fisheries industry offers transformative economic and environmental impacts, reshaping the sector's sustainability and profitability:

Cost Savings

Technologies such as AI-powered systems, IoT-based monitoring, and energy-efficient equipment significantly reduce operational costs. For example, smart water circulation systems cut energy expenses by over 90%, replacing traditional water wheels. Automation of feeding and water quality management decreases waste and optimizes resource use, boosting productivity and profitability.

Enhanced Productivity

Real-time data from IoT devices improves decision-making, leading to higher yields and better resource allocation. AI-based systems predict market demands, reducing overproduction and aligning supply chains with consumer needs.

Labor saving

Low-Carbon Smart Fishing Fleet System replaces traditional, labor-intensive methods like fuel-consuming helicopters for fish detection. Instead, drones equipped with AI for fish school detection and automatic flight route planning perform these tasks. This automation reduces manual workload, increases operational efficiency by threefold, and lowers costs by up to 65%.

Economic growth in the case of Aruna

Using technology in fisheries, as demonstrated by platforms like Aruna, brings significant economic benefits, particularly for coastal communities and the broader seafood industry. By integrating technology across the supply chain, these initiatives transform traditional fishing practices into more efficient, transparent, and profitable operations.

For fishers, technology increases their income substantially. Tools for traceability, market insights, and efficient processing have allowed many fishers to multiply their earnings by three to twelve times. The economic empowerment extends beyond individual fishers to their families and communities, improving living standards for tens of thousands of people.

SMEs involved in seafood processing benefit from streamlined operations through platforms like Aruna Mitra SME. These systems help add value to raw seafood, enabling SMEs to enter new markets and achieve higher revenues. The improved efficiency also reduces waste, further boosting profitability.

Increased connectivity with domestic and international markets fosters economic growth. By utilizing e-commerce platforms, B2B sales tools, and campaign analytics, businesses can access a wider customer base. Export opportunities have expanded significantly, with seafood products now reaching multiple economies, generating substantial foreign exchange earnings.

The creation of jobs and capacity-building programs for coastal communities amplifies the economic impact. Thousands of jobs have been created in activities such as fish processing, logistics, and technology implementation. This fosters regional economic development, reduces poverty, and strengthens the resilience of coastal economies.

2.4. Low-Carbon Smart Technology for the Environment

Low-carbon smart technologies are pivotal in mitigating the environmental impacts of the fisheries industry. Traditional fishing practices are often energy-intensive and contribute significantly to greenhouse gas emissions. For example, diesel-powered fishing vessels are major contributors to CO_2 emissions. In contrast, smart technologies such as AI-driven route optimization and solar-powered systems significantly reduce the carbon footprint of fishing operations.

Improving environmental sustainability

In aquaculture, smart technologies enhance environmental sustainability by improving water quality management and reducing the reliance on chemical treatments. IoT-enabled sensors monitor critical parameters such as pH levels, dissolved oxygen, and temperature in real time, ensuring optimal conditions for fish farming. This precision reduces the overuse of resources and minimizes pollution, creating healthier aquatic ecosystems.

Reduction in Carbon Emissions

Low-carbon technologies, such as solar-powered IoT systems and AI-managed drone fleets, drastically lower the carbon footprint of fishing operations. Initiatives like carbon sequestration through aquaculture practices, including biological chain breeding methods, contribute to reducing carbon emissions.

Conservation of Marine Ecosystems

Precision fishing technologies like AI and AIoT reduce bycatch, preserving biodiversity and ensuring the sustainability of fish stocks. Integrating low-carbon smart technologies ensures economic resilience for fisheries and safeguards marine ecosystems, positioning the industry as a leader in sustainable practices.

2.5. Low-Carbon Smart Technology for Society

Low-carbon smart technologies are reshaping the social fabric of fishing communities by creating new opportunities and improving livelihoods. Adopting these technologies fosters skill development and capacity building, particularly in rural and coastal areas. Training programs in using and maintaining smart technologies empower local populations, enabling them to participate in the growing blue economy.

Digital platforms that connect small-scale fishers directly to consumers and markets eliminate the need for intermediaries, thereby increasing incomes. For instance, mobile apps and online marketplaces allow fishers to showcase their sustainably sourced products, attracting environmentally conscious buyers and enhancing economic resilience.

Inclusivity is another critical dimension. Women and underrepresented groups are increasingly involved in managing aquaculture operations and adopting new technologies. Community-based initiatives prioritizing gender equity and inclusivity ensure that the benefits of technological advancements are equitably distributed, fostering social cohesion and empowerment.

2.6. Challenges in Adoption

Despite their numerous benefits, adopting low-carbon smart technologies faces several obstacles. Financial barriers are among the most significant, particularly for small-scale operators who lack access to credit or subsidies. The high initial costs of implementing these technologies deter many fishers and aquaculture operators.

Knowledge gaps and resistance to change also pose challenges. Many stakeholders are unfamiliar with advanced technologies or lack the training to use them effectively. Additionally, cultural attachment to traditional fishing practices can hinder the adoption of innovative solutions.

Policy and regulatory inconsistencies across APEC economies further complicate the scaling of these technologies. Harmonized standards and supportive policies are essential to create an enabling environment for innovation.

2.7. Future Opportunities

The future of low-carbon smart technologies in the fisheries industry is filled with promise. Emerging trends in AI, machine learning, and advanced materials science offer exciting possibilities for enhancing efficiency and sustainability. For instance, AI-driven predictive models can help fishers anticipate shifts in fish populations due to climate change, enabling proactive and adaptive responses.

Collaborative initiatives among APEC economies can accelerate innovation and knowledge sharing. Regional partnerships can address common challenges, such as illegal, unreported, and unregulated (IUU) fishing, by leveraging shared resources and expertise.

Aligning technological advancements with global sustainability frameworks, such as the United Nations (UN) Sustainable Development Goals (SDGs), can attract international funding and support. These efforts will ensure the long-term viability of the fisheries industry.

Developing low-carbon smart technologies represents a paradigm shift in the fisheries industry. By addressing environmental challenges, enhancing economic opportunities, and fostering social inclusivity, these innovations pave the way for a more sustainable and resilient future. Overcoming barriers to adoption through strategic investments, capacity building, and policy reforms will be critical. As APEC economies continue to innovate and collaborate, the fisheries industry is poised to become a global leader in sustainability and technological excellence.

3. Best Practices for Digital Transformation

Digital transformation is not just a technological shift but a comprehensive restructuring of how fisheries and aquaculture operate, addressing inefficiencies and unlocking new opportunities for sustainability and growth. By embracing technologies such as AI, IoT, blockchain, and advanced analytics, stakeholders can revolutionize the management of resources, improve economic outcomes, and meet growing global demands for traceability and sustainability.

3.1. Digital transformation implementations in APEC economies

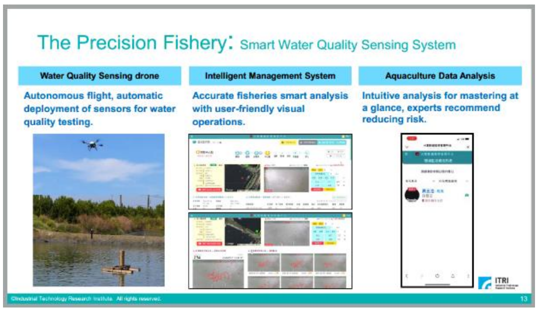
Several APEC economies have embraced AIoT technologies, showcasing significant advancements in digital transformation across the region. In Chinese Taipei, low-cost AI buoys have been developed to monitor offshore water quality, significantly enhancing the management of aquaculture cages. Indonesia has implemented IoT platforms such as Jala and eFishery to optimize shrimp farming practices, reducing operational risks and improving efficiency. Japan and Singapore have utilized Umitron systems, integrating computer vision with sensor data to maximize feeding processes in aquaculture. These implementations exemplify how digital transformation revolutionizes fisheries and aquaculture across APEC economies.

Speakers at the forum demonstrated the digital transformation implemented in APEC economies.

3.2. Experience of Promoting Smart Technology on Precision Fishery

Mr. Kenny Yeh-Kai Chou (ITRI, Chinese Taipei)

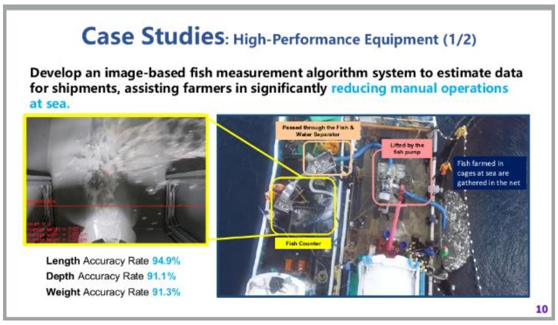
ITRI developed the Low-Carbon Smart Fishing Fleet System, replacing traditional fuel-powered helicopters with AI-equipped VTOL drones. These drones enhance operational efficiency and reduce environmental impact through precise data collection and route optimization. Additionally, the Smart Water Quality Sensing System uses IoT and AI for real-time monitoring of aquaculture environments, automating feeding schedules, and alerting anomalies to ensure sustainability.

