Workshop on Microplastics in the Coastal Aquaculture Input Chain: From the Perspectives of Policy, Regulation and Research to a Recommendation of a Mitigation Plan

APEC Oceans and Fisheries Working Group

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ABREVIATION

AMS	Action Plans Member States
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
CEPA	Communication, Education & Public Awareness
CPR	Continuous Plankton Recorder
CSIRO	Commonwealth Scientific and Industrial Research Organization
FAO	Food and Agriculture Organization
IMO	International Maritime Organization
MP	Micro Plastic
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
OFWG	Oceans and Fisheries Working Group
OSPAR	Oslo and Paris Conventions
PET	Polyethylene Terephthalate
PP	Polypropylene
RPOA	Regional Plan of Action
SDG	Sustainable Development Goal
UNEP	United Nations Environment Programme
USMDMP	United State Marine Debris Monitoring Program
WTTP	Wastewater Treatment Plant

1. INTRODUCTION

1.1. Background

Marine debris, primarily plastic/microplastics pollution, has entered virtually all marine ecosystems and affected not only marine organisms but also humans (Barboza et al., 2018, FAO, 2017, Lusher et al., 2017). The exposures of microplastics and their associated pollutants to humans either directly or via consumed foods have been well documented in the literature. The growing body of knowledge has triggered various policy, regulatory measures, and public discussions worldwide to combat plastic/microplastics pollution and reduce/prevent the risks of exposure to humans and the marine ecosystem. In the coastal aquaculture subsector, microplastics-contaminated farmed-produced seafood is no longer a myth due to recently published scientific studies discussing the issues. A publication by National Geographic in 2019 estimated that an individual could ingest 11,000 particles of Microplastics annually through seafood consumption. The estimate might be overly generalized to all regions and economies. However, this safety concern could discourage seafood consumption, leading to a reduced market share of seafood products exported by most APEC economies. With its increasing role in replacing fish products from capture-based fisheries, coastal aquaculture might face unprecedented challenges related to microplastics exposure in the future if it is not addressed early. This potential issue could mimic the cases of antibiotic contamination in aquaculture products. The widespread use of various antibiotics of at least 65 compounds in aquaculture in the last three decades has triggered port-of-entry refusals in Europe; Japan; and United States (Lulijwa et al., 2020). Exporting economies, including APEC economies, scrambled to mitigate the situation. Some even had to invest considerably to reduce antibiotic residues in aquaculture products so as not to lose market quotas to other economies. Therefore, APEC and its economies should learn from this particular issue by addressing it early to avoid similar mishaps.

Considering APEC economies produced 70.28% (61.5 million tons) out of 87.50 million global coastal aquaculture products (FAO, 2022), a larger portion of microplastics within these products could be circulated within APEC economies. Despite the increased number of studies regarding microplastics distribution in coastal aquaculture, the origin and level of its exposure within the APEC region’s coastal aquaculture input chains is relatively unknown. For example, 10 APEC economies imported at least 2.1 million metric tons of fishmeal, known to contain high amounts of microplastics, used for various purposes, including fish feed. However, microplastics contamination in fishmeal has only been reported in People's Republic of China; and Malaysia. Furthermore, the APEC White Paper titled *Microplastics in Coastal Aquaculture Systems: Development of Regulatory Frameworks, Practices and Mitigation Efforts in APEC Economies* (APEC, 2023) has revealed minimal to

the non-existence of public policy and regulatory measures to mitigate or prevent microplastics contamination in coastal aquaculture input chains. With the absence of these policies and regulatory frameworks, APEC economies will be disadvantaged if importing economies outside or within APEC begin to put forward the microplastics contamination threshold requirement for the export-import of coastal aquaculture products.

1.2. Objectives

This Final Report highlights the OFWG 03 2021A goals to provide some insights into addressing the problems above to secure future market share of seafood products exported by most APEC economies and contribute to improving seafood safety for human consumption. In addressing the issues, the project tried to:

1) Identify the existing regulatory frameworks and standard methods related to microplastics contamination in coastal aquaculture input chains;
2) Provide scientific information regarding the concentrations of microplastics in the coastal aquaculture input chains;
3) Develop a recommendation for a mitigation plan to reduce microplastics contamination in coastal aquaculture systems.

Hence, the overall goal of OFWG 03 2021A project "Microplastics Distribution in Coastal Aquaculture Input Systems and Developing a Mitigation Plan towards Seafood Safety" consisted of:

1. Defining the existing policy and regulatory framework regarding prevention and mitigation of contamination and distribution of microplastics in coastal aquaculture input chains among APEC Member Economies,
2. Producing research based on information on the level of contamination and distribution of microplastics in the input chain of coastal aquaculture,
3. Developing a mitigation plan to further refine the policy and regulatory framework in preventing and mitigating contamination and distribution of microplastics in coastal aquaculture in APEC Member Economies.