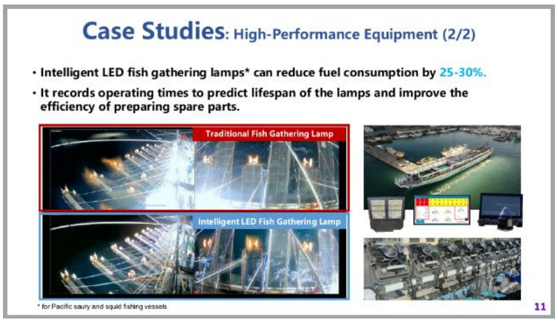


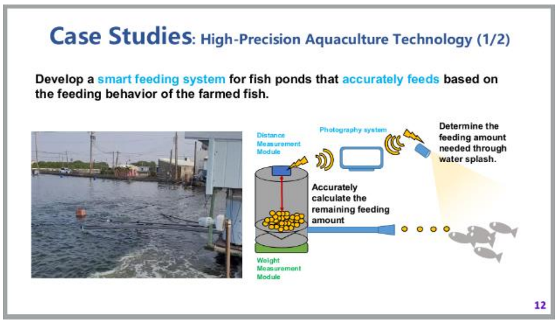
3.3. Intelligent Transformation Strategies for Fisheries

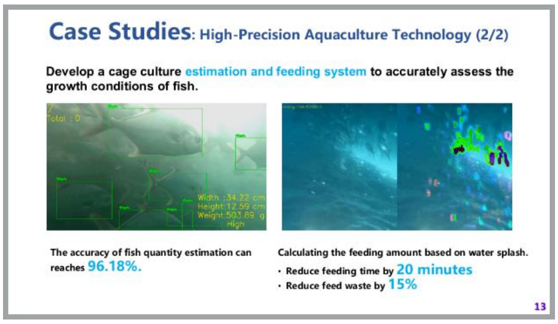
Ms. Fang Lan Chen (Fisheries Agency, Chinese Taipei)

Chinese Taipei employs Digital Twin Systems integrating water quality monitoring, video surveillance, and feeding records to manage aquaculture. Smart LED fish-gathering lamps reduce fuel consumption by 30%, while AI-powered feeding systems optimize resource use. A 24/7 Fisheries Monitoring Center consolidates data from multiple sources, improving administrative efficiency and compliance with international standards.





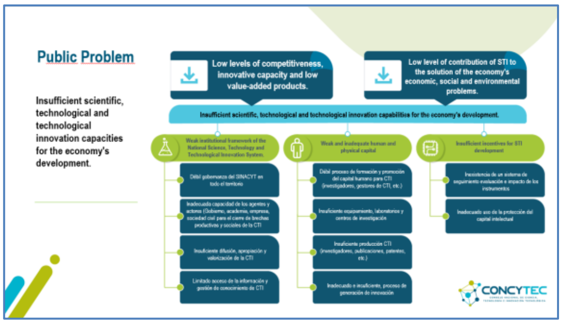


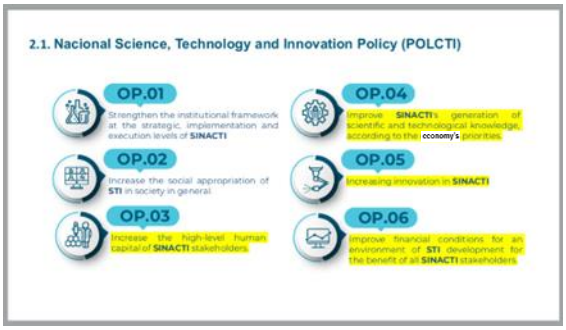


3.4. Peru's Experience and Challenges Promoting the Development of Smart Fisheries Technologies in Value Chains

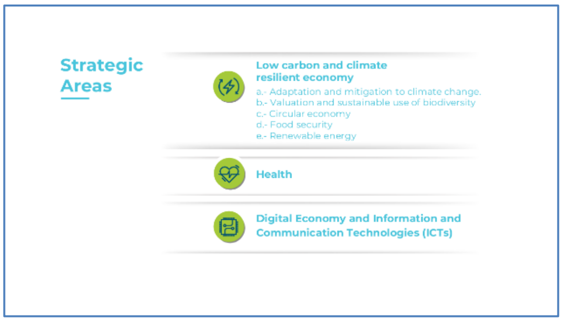
Mr. David Lujan (CONCYTEC, Peru)

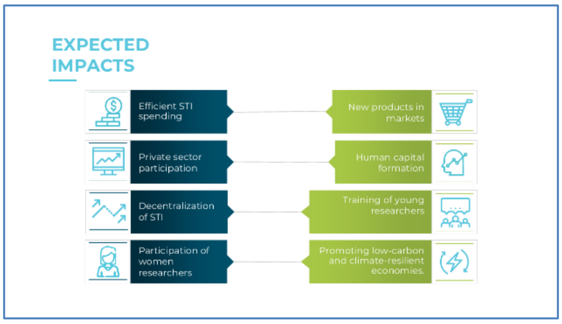
Mr. Lujan highlighted the importance of science, technology, and innovation (STI) in addressing the needs of the fisheries and aquaculture sectors, particularly through the development of strategic frameworks and collaboration with various stakeholders.

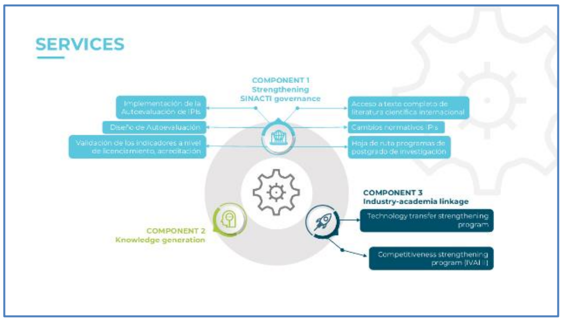




STI in Fisheries Peru integrates ICT tools in shrimp aquaculture. Collaborative programs between industry and academia focus on validating technology through pilot projects, ensuring applicability to real-world challenges. These tools streamline data collection, improve sustainability, and enhance competitiveness in global markets.







3.5. How AI Anchors the Future of Fishing & Charts the Course to Sustainability

Neil Sahota (ACSI Lab, USA)

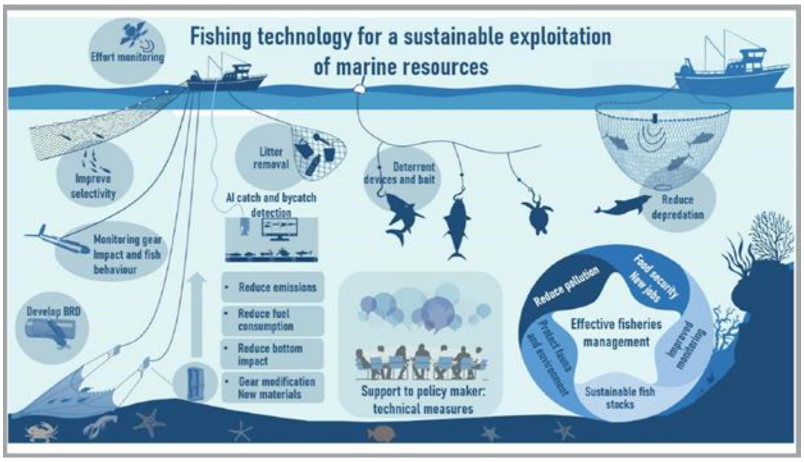
AI-enabled fishery tools include smart nets that scan fish for species, size, and age, reducing bycatch. Real-time ecosystem monitoring uses satellite and GPS data to track illegal fishing and population health. AI in aquaculture manages feeding schedules, tracks growth rates, and detects infections, optimizing productivity while minimizing waste.

IoT and sensor-based systems include sensors for fish tracking, aquafarm monitoring, and cold storage management, ensuring real-time environmental data collection and operational precision. AI-powered nets significantly reduce bycatch by identifying species, size, and age before capture, promoting sustainable fishing practices. Precision fishing technologies leverage real-time data on fish schools, water conditions, and obstacles, often pairing AI robots with human-operated vessels to enhance efficiency and adaptability.

Real-time ecosystem monitoring further strengthens sustainability efforts, with AI models predicting fish health, population trends, and environmental risks, enabling proactive measures to address ecosystem changes. Closed-loop aquaculture systems, managed by AI, operate with zero waste, integrating blockchain to ensure transparency and sustainability certifications.

Enhanced workforce management includes AI-powered training and wearable AI devices that provide real-time operational support to fishermen. To address climate challenges, AI aids in resilience planning and risk prediction, ensuring fisheries can adapt to changing conditions. Collaborative efforts across global fisheries are facilitated by shared AI models and data exchanges, automating legal compliance and ethical practices.

Predictive maintenance and cost management tools streamline operations, reducing downtime and operational expenses while maximizing efficiency. These technologies collectively drive precision fishing, align operations with the blue economy principles, and ensure environmental sustainability, making fisheries a model for technological and ecological innovation.



3.6. A Decade of Small-Scale Fisheries Management Technology - From the Past and into the Future

Dr. William Hsu (NTOU[1], Chinese Taipei)

Integrating advanced technologies has transformed catch management in fisheries, addressing challenges of efficiency, sustainability, and regulatory compliance. Real-time monitoring systems have revolutionized how catch data is gathered and managed. Technologies like IoT-enabled sensors and onboard cameras allow fisheries to monitor catch size, species composition, and location. These systems also record environmental data, such as water temperature and salinity, aiding in operational planning. Additionally, e-logbooks provide an accurate and

[1] National Taiwan Ocean University

instant way to document catch information, replacing traditional paper logs and ensuring compliance with regulations.

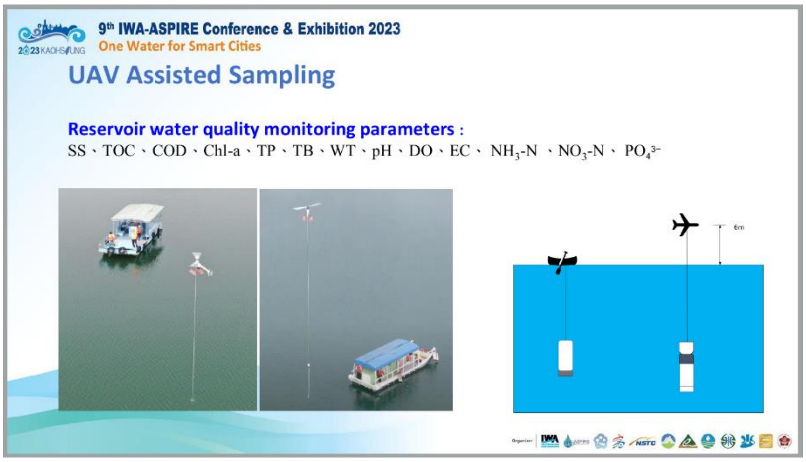
AI plays a pivotal role in catch management. AI-powered nets minimize bycatch by identifying fish species, size, and age before capture, ensuring that only target species are caught. Analytical tools like Density-Based Spatial Clustering (DBSCAN) and Long Short-Term Memory (LSTM) models further enhance understanding of catch distribution, helping fishers optimize efforts while minimizing resource use. AI-integrated video monitoring systems improve species identification and ensure regulatory adherence by analyzing vessel activities and catch in real-time. These systems help fisheries align operations with legal and sustainability standards.

Real-time tracking tools equipped with GIS technology enhance operational efficiency by pinpointing fishing locations and enabling precise vessel navigation. To address regulatory demands, systems such as VMS and Automatic Identification Systems (AIS) ensure vessels adhere to authorized fishing zones and quotas. These technologies, coupled with real-time data-sharing platforms, facilitate compliance with fishing regulations and reduce illegal activities. Platforms like iFISH combine AI, GIS, and video monitoring to streamline compliance, detect illegal fishing, and ensure sustainable resource use.

3.7. AIoT Applications in Pelagic Fisheries

Dr. Max Lo (Geosat Aerospace, Chinese Taipei)

AIoT integrates drones with multispectral and thermal imaging for fish behavior analysis and water sampling. IoT buoy sensors monitor dissolved oxygen, salinity, and temperature, while AI platforms analyze data for predictive insights. VTOL drones streamline coastal surveillance, addressing illegal fishing and environmental monitoring challenges.



3.8. Precision Aquaculture Environmental Detection with AIMDS

Dr. Po-Tsang Lee (NTOU, Chinese Taipei)

Dr. Lee's AI-driven systems include water quality sensors for dissolved oxygen, pH, and ammonia levels. Automated feeding systems based on AI analysis optimize schedules and reduce waste. Cloud-based platforms track historical data for predictive risk management, enhancing sustainability and reducing labor dependency.

The concept of precision fishery leverages advanced technologies to optimize aquaculture and fishery operations, ensuring sustainability, efficiency, and environmental stewardship.

Artificial Intelligence Manufacturing Decision System (AIMDS)

The AIMDS facilitates precise aquaculture management by integrating data from water quality sensors, growth records, and environmental conditions. Real-time data collection and cloud-based storage allow automated risk assessment, enabling farmers to transition from reactive to proactive management. This system includes features like multi-risk warnings, expert consultations, and traceable record-keeping, ensuring optimal decision-making.

Water Quality Monitoring and Early Warning Systems

Advanced water quality sensors monitor parameters like temperature, pH, dissolved oxygen, and salinity. Automated systems analyze water data, providing real-time warnings for risks such as oxygen depletion or contamination. This allows immediate intervention, improving fish health and survival rates.

Intelligent Feeding Management Systems

AI-powered feeding systems determine the precise amount of feed needed based on fish behavior and environmental data. These systems reduce waste, optimize growth, and minimize the environmental impact of overfeeding. Data from underwater imaging and sonar analysis supports accurate decision-making for feeding schedules.

Underwater Sonar and Image Analysis Technology

Sonar and stereoscopic imaging provide detailed data on fish populations, including size, weight, and activity. AI models, such as Mask R-CNN, analyze fish skeletons to estimate body dimensions, aiding in grading and inventory management.

Intelligent Fish Transfer and Grading Pumps

These systems automate the grading of fish by size and weight while minimizing stress and handling errors. By integrating AI and image recognition, the pumps ensure safe and efficient fish transfer, optimizing aquaculture processes.

Smart Cage Monitoring Systems

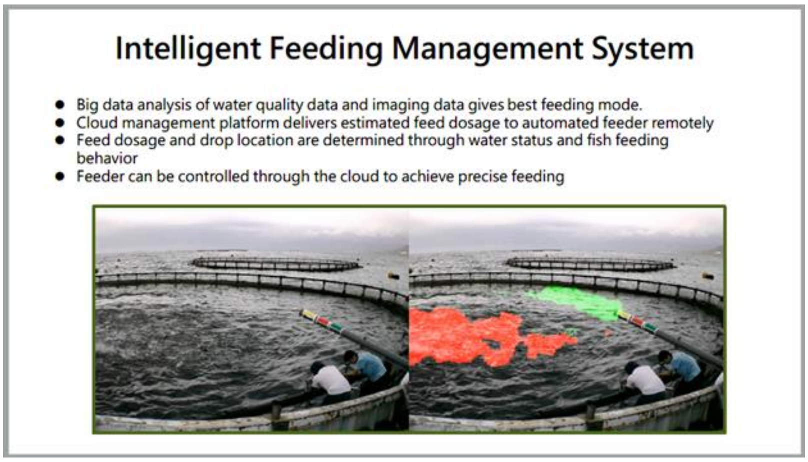
Big data analytics and AI integrate underwater and sonar imaging, water quality monitoring, and feeding data into a unified cloud platform. These systems provide insights into fish behavior and environmental conditions, enabling precise adjustments to maximize productivity.

Intelligent Underwater Net Cleaning Systems

Automated cleaning devices equipped with cameras detect algae buildup and cage damage. These systems trigger cleaning mechanisms and alert operators to maintain an optimal environment for fish growth, reducing losses and preventing fish escapes.

VR-Based Fish Breeding and Cloud Computing Systems

Virtual reality (VR) interfaces simulate equipment placement and operational scenarios, improving planning and training. These systems allow users to visualize and mitigate potential issues before they occur.



3.9. Digital Innovation from the Ocean to the Table

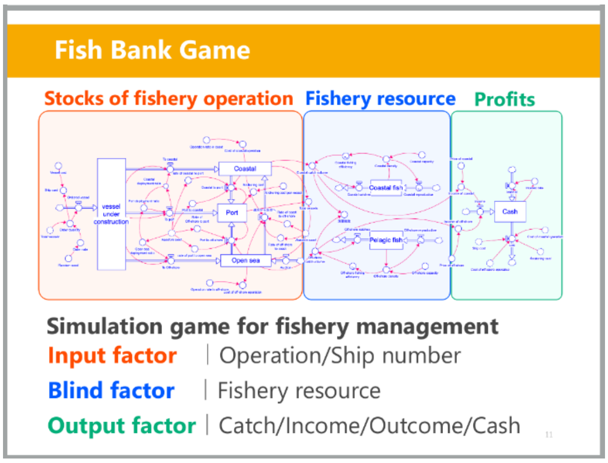
Utari Octavianty (Aruna, Indonesia)

Aruna employs mobile apps for fishermen to log catch data, ERP systems for supply chain optimization, and e-commerce platforms connecting local producers to international markets. AI tools analyze price trends, ensuring fair trade and reducing waste while improving transparency across the seafood value chain.

3.10. Smart Aquaculture Innovation under System Simulation

Dr. Kenji Yasuda (Japan Fisheries Research and Education Agency, Japan)

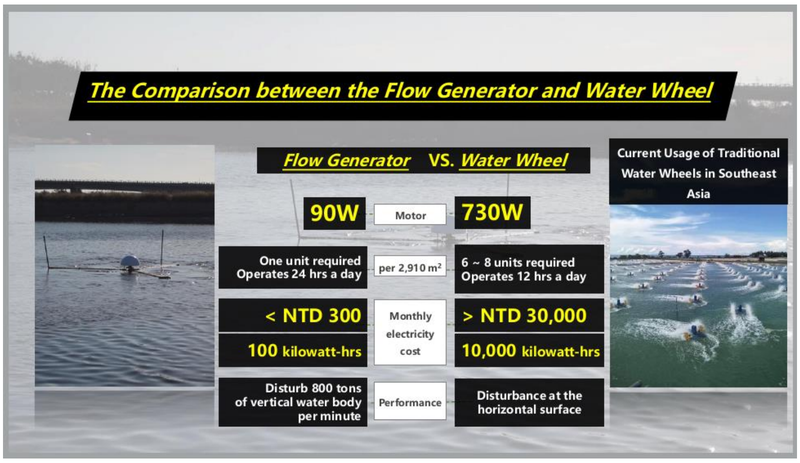
System simulation models by Dr. Yasuda use feedback loops and scenario analysis for Kuruma prawn farming. Simulations optimize seed inputs, predict growth trends, and adjust shipping strategies. Digital Twin technology replicates aquaculture environments, enabling real-time monitoring and decision-making under variable conditions.