This project directly facilitates capacity building in the form of knowledge and information exchange among representatives of the APEC economies through three interrelated outputs as the following:

1) The White Paper aimed to take stock of existing policy and regulatory frameworks regarding the prevention and mitigation of microplastics contamination and distribution in coastal aquaculture input chains in the APEC region. The White Paper was developed in collaboration with 42 contributors from 15 APEC economies, which can be accessed at https://www.apec.org/publications/ 2023/06/microplastics-in-coastal-aquaculture-systems-development-of-regulatory-frameworks-practices-and-mitigation-efforts-in-apec-economies
2) The Research Report described the scientific evidence regarding the potential contamination of aquaculture input chains from microplastics in

two APEC economies. Two economies, Indonesia and Viet Nam, contributed to this Research Report to provide reference/baseline information regarding microplastics exposure in shrimp pond and finfish fish farming systems within the APEC region. Despite the research taking place in both economies, it is essential to note that a similar situation most likely occurs in other APEC economies. Hence, a regional effort has to be initiated to solve this challenging issue.

3) The Workshop intended to devise a consensus between representatives and officials representing APEC economies in the form of a mitigation plan to prevent/reduce microplastics in the coastal aquaculture input chain within the APEC region. The Workshop provides a venue for researchers, practitioners, experts, and government officials to build knowledge based on the results of the previous project's activities (White Paper and Research Report).

2. WORKSHOP IMPLEMENTATION

Microplastics Distribution in Coastal Aquaculture Input Systems and Developing a Mitigation Plan for Seafood Safety

2.1. Objectives, Methodology and Participants

The overarching objective of the workshop is to develop a mitigation plan to prevent and reduce microplastics contamination in coastal aquaculture products based on the consensus of the workshop's participants. The mitigation plan was proposed to cover four fundamental aspects of feasible mitigation plans as the following.

a) Identifying the risks of microplastics contamination and lack of related policy and regulatory framework in coastal aquaculture input chains:
b) Formulate mitigation goals in addressing the risks
c) Identify and prioritize applicable mitigation actions to reduce the level or prevent the identified risks within APEC economies
d) Recommendation of implementation and monitoring activities regarding the mitigation actions:
    - General recommendation to implement the mitigation actions
    - General recommendation to monitor the progress of the implementation

The workshop consisted of several stages. The first stage consisted of presentations from government officials and keynote speakers to provide participants with the latest domestic and international policies, regulations, and scientific information on microplastics issues, including those that the OFWG 03 2021A has achieved through the White Paper and Research Report. The second stage was intensive discussion sessions led by expert facilitators to discuss the previously presented presentations as well as share experience and knowledge by the participants regarding the current development of microplastics management in their respective economies concerning coastal aquaculture. The third stage was working group discussion and consensus build-up based on the above four fundamental elements of a mitigation plan. The workshop agenda is provided in Annex 1 of this Final Report.

All 21 APEC member economies were invited to attend and actively participate in the Workshop. There are two categories of invited participants for this event to ensure the continuous transmission of data and information from the previous project's stages (White Paper and Research Report), representation of APEC economies and most importantly, the achievement of the project goals. The first category is participants from 21 APEC economies who were involved and supported the initial stage of the project (White Paper Contributors). These participants' knowledge is vital in achieving the Workshop objectives. The second category is participants from 21 APEC economies nominated by their respective APEC Ocean and Fisheries Working Group (OFWG) representatives.

2.2. Workshop Implementation

2.2.1. Attendance

The APEC OFWG 03 2021A workshop on ***Microplastics in Coastal Aquaculture Input Chains: Developing a Mitigation Plan to Reduce/Prevent Microplastics Contamination in APEC Economies*** was held for three days 8 – 10 November 2023 at Truntum Kuta Hotel, Bali, Indonesia. The workshop was attended by 32 representatives from 11 APEC economies, consisting of 5 APEC-funded speakers, 2 self-funded speakers, 14 APEC-funded active participants, and 12 (twelve) self-funded participants. The participants included official APEC delegates, researchers, academia, civil servants and Non-governmental Organizations (NGOs) (Table 1). The ratio of men and women attending the event was 46:54, indicating a slightly above-average participation for women in any APEC event. The complete list of attendance is presented on the Workshop Committee and Contributors page.

Table 1.

No.	Economy	Participant(s)
1	Australia	1
2	Chile	1
3	People's Republic of China	1
4	Indonesia	17
5	Japan	1
6	Malaysia	2
7	Peru	1
8	Singapore	1
9	Thailand	2
10	United States	2
11	Viet Nam	3
Total		32

2.2.2. Project Summary

The event started with the opening remarks delivered by Hatim Albasri, Ph.D, as the Project Overseer of OFWG 03 2021A from the Research Center for Fisheries, Research Organization for Earth Sciences and Maritime, National Research and Innovation Agency, Indonesia. He acknowledged and thanked all the invited participants who attended this workshop despite their other demanding schedules and obligations. He reiterated that their in-person attendance shows that this workshop's themes align with their personal and economic interests to prevent/reduce microplastics contamination within coastal aquaculture input chains and thus improve the safety of the products resulting from the activity.