3.11. Smart Fishery Innovation and Transformation

Mr. Guo Liang Huang (APOLLO, Chinese Taipei)

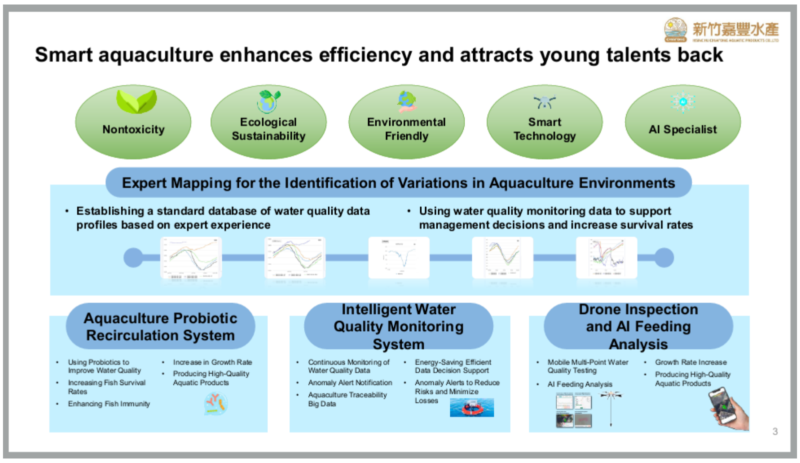
The APOLLO system uses solar-powered AIoT platforms for water quality monitoring and automated management. A flow generator technology improves water circulation with 90% energy savings. Co-culture systems integrate species like milkfish and mussels, enhancing ecological balance and reducing dependency on chemical inputs.



3.12. Organic, Pesticide-Free Smart Mullet Aquaculture

Mr. Fong-Li Hsu (Chia Fong Aquatic Products Co., Chinese Taipei)

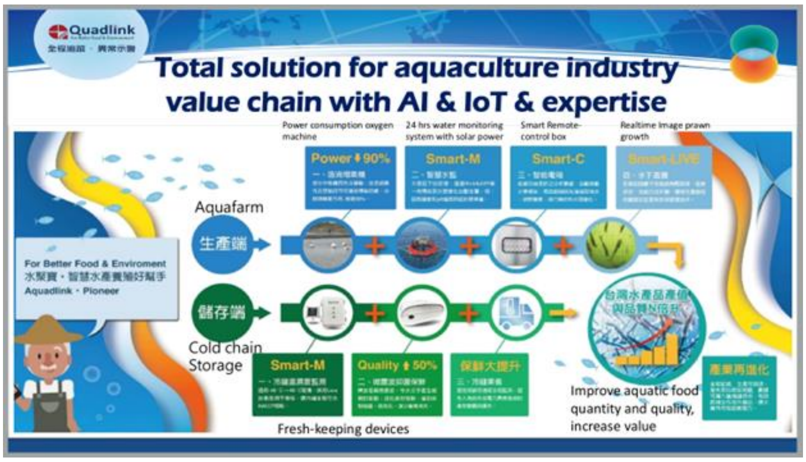
Chia Fong's probiotics-based systems enhance fish immunity and improve water quality. AI drones track aquaculture conditions, providing real-time data for optimal resource use. Big data platforms analyze trends and maintain traceability, ensuring sustainability and reducing environmental impact.



3.13. Smart Technology Solutions from Fish Ponds to Dining Tables

Ms. Penny Chien (Quadlink Technologies Co., Chinese Taipei)

Quadlink's Aquadlink platform integrates IoT with smart water quality monitors and nano-level air aerators for efficient oxygenation. Underwater cameras provide live feeds for health monitoring, and cloud-based systems ensure product traceability from aquaculture to retail, enhancing food safety and market access.



An in-depth analysis of best practices to guide the effective implementation of digital transformation in the fisheries sector is further provided, highlighting critical success factors and real-world case studies.

3.14. Technological Integration

A cornerstone of digital transformation is the seamless integration of advanced technologies into fisheries and aquaculture systems. Technological integration ensures operations are optimized, resources are utilized efficiently and minimizes environmental impacts. Key components include:

IoT Sensors and Devices

IoT technologies are widely adopted to gather real-time data on environmental conditions, fish health, and operational metrics. For example, IoT-enabled water quality monitoring systems track pH levels, temperature, and dissolved oxygen, providing actionable insights that enable timely interventions and reduce resource wastage.

AI and Predictive Analytics

AI-powered systems can analyze patterns and predict outcomes, allowing operators to optimize feeding schedules, anticipate risks, and adapt to changing environmental conditions. This reduces operational costs while ensuring consistent yields.

Automated Feeding Systems

Advanced automation technologies optimize feeding practices in aquaculture by using AI to determine the appropriate quantities and timing of feed distribution, minimizing waste and promoting fish health.

3.15. Stakeholder Collaboration

Digital transformation is a collaborative effort that involves various stakeholders, including fishers, technology providers, researchers, and policymakers. Collaboration ensures that digital initiatives are aligned with the needs and priorities of all participants. Best practices include:

Public-Private Partnerships

These partnerships are crucial in funding and implementing large-scale digital transformation projects. Economies can provide policy support and funding, while private enterprises contribute technological expertise and innovation.

Community-Based Engagement

Engaging local communities in the design and implementation of digital tools ensures that solutions are context-specific and meet local needs. Community involvement fosters ownership and long-term sustainability.

International Collaboration

Fisheries often span multiple jurisdictions, requiring regional cooperation. Initiatives such as shared data platforms and joint research programs among APEC economies can enhance collective outcomes.

3.16. Capacity Building and Education

The success of digital transformation depends on the skills and knowledge of those implementing and using the technologies. Capacity-building initiatives should address skill gaps and empower stakeholders at all levels. Best practices include:

Comprehensive Training Programs

Develop training workshops for fishers, aquaculture professionals, and policymakers, covering digital literacy, technology use, and data interpretation. These programs should be tailored to the specific needs and capabilities of the target audience.

Focus on Women and Youth

Special initiatives to include women and young professionals ensure broader participation and bring diverse perspectives to digital transformation projects.

Collaboration with Academia

Universities and research institutions can play a pivotal role in advancing digital transformation through research, training, and the development of innovative solutions.

3.17. Real-world Applications and Success Stories

Successful case studies provide valuable insights into the potential and implementation of digital transformation in fisheries:

Aruna Digital Platform

Aruna connects fishers in Indonesia to markets through a digital ecosystem, streamlining operations and enhancing income through direct sales.

IoT in Chinese Taipei Aquaculture

IoT sensors deployed in aquaculture farms in Chinese Taipei monitor critical water quality parameters, leading to higher yields and reduced environmental impact.

3.18. Future Directions and Innovations

Technological advancements and global sustainability priorities will shape the future of digital transformation in fisheries and aquaculture.

AI-Driven Ecosystem Management

Using AI to model and predict ecosystem changes will enable more sustainable resource management.

Advanced Automation

Fully automated systems for feeding, harvesting, and monitoring will further reduce labor and resource requirements.

Integration with Global Goals

Aligning digital transformation with the UNs SDGs will ensure a focus on long-term sustainability and inclusivity.

4. Lessons Learned and Policy Recommendations targeted at APEC economies

The fisheries and aquaculture sectors are integral to the economies and food security of APEC economies, representing a critical intersection of economic activity, environmental sustainability, and social well-being. Over the past decade, numerous initiatives and pilot projects have demonstrated the potential of technological innovation and regional collaboration to address challenges faced by the fishery industry. This chapter synthesizes key lessons learned from these efforts and offers comprehensive policy recommendations tailored to the unique contexts of APEC economies. By leveraging these insights, APEC members can lead the way in developing a sustainable, resilient, and inclusive fisheries sector.

4.1. Model Cases of Precision Fishery:

Low-Carbon Smart Fishing Fleet System for Pelagic Fishery

This system demonstrates how smart technology can drive sustainability and efficiency in fisheries. By replacing fuel-intensive helicopters with VTOL drones, this system significantly reduces environmental impact, achieving zero carbon emissions. The integration of AI enhances operational efficiency, offering features such as automatic route planning and fish school recognition, which streamline operations and improve outcomes. Deploying multiple drones simultaneously allows for broader and more effective monitoring, tripling the efficiency of traditional methods. Additionally, the system eliminates the risks associated with human-operated helicopters, enhancing safety and reducing costs by 65%. Collaborations with major fishing companies in Kaohsiung, such as tests near Kosrae Island, have validated the system’s effectiveness in real-world applications.