Dr. Albasri continued by stating that most APEC economies depend on their economy from the fisheries sector. Some economies are, in fact, listed within the 5 top global aquaculture producers of aquaculture products. Therefore, the theme of this project is strongly correlated with the strategic development of APEC economies to provide a steady and sustainable supply of aquaculture products while improving the safety of the products they produce. Considering the increased body of knowledge and policy direction related to the intertwined relationship between microplastics and food safety in which aquaculture products are dominating the market supply as one of the most affordable protein sources, immediate actions to mitigate the potential exposure of microplastics to aquaculture products have to be proposed and implemented.

In general, the outputs produced from this project consist of a White Paper, Research Report, Workshop and Final Report. As the first output of the project, the whitepaper was developed in 2022 and is now available on the APEC publication website. The preparation of the White Paper involved 42 contributors from 15 APEC economies who worked voluntarily to collect the data in the form of regulations, policy direction/framework, secondary database and literature, and other data related to microplastics exposure in their economies.

The second output of this project was the research report produced by a collaboration between the Key Laboratory of Advanced Materials for Green Growth, Viet Nam National University (KLAMAG VNU) and the Research Center for Fisheries of the Indonesian National Research and Innovation Agency. The research report covers the results of the study in Indonesia and Viet Nam regarding the contamination level of microplastics within several input chains of coastal aquaculture, such as feed, fishmeal, sediment, water, farmed fish and shrimp, as well as wild fish associated with the farming platforms.

The third stage is the workshop, where the output to be produced is a final Report, which synthesizes the results of the White Paper, Research Report and the Mitigation Plan produced from the Workshop. The final report will contain a recommended mitigation plan, including, but not limited to, mitigation risks, priorities of action plans, and mechanisms for monitoring microplastics exposure, and policy development in aquaculture input systems.

3. DEVELOPING A MITIGATION PLAN TO PREVENT AND REDUCE MICROPLASTICS CONTAMINATION IN COASTAL AQUACULTURE INPUT CHAINS

"From Policy, Research, Perspective to a Consensus"

3.1. A Local Government Perspective toward Microplastics and Aquaculture

The Provincial Government of Bali supports the implementation of the workshop of which a provincial representative, Mrs. Ir. IGA Yuliadi Astiti, M.Si, Head of Aquaculture Production, Regional Technical Implementation Unit, Bali Province, Indonesia, delivered the Bali Province view regarding the objective of the project. Mrs. Astiti expressed her appreciation to APEC, the Ministry of Marine Affairs and Fisheries and the National Research and Innovation Agency for selecting Denpasar, Bali, to hold the workshop. She argued that Bali is one of the provinces that has extensively managed and regulated the level of plastic waste in Indonesia. She explained that plastic waste is increasingly becoming a problem, especially in Bali, where the tourism rate is increasing yearly. More specifically, plastic waste in the form of microplastics could contaminate food consumed by humans and thus pose significant risks to human health. Fish farming activities at sea can be a source of exposure to microplastics. Considering that at least 1.4% of human food comes from seafood, this issue could be one of the future challenges in human health and, specifically, the sustainability of coastal aquaculture itself. The results of this workshop are expected to provide some solutions and insights on developing mitigation measures to protect against exposure to microplastics in fishery products. The cooperation of all fisheries stakeholders is necessary to implement this mitigation action. The Bali Provincial Government is taking advantage of this opportunity to educate the fish farming community to carry out sustainable mariculture. In addition, to reduce plastic input into the environment, the Bali Provincial Government has banned single-use plastic since 2019. She concluded her welcoming speech by stating that this workshop is critical and one of the first regional efforts to address microplastics exposure in fisheries.

3.2. Indonesian Research Strategies and Opportunities to Combat Plastic and Microplastics Pollutions

Prof. Dr. Ocky Karna Radjasa, M.Sc., the Chairman of the Research Organization for Earth Scientist and Maritime, opened the workshop on behalf of the Head of the National Research and Innovation Agency (NRIA/*BRIN)*, Indonesia. Prof. Radjasa started his opening remarks by explaining the NRIA and its strategic plans to combat and reduce plastic waste through research and innovation. The NRIA is a newly formed ministerial-level institution whose tasks are to exclusively manage, execute and provide funds for all research and innovation activities in Indonesia, excluding universities. It merges all research

organizations previously owned by each of the 39 ministerial and ministerial-level institutions. Currently, the NRIA has 12 research organizations and 85 research centers working together to achieve BRIN's goals in research and innovation. Prof. Radjasa confirms that one of the leading research focuses of NRIA is in plastic and microplastics studies. He invited all attending participants to reach out to BRIN to conduct research collaboration mainly related to the field science of plastic and microplastics waste.