Smart Water Quality Sensing System for Aquaculture

This system exemplifies the use of AI and automation in aquaculture. This system leverages drones to deploy sensors that precisely measure six critical water quality parameters, providing actionable insights and anomaly alerts. Maintenance-free features, including automatic cleaning, disinfection, and charging, ensure uninterrupted operation. The AI-driven analysis also aids in understanding fish-feeding behaviors and optimizing aquaculture practices. The system makes water quality data easily accessible through intuitive user interfaces, offering clear and actionable insights for managing multiple ponds efficiently. Field implementations in collaboration with Quadlink Technology and Hsinchu Chia Fong Aquatic Products have proven the practicality and effectiveness of this technology in real-world aquaculture scenarios.

Precision Fishery Ecosystem

The ecosystem system highlights a collaborative and integrated framework that supports the sustainable development of fisheries and aquaculture through smart technology. This ecosystem involves multiple stakeholders, each critical in driving innovation and addressing industry challenges.

Industry needs

On the industry side, the ecosystem involves active participation from associations, pelagic fishery operators, aquaculture businesses, and research institutes. Their collaboration ensures that the technologies address real-world challenges, such as labor shortages, environmental sustainability, and cost reduction.

Policy formation

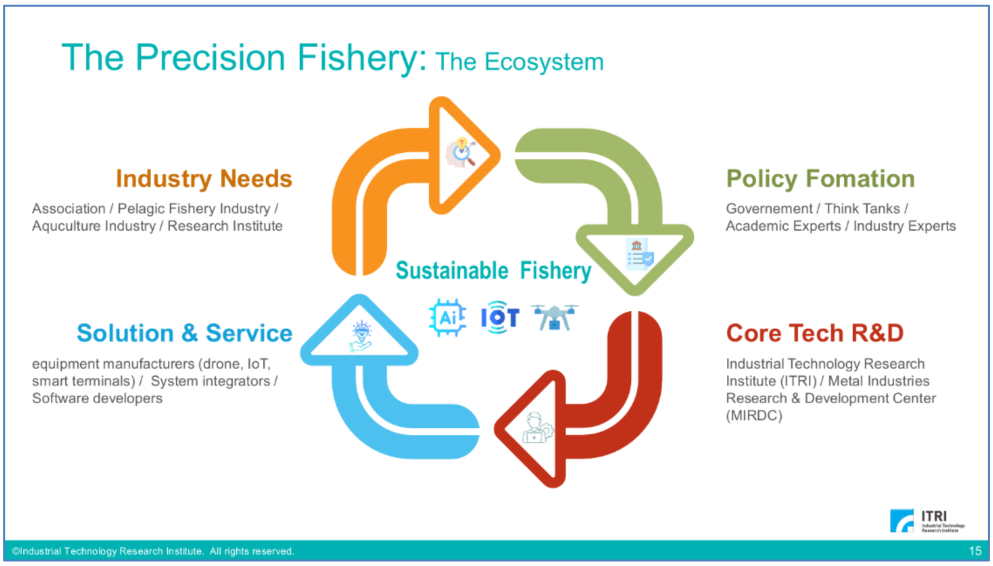
Policy formation is another vital component, with the economy, think tanks, academic experts, and industry stakeholders working together to create supportive regulatory and operational frameworks. These policies ensure that technological solutions align with environmental and economic goals, facilitating industry-wide adoption.

Core Tech R&D

At its core, the ecosystem is built on research and development (R&D) led by institutions such as ITRI and MIRDC. These organizations focus on developing advanced technologies, including IoT, AI, drones, and smart systems, tailored to meet the needs of fisheries and aquaculture industries.

Solution & Service

The ecosystem also includes solution and service providers, such as drone manufacturers, IoT equipment suppliers, system integrators, and software developers. These entities translate R&D into practical tools and services that enhance the efficiency and effectiveness of fishery operations, from smart water quality sensing to low-carbon fishing fleet management.



4.2. Achievement of the Precision Fishery

Cost reduction/Increase in efficiency

The Precision Fishery initiative has achieved significant milestones in transforming the fishing industry through smart technologies. Adopting drone fleets for fish detection has drastically reduced operational costs by 65% while tripling efficiency. Flexible multi-drone patrols enable the automatic identification of fish schools, allowing for better utilization of fishing opportunities.

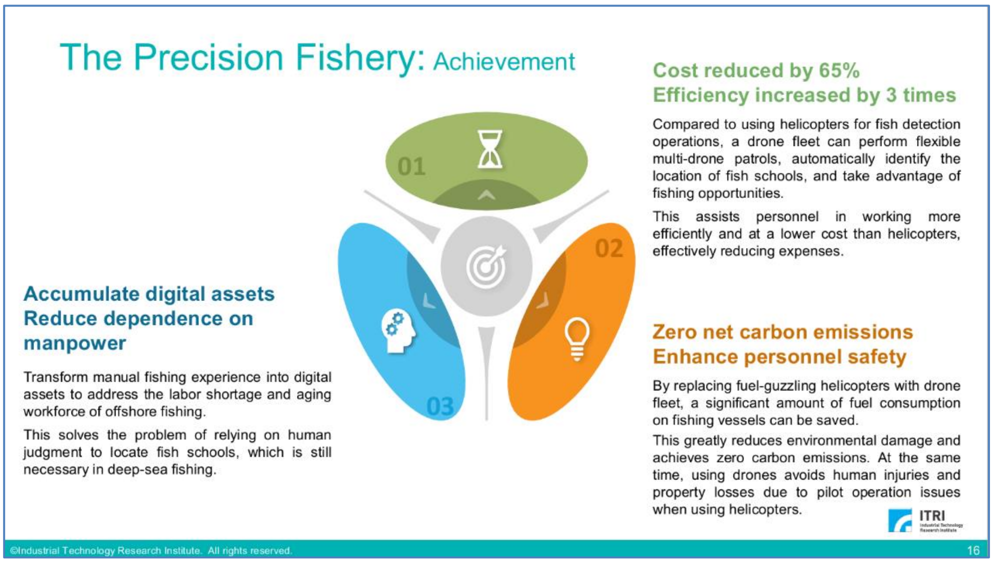
Accumulate digital assets/Reduce dependence on Manpower:

This initiative has also facilitated the digital transformation of traditional fishing practices into digital assets. This shift addresses labor shortages and the challenges posed by an aging workforce. By reducing dependence on human judgment for locating fish schools, the Precision Fishery initiative paves the way for a more efficient and sustainable future in deep-sea fishing.

Zero net carbon emissions/Enhance personnel safety

The transition to drone technology has also resulted in zero carbon emissions, replacing fuel-consuming helicopters and significantly reducing environmental damage. Additionally, drones enhance personnel safety by eliminating the risks of piloting helicopters and avoiding human injuries and property losses.

This well-rounded ecosystem fosters the creation of sustainable fisheries, balancing environmental protection with economic growth. By leveraging cross-sector collaboration and promoting early stakeholder involvement, the ecosystem accelerates the adoption of smart technologies, transforming traditional practices into efficient, data-driven solutions. This model is replicable and adaptable, enabling its application across different regions and industries.



4.3. Case: A Decade of Small-Scale Fisheries Management Technology

The implementation of technologies in small-scale fisheries management in Chinese Taipei, as depicted in the shared images, is multifaceted and focuses on the following areas:

Real-Time Monitoring Systems

The fisheries monitoring system was developed in response to international regulations, particularly after receiving a yellow card in 2016. Initiated in 2017, this system enables real-time monitoring of fishing vessel fleets. It includes tools like Automatic Identification Systems (AIS) and data integration platforms that track vessel movements, catch quantities and compliance with the Distant Water Fishing Act. Over the years, the system expanded to cover coastal, recreational, and specialized vessels.

Artificial Intelligence for Catch Distribution

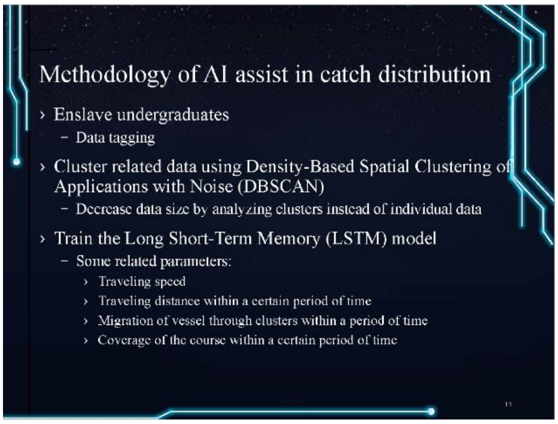
AI methods are employed to optimize the understanding of catch distribution. Techniques like DBSCAN reduce data complexity by clustering large datasets, while LSTM models analyze parameters such as vessel speed, migration patterns, and spatial coverage over time. These approaches ensure efficient data management and provide actionable insights for better fisheries planning.

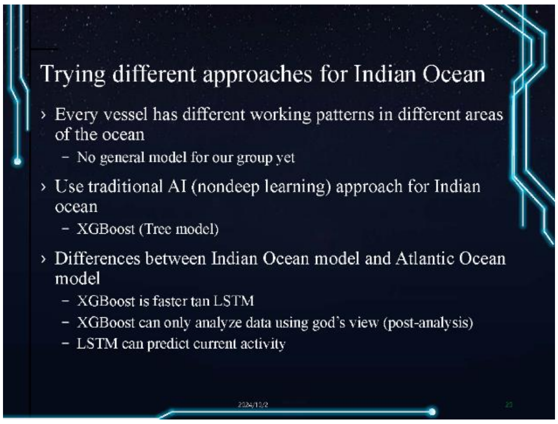
Advanced Data Analytics

Traditional AI models like XGBoost are utilized to analyze fishing patterns in specific regions, such as the Indian and Atlantic Oceans. These models focus on differences in vessel behavior across regions, leveraging non-deep learning approaches for rapid post-analysis.