Prof Radjasa continued his opening speech by describing that many studies have found that land and marine biota have been exposed to microplastics. With Indonesia being the second-largest plastic-producing economy in the world, this project will provide Indonesia with information on how to manage its plastic waste better and reduce and prevent microplastics contamination in food products. Prof Radjasa sincerely hopes the workshop could produce the expected microplastics mitigation plan and trigger further research collaborations between APEC economies related to microplastics prevention/reduction in the coastal aquaculture input chains. NRIA has an existing research collaboration framework in the form of capacity building related to microplastics for international collaborators, postdoc (1 year), and visit research (3 months) as part of the Indonesian domestic implementation strategy to reduce and prevent plastic litter and microplastics contamination in the environment. These efforts aim to improve the quality of human resources through degree-by-research programs at foreign universities, including Australia; England; Germany; Malaysia; and Netherlands. In supporting these efforts, NRIA research facilities can facilitate research collaborations, including research vessel facilities accessible to all Indonesian and foreign researchers. In 2025, NRIA will launch a new research vessel that can be used for any research activities at sea, including plastic and microplastics-related research. NRIA also has a research and innovation funding mechanism for Advanced Indonesia (abbreviated as RIIM/*Riset dan Inovasi untuk Indonesia Maju*). This program is open to all researchers, allowing collaboration with foreign researchers, lecturers and the private sector.

3.3. Indonesian Aquaculture Policy in Reducing Microplastics Contamination

After being introduced by the Chair of the Key Note Session, Prof. Brian Walter Szuster from the University of Hawaii at Manoa, United States, Dr. TB Haeru Rahayu, A.Pi, M.Sc, the Director General, Directorate General of Aquaculture from the Ministry of Marine Affairs and Fisheries of Indonesia presented the first keynote speech titled “the Indonesian Aquaculture Policy in Reducing Microplastics Contamination”. In starting his presentation, Dr. Rahayu stated the five main strategies of the blue economy framework currently pursued by the Ministry consisting of:

1. Expanding marine conservation areas
2. Quota-based fishing policy

3. Development of Sustainable Marine Aquaculture
4. Surveillance and management of coastal areas and small islands
5. Controlling plastic waste in the sea

These strategies are primarily addressed to reduce the negative pressure of human activities and conserve and maintain the quality of marine ecosystems and their ecosystem services. The strategy of controlling paste wastes in marine environments has been translated into various programs within the five technical directorates and an agency of the ministry. This last strategy is strongly related to the Workshop objective of controlling plastic waste in the sea. Dr. Rahayu discussed the implementation of this particular strategy using seaweed farming to reduce plastic use and its possible contamination in seaweed farming industries in Indonesia. Indonesia is now the second largest seaweed producer in the world, with a production volume of 9.6 million tons/year. The main commodity of Indonesian seaweed is *Eucheuma cottonii (*current name*: Kappaphycus alvarezii)*. Currently, seaweed farming methods in Indonesia use off-bottom, longline, and raft methods. Plastic materials are used extensively in these farming methods as buoys, ropes, farming and post-harvest tools.

These excessive uses of plastic materials in seaweed farming could lead to contamination of microplastics in seaweed products, resulting in increased risks to human health. Reciprocally, using plastic material in seaweed farming could exacerbate the distribution of marine plastic debris in marine environmental. Therefore, the ministry has developed action plans for controlling microplastics in seaweed cultivation through:

1) Modeling seaweed cultivation in which free plastic tools and materials are implemented using alternative tools and materials.
2) MMAF priority program based on blue economy, seaweed market potential, and seaweed culture development policy.
3) Modeling seaweed business plan: upstream, downstream, off-taker, and distribution
4) Utilization of coconut shell buoys to replace plastic buoys in pilot farming projects:
    - Improving local community roles and awareness in controlling microplastics contamination in coastal aquaculture via plastic use reduction, increasing awareness and knowledge, and good waste management.

Dr. Rahayu reiterated that the ministry pursued this seaweed farming model because the ministry recognizes the potential harm of microplastics in seaweed products. Microplastics contained in seaweed products could cause direct issues to aquatic animals such as:

1. Biodiversity interaction to transfer microplastics: small organisms living on seaweed and consuming the seaweed contaminated by microplastics can transfer it to other larger and higher tropic aquatic animals through predation.

2. Increasing mortality risks of aquatic animals eating microplastics-contaminated seaweed due to disruption of their digestive system and metabolism.
3. Reducing survival rate and increasing behavioral and reproductive disorder

The pilot project of modeling the free-plastic seaweed farming is being conducted in the waters of Wakatobi Island, South East Sulawesi, consisting of a seaweed seed farm (1.25 ha), nursery (5 ha) and grow out (45 ha). The pilot project aims to produce 7,200 tons of wet seaweed annually and needs at least 180.000 coconut shells. The primary purpose of this project is to showcase to seaweed farmers and industries that using alternative materials to replace plastic buoys is technically possible and economically feasible.