Challenges in Automation

Efforts to automate fish catch identification face challenges due to diverse vessel designs, fishing methods, and data collection difficulties. Observers and advanced imaging systems are deployed on select vessels to overcome issues related to sample variability and species targeting. These systems aim to improve species identification and streamline data processing, though further technological refinement is needed.





4.4. Case: Optimizing Small-Scale Offshore Fisheries Using VTOL Drones and Collaborative USV/UUV Models

VTOL drones are revolutionizing fisheries management by utilizing cutting-edge technologies for various applications. These drones operate using advanced sensor systems, GPS navigation, and real-time data-sharing capabilities, making them a versatile tool in addressing challenges such as overfishing, operational inefficiencies, and environmental sustainability.

Fish Location and Tracking

Equipped with ISR (Intelligence, Surveillance, and Reconnaissance) capabilities, VTOL drones use thermal imaging, multispectral cameras, and SAR radar systems to detect fish schools. These sensors analyze surface conditions, temperature variations, and fish movement patterns. The data collected enables VTOL drones to precisely identify fish locations, often associated with migratory species, and relay this information back to vessels for targeted fishing.

Feeding Delivery and Monitoring

In aquaculture systems, VTOL drones are used for feeding fish in remote box-net setups located offshore. GPS-guided VTOL drones ensure even distribution of feed, reducing the risks of overfeeding or underfeeding. Additionally, VTOL drones monitor fish behavior from above, providing real-time insights into fish activity, health, and feeding efficiency. This dual functionality of feed delivery and behavioral monitoring enhances productivity and reduces labor costs.

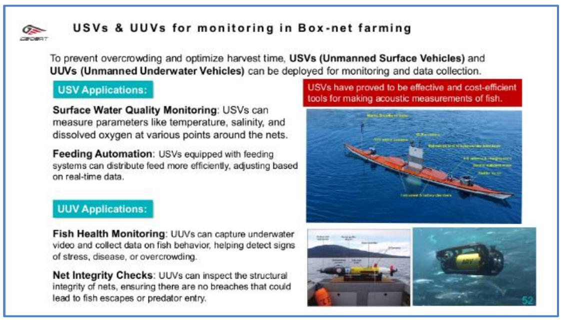
Collaborative Use with USVs and UUVs

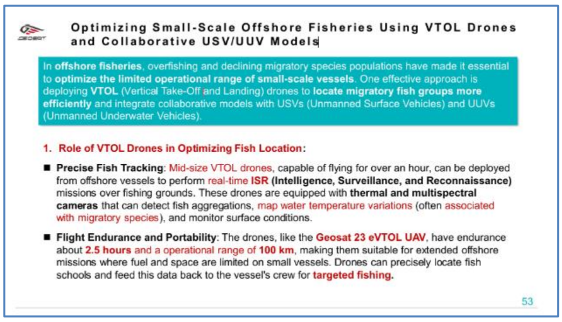
VTOL drones often operate alongside Unmanned Surface Vehicles (USVs) and Unmanned Underwater Vehicles (UUVs) to optimize data collection. While VTOL drones focus on aerial surveillance and surface monitoring, USVs measure water parameters like salinity, oxygen, and temperature. UUVs dive deeper, inspecting net integrity and fish behavior. Together, these technologies provide a comprehensive monitoring solution for both aquaculture and wild fisheries.

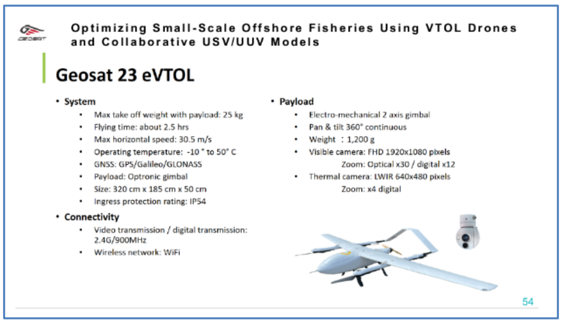
Real-Time Data Sharing

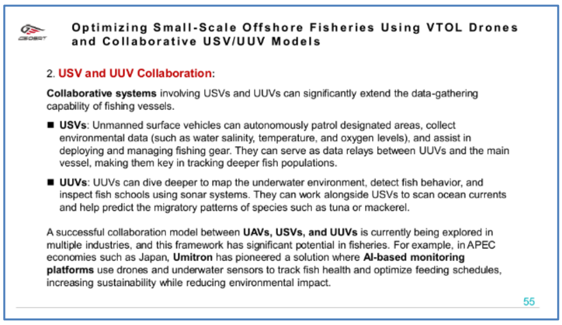
VTOL drones relay real-time data to vessels via advanced communication systems. This enables dynamic decision-making during fishing operations, such as adjusting routes or strategies based on current fish locations. These communication capabilities also ensure seamless collaboration between aerial VTOL drones and other unmanned vehicles in the ecosystem.

VTOL drones are integral to modern fisheries management by leveraging real-time data, advanced sensor technologies, and coordinated operations. Their ability to perform diverse tasks, from fish detection to feeding automation and collaborative monitoring, positions them as a critical tool in promoting sustainable and efficient fishing practices.









4.5. Case: Precision Aquaculture Environmental Detection with Artificial Intelligence Manufacturing Decision System

AI transforms aquaculture management by integrating advanced monitoring, decision-making systems, and automated operations. The adoption of AI enables precision aquaculture, reducing risks, improving productivity, and ensuring sustainability.

Intelligent Environmental Monitoring Systems

AI-powered systems continuously monitor water quality parameters, including temperature, pH, dissolved oxygen, and salinity. These systems utilize wireless water quality detection instruments, underwater sonar, and imaging technologies. AI analyzes real-time data to provide early warnings of adverse conditions, helping farmers take proactive measures to maintain optimal environmental conditions.

Smart Feeding Management

AI-driven feeding systems optimize feed distribution based on data analysis of fish behavior and water conditions. These systems utilize underwater and surface imaging to assess fish activity and population density. Big data analytics and cloud management platforms calculate precise feed dosages and locations to minimize waste. This approach improves feeding efficiency, reduces costs, and enhances fish growth.

Fish Behavior and Health Analysis

AI leverages sonar and stereoscopic imaging technologies to analyze fish behavior, body size, and population density. By combining sonar data with AI models like Mask R-CNN, the system provides detailed insights into fish health, movement patterns, and stress levels. This information supports better decision-making for harvest timing and health management.

Automated Fish Grading and Transfer

AI-powered systems automate fish grading based on size and weight. These systems use image recognition to accurately classify fish and reduce human error. Intelligent pumps and separators improve the efficiency of transferring fish, ensuring the safety of both fish and personnel while streamlining the processing workflow.

Underwater Net Cleaning and Maintenance

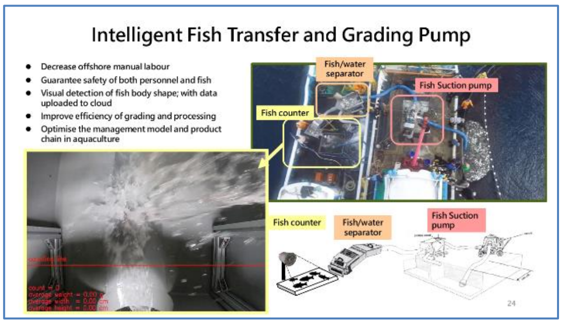
AI-based underwater net cleaning machines detect algae buildup and damaged cage sections using integrated cameras. These systems trigger automated cleaning mechanisms and alert operators to potential risks, ensuring an optimal environment for fish growth while reducing the risk of fish escape.

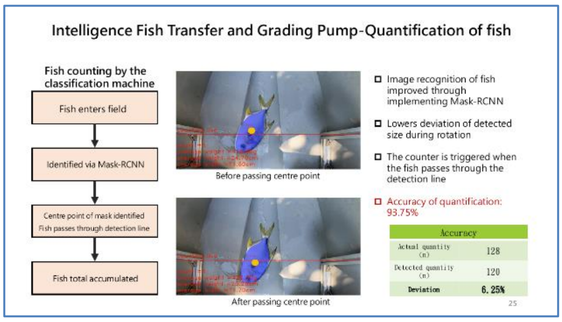
Data-Driven Risk Management

AI integrates data from multiple sources, including water quality, fish behavior, and environmental conditions, into a unified monitoring platform. The system visualizes data and provides actionable insights to address real-time risks. By transitioning from reactive to proactive risk management, AI enables farmers to mitigate challenges efficiently.