Figure 1 Pilot project modeling of seaweed farming using coconut shells to replace plastic-based buoys in Wakatobi Island, Indonesia

Key Discussion and Highlights

The current policy of the Ministry of Marine Affairs and Fisheries is reducing the marketing of raw materials, and instead, value-added products are fully supported and facilitated. Regarding packaging of coastal aquaculture value added products, the strategy belongs to another directorate general responsible for regulating the use of plastic packaging. However, it has been one of the key programs of the ministry to reduce single-use plastics usage within the fisheries system, whether it is the products of fisheries or aquaculture.

In response to microplastics contamination in fishmeal, Dr. Rahayu suggested reducing the contamination issue by utilizing alternative protein sources such as *Ulva* sp. (a macro algae species) in fish diet formulations. Replacing fishmeal with alternative protein sources is still challenging for traditional small-scale farmers, who make up 80% of the total fish farmers in Indonesia, due to the price, availability, and sustainability of alternative

ingredients. There are also efforts to establish and strengthen farm-formulated diets *(pakan mandiri).* However, this alternative also opens another pathway of microplastics distribution due to non-standardized feed-making processes.

The blue economy concept in seaweed cultivation has promoted the use of coconut shell buoys in several pilot projects in Indonesia. These pilot projects are intended to provide alternatives for reducing plastic, bottles, and Styrofoam use in seaweed farming, reducing plastics/microplastics waste, and utilizing local raw materials. Other free-plastic farming methods should be kept searched and developed to provide efficient and cheap free-plastic aquaculture methods.

The material for this presentation can be found at the link:

https://drive.google.com/file/d/1i87DzezkVTzBzIcZwhbTRZ_icOvhylRK/view?usp=drive_link

3.4. Design Principles, Analytical Methods and Data Analysis of Microplastics Contamination and Its Associated Pollutants

The second keynote speaker was Dr. Kay Ho from United States Environmental Protection Agency. She began her presentation by describing some legislations indirectly and directly related to plastic and microplastics. United States has legislation that addresses plastic waste directly and indirectly, such as the Clean Water Act (1972), Toxic Substances Control Act (1976), Marine Debris Act (2006), Marine Pollution Prevention Act (2008), Microbeads-Free Waters Act (2015) and Save Our Seas 2.0 (2020). The Clean Water Act basically mandates toxic waste and toxic compounds in waterways. Toxic Substance Control Act serves as the tool for the EPA to control and monitor toxic compounds, including plastic wastes. The Marine Debris Act aims to direct NOAA to identify and determine the sources of marine pollution/debris in the ocean, which works in tandem with the Marine Pollution Prevention Act under NOAA. These regulations do not directly tackle or address plastic waste issues, including plastic recycling. The last two regulations, the Microbeads-Free Waters Act and Save Our Seas 2.0, directly tackle plastic wastes, including microplastic and nanoplastic.

Dr. Ho also explained that a federal initiative involving 20 federal agencies has been implemented in the form of the US Interagency Nanoplastic Interest Group aimed at sharing information, enhancing collaboration and research efficiency and understanding the knowledge gaps between agencies relating to microplastic and nanoplastic issues. The interest groups have held various domestic and international public disseminations and webinars to promote the risk and potential solutions in addressing plastic waste.

These legislations and public disseminations help to drive research on microplastic and nanoplastic. Addressing smaller microplastic and nanoplastic particles sized less than 20 microns is the current focus of the effort in the US, considering that these smaller plastic particles are more numerous and have

potential effects on human and ecological effects. Specifically to fisheries, including aquaculture, the US focuses on the effect of 6-PPD, 6-PPD Quinone and tire wear particles as research suggests that these compounds are proved toxic to fisheries resources in the US such as salmonids fish. Microfiber pollution also has become another research focus within the USEPA, where the agency's scientists have published at least 50 peer-reviewed journal articles.

Based on the current progress and available scientific evidence, the US is currently drafting a National Strategy to Prevent Plastic Pollution aiming at three distinctive strategies:

1. Reducing pollution during plastic production
2. Improving post-use material management
3. Prevent trash and micro-nano plastics from entering the aquatic environment and remove escaped plastics.

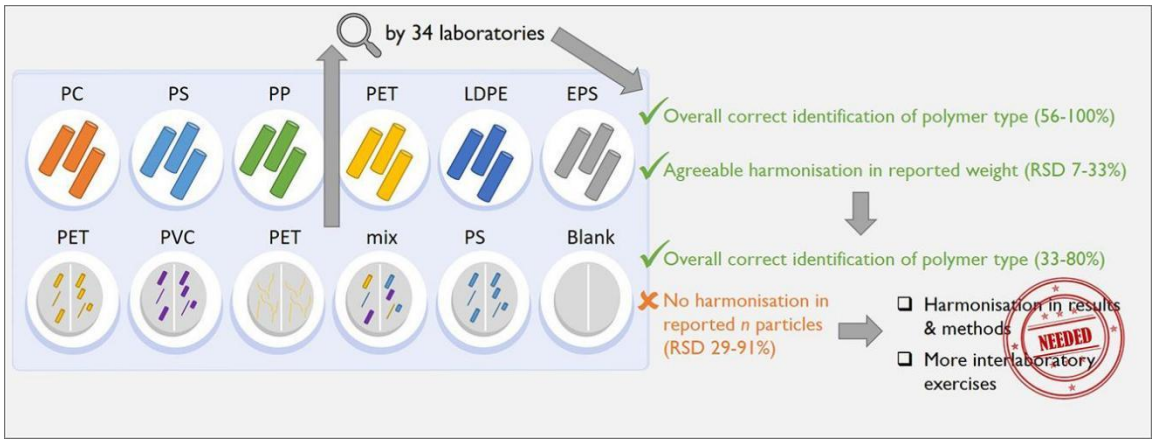

Figure 2. Results variations of microplastics analyses from various laboratories.

Accurate and reproducible methods to support legislative mandates and monitoring programs are critical. Without these standard methods agreed upon by all related stakeholders, we cannot determine whether effective criteria levels, exposure concentrations, or remediation methods are valid or practical. For example, California was one of the first states to pass a bill to adopt state-wide regulations to address ocean microplastics. The bill was successful at least two folds:

1. Allowing California to publish a standard method to determine microplastics occurrence in drinking water using Micro FTR and Raman
2. Having a laboratory accreditation program to address microplastics standardized methods for sediments, water, and fish tissues.

Dr. Ho concluded that despite having multiple legislative mandates coupled with the development of new methods with improved results, it is more feasible to pursue the direction that a more prescribed method is needed to have fully comparable analytical results across laboratories. Standard reference materials are also crucial to improving analytical methods, and interlaboratory tests help show us the validity of our methods. Interagency

interest groups can help groups coordinate research, leverage resources, and help prevent redundancies.

Key Discussion and highlights

1. Microplastics contamination in aquaculture is multifaceted. The use of plastic in aquaculture ranges from the use of HPDE to line the bottom surface of earthen ponds in shrimp to the increased use of plastic tanks. Both plastic types and their associated chemical compounds can leach to cultured organisms. However, determining the possible leaching of microplastics and plastic additives is complicated and needs further research and scientific discussions.
2. Legislation to address marine plastic pollution is needed to establish and drive ongoing research. However, the role and awareness of citizen science in pushing the issue is vital for any agency to make statements in line with the majority of the community related to the prevention and reduction of microplastics.
3. Standardized analytical methods are needed to increase the accuracy and precision of microplastics pollutant measurements.
4. Accurate and reproducible methods are needed to support legislative mandates and monitoring programs.
5. Creating dedicated working groups for microplastics is highly recommended. These groups should be established and have regular meetings/interactions, providing opportunities for information sharing and cooperative learning among members.

The material for this presentation can be found at the link:

https://docs.google.com/presentation/d/1N1EXGIWygN5jqbiTjgHKYj0NrwzBvKLD/edit?usp=drive_link&ouid=103273235577263122164&rtpof=true&sd=true

3.5. Research and Best Practice of Microplastics Prevention and Monitoring in Marine and Coastal Organisms and Areas

The third speaker of the workshop was Dr. M. Reza Cordova from the Research Center for Oceanography, National Research and Innovation Agency (NRIA/*BRIN*). Dr. Cordova argues that monitoring land-derived debris is critical for identifying effective mitigation strategies as marine debris becomes increasingly prevalent and induces cascading impacts on marine ecosystems. Given its extensive coastline, large population, and high waste production, Indonesia could play a pivotal role in reducing land-derived debris flowing into the oceans. The growing incidence of plastic pollution in marine environments raises concerns over the detrimental impact on ecosystem dynamics, encompassing modifications to the oceanic carbon cycle and toxicological injury to organisms. Regrettably, current scientific research has accumulated significant evidence concerning the presence of small-sized plastic debris (i.e., microplastics) in all freshwater and marine ecosystems.

Indonesia has recorded 128 studies on marine plastic litter according to the ASEAN+3 marine plastic research database in 2022. This includes 58 studies on macroplastics, 63 studies on microplastics, and six publications covering both categories. Approximately 75% of microplastics research in Indonesia focused on its presence in water, sediment and ingestion by organisms. The remaining 10-20% covered other topics such as microplastics deposition from the atmosphere, impact assessment, bioassay, management strategies and social aspects.