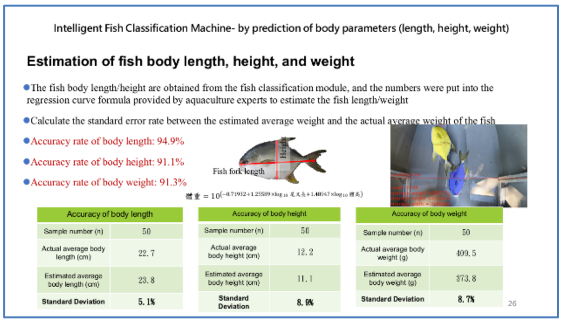
AI-Driven Decision Support

AI systems compile and analyze historical and real-time data to support decision-making. These systems automate reporting, visualize trends, and provide expert recommendations, enabling better management of aquaculture operations. The integration of data into traceable agricultural product systems ensures transparency and accountability.





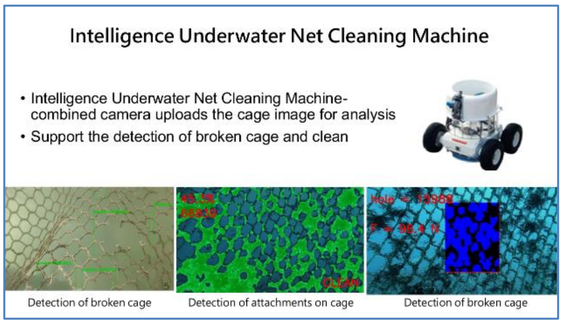
Accuracy	
Actual quantity (n)	128
Detected quantity (n)	120
Deviation	6.25%



Accuracy of body length	
Sample number (n)	50
Actual average body length (cm)	22.7
Estimated average body length (cm)	23.8
Standard Deviation	5.1%

Accuracy of body height	
Sample number (n)	50
Actual average body height (cm)	12.2
Estimated average body height (cm)	11.1
Standard Deviation	8.9%

Accuracy of body weight	
Sample number (n)	50
Actual average body weight (g)	409.5
Estimated average body weight (g)	373.8
Standard Deviation	8.7%



4.6. Case: Smart Fishery Innovation and Transformation

Energy-Saving Measures/Flow Generator Technology

The flow generator is a groundbreaking energy-saving innovation designed to replace traditional waterwheels. Operating continuously for 24 hours, it disturbs large volumes of water vertically, improving water quality and enhancing energy efficiency. This technology significantly reduces power consumption compared to conventional methods, making it an economical solution for aquaculture operations. By minimizing energy usage, it supports sustainable practices while ensuring optimal conditions for aquatic life.

Renewable Energy Integration

A combination of solar and wind power systems is at the core of the energy strategy. Solar panels capture sunlight effectively, while wind turbines generate additional energy to meet operational needs. The energy generated is stored in advanced storage devices, ensuring a stable power supply. Surplus electricity can be distributed to nearby communities or reinvested into the supply chain through a microgrid system, creating a sustainable and self-sufficient energy loop.

AIoT Smart Monitoring System

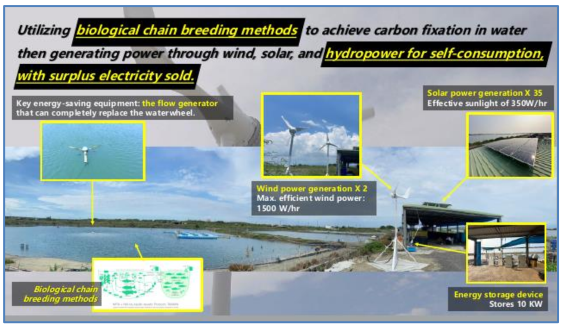
The AIoT-enabled Aquadlink® platform revolutionizes aquaculture management. It employs solar-powered sensors to monitor critical water parameters such as temperature, pH levels, dissolved oxygen, and ORP. This data is transmitted to the cloud, allowing aquaculture operators to manage and control systems remotely via mobile devices. By turning unpredictable natural factors into manageable ones, the AIoT system enhances operational efficiency, reduces risks, and enables smarter decision-making.

Biological Chain in Aquaculture

A biologically integrated approach is used to cultivate multiple species in a single pond, including filter feeders, predators, and other aquatic organisms. This method harnesses natural interactions within the ecosystem to control diseases, manage organic waste, and purify water. By eliminating the need for chemicals and antibiotics, this process supports the production of safe and high-quality seafood while fostering a balanced and sustainable aquatic environment.

Carbon Sequestration and Environmental Benefits

Aquaculture practices incorporate species such as oysters, which effectively capture and store carbon. This approach aligns with global efforts to mitigate climate change by contributing to net-zero and negative carbon emissions. Sequestering carbon directly through aquaculture presents a cost-effective and immediate alternative to traditional reforestation methods. Moreover, the biological chain strategy enhances water quality and minimizes ecological footprints, further demonstrating the industry's commitment to sustainability.



4.7. Case: Organic, Pesticide-Free Smart Mullet Aquaculture

ChiaFong Aquatic Products Co., Ltd. is a unique firm that leverages AI and advanced technologies to transform traditional aqua-culture practices into efficient, sustainable, and environmentally friendly operations.

Smart Aquaculture Systems

The adoption of smart aquaculture systems allows farmers to monitor and manage water quality in real time. These systems use sensors to measure critical parameters such as temperature, pH levels, dissolved oxygen, and oxidation-reduction potential (ORP). The data collected is analyzed using AI algorithms and stored in cloud platforms, enabling anomaly detection and instant alerts. This ensures optimal living conditions for aquatic life and reduces risks associated with environmental changes.

AI-Powered Monitoring and Feeding Analysis

AI drones are used for aquaculture inspections while feeding analysis systems optimize feed distribution. These technologies monitor fish behavior and growth patterns, ensuring precise feeding schedules that minimize waste and maximize efficiency. This approach not only reduces costs but also improves the overall productivity and health of the fish stock. Additionally, big data from these systems enhances aquaculture traceability and supports better resource management.

Probiotics for Environmental Management

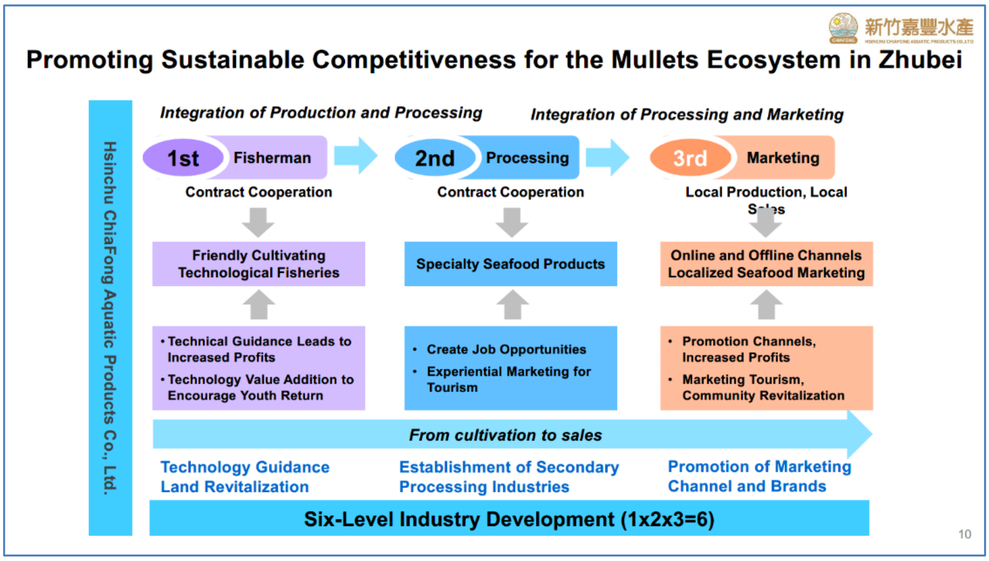
Farmers use probiotics as an eco-friendly solution to improve water quality and maintain a balanced aquatic ecosystem. Probiotics increase fish survival rates, enhance immunity, and promote faster growth. They also play a vital role in regulating ORP levels, ensuring the water environment is suitable for aquatic life. Over time, using probiotics results in cleaner pond bottoms and a more stable ecosystem, reducing the need for chemical interventions.

Expert Mapping and Big Data Utilization

By combining expert knowledge with advanced mapping techniques, farmers create standardized databases for water quality management. These predictive models are built using historical and real-time data to assist in decision-making. The result is a more precise and efficient aquaculture management process, leading to higher survival rates and improved productivity.

Energy-Saving Innovations

Energy-efficient technologies, such as solar-powered water wheels and smart electric boxes, are employed to reduce operational costs and carbon footprints. These solutions align with sustainability goals and are supported by subsidies and government initiatives, further incentivizing their adoption.



4.8. Policy Recommendations

Foster the government-led policy of promoting cross-field R&D

It enables effective identification and application of industry needs, optimizes the R&D capabilities of research institutions, and accelerates the commercialization of solutions.

Encouraging early participation of fisheries and aquaculture farmers in R&D

This enhances the grasp of actual demand, improves user experience, increases personnel safety and efficiency, facilitates the accumulation of digital assets, and makes it easier to transmit professional experience. Successful cases are also easier to replicate and spread, accelerating the achievement of a balance between environmental protection and economic development.

Enhance APEC regional cooperation for inclusiveness and adaptability of solutions

The precision fisheries solution developed by Chinese Taipei has been successfully introduced into the fishing industry, and a complete ecosystem has been established. We hope to deeply exchange and establish a cooperation model with APEC member economies, and work together for the sustainable development of APEC fisheries.