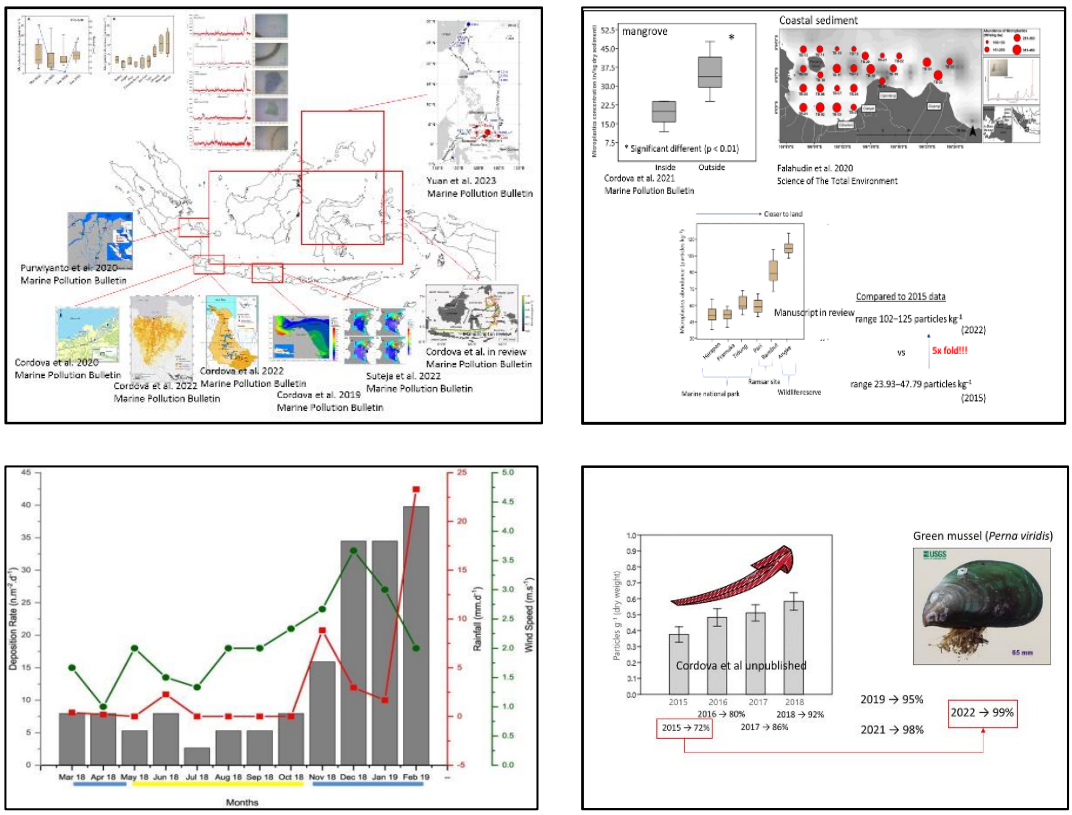

Figure 3. Distribution of microplastic research in Indonesia categorized into four main subjects: water, sediment, aquatic organisms and air (clockwork direction).

This literature review suggests that microplastics have been detected in water and sediment samples throughout Indonesia, correlating to rainfall and season. Ocean circulation is a significant factor in the distribution of microplastics. Areas with substantial human influence show a 6-10 times higher abundance of microplastics pollution, and point sources such as the textile industry and landfills have been identified as significant contributors. Leachate water from landfills can lead to a threefold increase in the presence of microplastics in water bodies. There is clear evidence of an increase in the abundance of microplastics observed within sediment and marine organisms over time. For example, our research result in one of the Indonesian marine protected areas shows that the increase rate of microplastics reached fivefold within seven years. Such an increase is alarming considering the protected status of the area, and other MPAs might suffer a similar fate. Therefore, obtaining more data is essential to prevent microplastics pollution. Quality control measures should be implemented for recovering and reusing plastics, focusing more on disposing of unattended items.

Extensive research on microplastics in Indonesia has concentrated on their dispersal and distribution in Java. Still, there have been limited studies on toxicity impact testing and air dispersion compared to water and sediment spread research. Indonesia needs to broaden its scope and match the level of study being pursued globally to keep up with the global expansion of microplastics research. Several challenges have limited the capability to do microplastics research in Indonesia. The challenges are primarily related to different sample preparation methods, limited identification capability where most research only use visual observation via microscope, no clear quality control/assurance over the analyses, limited information on chemical composition tests and of course the relatively expensive analysis cost.

Efforts to prevent or reduce microplastics distribution could be accelerated by;

1) Obtaining additional data to fully describe the complete picture of microplastics distribution in different matrices
2) Enforcing quality control measures for recovery/up cycling associated with plastics
3) Disposal of unattended plastic items
4) Closing the cycle in point sources such as landfills and WWTPs.

Key Discussion

1. Realizing the report of studies that microplastics are present in marine water columns is quite concerning because these same waters are used in hatcheries where most farmed fish and shrimp seeds are produced. The use of live feed, such as rotifer, a non-selective filter feeder, could be the transferring of microplastics to fish and shrimp seed reared in these hatcheries. In addition, using plastic materials could also be one of the source points of plastic within the coastal aquaculture system.
2. The sources of microplastics pollution transported to the ocean from inland waters might be an issue that needs to be addressed in the guidelines. However, the current workshop focuses on marine and brackish water-related issues. Nevertheless, the inland water microplastics issue could be addressed in the next phase or other APEC projects.
3. Trans-boundary pollution is an issue, with each region having its own microplastics pollution commitment (some also have guidelines to combat plastic litter and microplastics). There is a need, however, to develop recommendations that could be referred to and followed by all APEC economies. This recommendation could be shared with representatives at the UNEA (United Nations Environmental Assembly) to highlight the concerns of the APEC aquaculture communities. There is also a need to enhance awareness and induce behavioral change in the use of plastics by the aquaculture community. Monitoring and regulation of coastal aquaculture siting and practices is needed to protect MPAs from plastic pollution.