Strengthening International Cooperation

International collaboration is essential to achieve sustainable fisheries management. Coastal economies must establish binding agreements to ensure equitable resource allocation and enforce catch limits. RFMOs should implement Conservation and Management Measures (CMMs) promptly, avoiding delays that exacerbate overfishing.

Reforming Total Allowable Catch Policies

TAC policies must reflect the best available scientific data and adapt dynamically to changing conditions. Adaptive management ensures that catch limits are adjusted based on stock and environmental data, preventing overfishing.

Leveraging Advanced Technology

Real-time data collection tools and satellite monitoring should be integrated into fisheries management. These technologies enable better stock assessments and faster response to environmental changes. Investments in research and development are critical to ensure the effectiveness of these tools.

Mitigating Climate Change Impacts

Climate change directly affects fish migration, spawning, and growth. Collaborative global efforts to reduce CO_2 emissions from fishing, along with the adoption of energy-efficient technologies, are necessary to mitigate these impacts and ensure sustainable practices.

Promoting Sustainable Aquaculture

Aquaculture can complement capture fisheries in meeting the growing demand for seafood protein. Environmentally friendly practices and technological advancements in feeds and farming methods should be prioritized to reduce environmental impacts and enhance productivity.

Enhancing Leadership and Accountability

Coastal economies, such as Japan, should lead efforts in managing shared stocks, enforcing CMMs, and fostering collaboration with neighboring economies. Independent oversight and regular evaluations of RFMO performance are essential to prevent illegal, unreported, and unregulated (IUU) fishing and ensure accountability.

5. Conclusion

The fisheries and aquaculture sectors within APEC economies are at a transformational juncture, where significant challenges intersect with immense opportunities. Pressing issues such as climate change, resource depletion, and workforce shortages demand innovative solutions. By embracing smart technologies, advancing precision fisheries, and fostering a blue economy, these sectors can achieve sustainable growth, resilience, and global leadership.

The Role of Smart Technology and Precision Fishery

The integration of smart technologies—such as AI-driven predictive models, IoT-enabled monitoring systems, and blockchain-based traceability platforms—has the potential to revolutionize fisheries and aquaculture. These tools enable precision fisheries, optimizing operations by providing real-time data on fish stocks, water quality, and environmental conditions. Smart systems, such as AI-powered drones and automated feeding technologies, reduce costs, minimize waste, and enhance productivity while protecting marine ecosystems. By mitigating overfishing, reducing bycatch, and improving resource allocation, precision fisheries exemplify the harmonious balance between technological innovation and environmental stewardship.

Enabling a Sustainable Blue Economy

The blue economy represents a holistic approach to managing marine resources, aligning economic growth with ecological preservation and social inclusion. Through the adoption of low-carbon smart technologies, APEC economies can significantly reduce the environmental impact of fishing and aquaculture while creating new economic opportunities. Renewable energy integration, digital platforms for supply chain optimization, and co-culture systems that support biodiversity are just a few examples of how a blue economy can thrive. These strategies not only ensure long-term resource sustainability but also empower coastal communities and foster inclusivity.

Addressing Challenges

Despite their transformative potential, smart technologies and precision fisheries face barriers to widespread adoption. High initial costs, knowledge gaps, and resistance to change hinder progress, particularly among small-scale operators. Overcoming these challenges requires strategic investments in education and capacity-building, the creation of accessible financing mechanisms, and supportive policy frameworks that incentivize innovation. Addressing these issues collaboratively across economies is essential to scale the solutions effectively.

The Path Forward

Policy and governance must underpin this transformation. Harmonizing regulations, promoting data-sharing standards, and aligning strategies with global sustainability goals such as the UNs

SDGs are critical steps toward fostering regional and international collaboration. Regional platforms should continue to serve as hubs for knowledge exchange, addressing transboundary challenges such as illegal, unreported, and unregulated (IUU) fishing and the impacts of climate change.

Community engagement is equally vital. Inclusive participation by local communities, particularly women and youth, ensures equitable access to the benefits of innovation. Early involvement of industry stakeholders and partnerships with academia can accelerate the development and implementation of practical, scalable solutions.

A Vision for the Future

The future of fisheries and aquaculture in APEC economies is one of innovation, sustainability, and inclusivity. The vision includes:

- Global Leadership in Precision Fisheries: By adopting and exporting cutting-edge technologies, APEC economies can set benchmarks for sustainable fisheries worldwide.

- Resilient and Inclusive Blue Economies: A sustainable approach to marine resource management will empower local communities, enhance livelihoods, and reduce poverty while maintaining ecological balance.

- Smart Technology Integration: Continued advancements in AI, IoT, and renewable energy will reshape the sector, making it more efficient, environmentally friendly, and economically viable.

- Collaborative Governance: Regional partnerships will drive collective solutions to shared challenges, enhancing the sector's global impact.

In conclusion, the fisheries and aquaculture sectors have the potential to lead the global charge toward sustainable marine resource management. By leveraging smart technologies, implementing precision fisheries, and embracing the principles of the blue economy, APEC economies can create a future where economic prosperity, environmental health, and social equity coexist harmoniously. Achieving this vision will require commitment, collaboration, and innovation, but it is well within reach. The path forward holds the promise of lasting benefits for the region and the world, building a legacy of sustainable development for generations to come.

APPENDIX: AGENDA

Time	Agenda	Speaker
09:00-09:20	Opening Ceremony & Group Photo	**Welcome Speeches from MOEA, MOFA & ITRI**
09:20-09:40	Keynote Speech	**Experience of Promoting Smart Technology on Precision Fishery** Yeh-Kai Chou, Deputy Division Director, Information and Communications Research Laboratories (ICL), Industrial Technology Research institutes (ITRI)
09:40-10:00	Keynote Speech	**Intelligent Transformation Strategies for Fisheries** Fen-Lan Chen, Director, Planning Division, Fisheries Agency, Ministry of Agriculture
10:00-10:20	Coffee Break	
10:20-11:00	**Session I** **Technology Application and Blue Economy Development** Host Dr. Jer-Liang Yeh Distinguished Professor, Department of Power Mechanical Engineering, National Tsing Hua University (NTHU)	**Japanese Fishery Policy Reform and Global Warming Impacts: Seeking Solutions through New Technologies** Masanori Miyahara, President, afc.masa, Japan
11:00-11:40		**Peru's Experience and Challenges Promoting the Development of Smart Fisheries Technologies in Value Chains** David Luján, Innovation and Technology Transfer Specialist, National Council of Science, Technology and Innovation, Peru
11:40-12:00		**Panel Discussion**
12:00-13:30	Lunch Break	
13:30-14:10	**Session II** **Building a Sustainable and Resilient Blue Granary with Smart Technologies** Host Dr. Tsun-Chieh Chiang Deputy General Director, Information and Communications Research Laboratories (ICL), Industrial Technology Research Institutes (ITRI)	**How AI Anchors the Future of Fishing & Charts the Course to Sustainability** Neil Sahota, CEO, AI Advisor at the United Nations, ACSILabs Inc., United Sates
14:10-14:50		**A Decade of Small-Scale Fisheries Management Technology– From the Past and into the Future** Dr. William Hsu, Director, Advanced Computation Laboratory, National Taiwan Ocean University (NTOU)
14:50-15:30		**AIoT Applications in Pelagic Fisheries** Dr. Max Lo, General Manager, GEOSAT Aerospace & Technology Inc.
15:30-15:50		Coffee Break
15:50-16:30		**Precision Aquaculture Environmental Detection with Artificial Intelligence Manufacturing Decision System** Dr. Po-Tsang Lee, Associate Professor, Department of Aquaculture, National Taiwan Ocean University (NTOU)
16:30-17:00		**Panel Discussion**

Asia-Pacific Economic Cooperation

DOIT 經濟部產業技術司 Department of Industrial Technology, MOEA

工業技術研究院

APEC Forum on Building Precision Fishery Model Cases in the APEC Region with Smart Technology

Scenario Lab 應用劇本實驗室

國立高雄科技大學

Field Visits Agenda

Time	Agenda	Speaker
14:00-14:05	**Opening & Group Photo**	
14:05-14:20	**Organic, Pesticide-free Smart Mullet Aquaculture**	**Fong-Li Hsu** Founder, Hisnchu ChiaFong Aquatic Products Co., Ltd.
14:20-14:40	**Smart Technology Solutions from Fish Ponds to Dining Tables**	**Penny Chien** Board of Director, Quadlink Technology Inc.
14:40-14:45	**Smart water quality sensing system** Demonstration Process Description	**Ken Chen** Deputy Technical Director, Information and Communications Research Laboratories (ICL), Industrial Technology Research Institute (ITRI)
14:45-15:10	**Smart water quality sensing system** Demonstration	
15:10-15:20	**Group Photo**	
15:20-15:50	**Traffic Time**	
15:50-16:40	**Visit to the Industrial Technology Research Institute Exhibition Hall**	**Exhibition Guide**
16:40-17:00	**Wrap up**	**Dr. Tsun-Chieh Chiang** Deputy General Director, Information and Communications Research Laboratories (ICL), Industrial Technology Research Institutes (ITRI)