4. Behavioral change is one of the priorities in terms of reducing plastic waste. This is because littering and limited number of collection points for plastic waste are two significant challenges, particularly in developing economies. Less than 60% of plastic waste is collected using the existing waste processing infrastructure. By inducing behavioral changes, people can reduce the use of single-use plastic waste, increasing efforts to separate plastic waste from other non-plastic waste, as well as placing waste plastic waste into available collection points.

The material for this presentation can be found at the link:

https://docs.google.com/presentation/d/1xniQ7gAt_K7GojDztVBoQAqGWZgdCEvW/edit?usp=drive_link&ouid=103273235577263122164&rtpof=true&sd=true

3.6. Contamination Level and Distribution of Microplastics In Coastal Aquaculture

Associate Professor Tranh Dinh Trinh from the Key Laboratory of Advanced Materials for Green Growth - Viet Nam National University (KLAMAG-VNU) presented the results of the research activity, which is one of the outputs of the OFWG 03 2021A project. The Research Report is a collaboration between KLAMAG-VNU and the Research Center for Fisheries, NRIA. In his presentation, A/Prof Trinh explained the research activities funded by APEC, where sampling activities were conducted in Lampung, Indonesia and the Haipong, Viet Nam territorial waters. The collected samples comprised sediment, surface water near floating *net cages/*KJA and ponds, biota (farmed fish/wild fish/shrimp) and fish feed. A/Prof. Tranh Dinh Trinh explained the method for preparing biota samples to measure their microplastics content through rigorous processes using the Viet Nam National University lab facilities for identifying microplastics. Some of the main tools used to identify microplastics were microscopes, Fourier Transform infrared (FTIR), micro FTIR, and scanned electron microscopes. The results show that microplastics were found in all samples of sediment, fishmeal, water, and GIT with varying particle sizes and numbers. The microplastics size that dominates fish samples is 0.3-1 mm. The most common forms of microplastics found were granules and fibers (22-76%). The dominance of microplastics size in sediment also depends on the location at sea. The most commonly found microplastics size is 0.3-1mm. Furthermore, the types of microplastics polymers most commonly found in samples were Polyethylene Terephthalate (PET), Polyethylene (PE), and Polyurethane (PU).

Based on the research findings, A/Prof Trinh concluded that the context of microplastics contamination in coastal aquaculture input systems in the selected sites could be similar in other APEC economies for the following reasons. Firstly, the interconnected marine environments allow the distribution of microplastics in waterways of APEC economies where coastal aquaculture takes place. Secondly, most APEC economies practice similar farming technologies and use similar or the same input products that are contaminated

by microplastics. However, the specific nature of microplastics and the contamination level may differ from one place to another. Therefore, research to determine the full extent of microplastics contaminations, improving policy and regulatory measures, including standardized microplastics methods, and engaging wider stakeholders will help prevent and reduce microplastics contamination in coastal aquaculture within APEC.

Key Discussion

1. Two sampling campaigns in Indonesia; and Viet Nam successfully collected surface water, sediment, farmed/wild/trash fish, farmed shrimp, farmed fish and shrimp feeds, and fishmeal. In total, 536 samples were collected to study the characteristics of microplastics.
2. The results revealed that most microplastics comprised granules and fibers, accounting for 22-76% of all forms.
3. PET, PE, and PU were among the most abundant microplastics found in the collected samples.
4. On average, the number of microplastics in water was lower than 1 microplastics/m^3 of seawater, but the number of microplastics particles in fish was relatively high, especially in wild/trash fish.
5. Most microplastics were found in 0.3-1 mm fraction, about 50-67% of all identified microplastics.
6. Separating microplastics from organic compounds in the samples can be done in several ways. Hydrogen peroxide was chosen based on the common method used, and it is less toxic than other chemical digestion methods. Alternatives such as acid and enzymatic-based processes are also available. However, using acid could produce toxic gases, and enzymatic processes require longer than hydrogen peroxide.
7. This research confirms that coastal aquaculture in the APEC region has highly likely been exposed to microplastics contamination.

The material for this presentation can be found at the link:

https://drive.google.com/file/d/1uZm5qHZK-0wn_zNFwU9St327wtCmjblu/view?usp=drive_link

3.7. Formulating Microplastics Mitigation Plan in Coastal Aquaculture Input Chain

The second and third days of the Workshop were conducted to discuss and formulate a mitigation plan to reduce or prevent microplastics contamination in coastal aquaculture input chains applicable to the APEC region. Based on the participants' agreement, the previously planned working group meetings to develop the mitigation plan separately were changed to a single group meeting. The three expert facilitators (Prof. Brian Walter Szuster, Prof. Jesmond Sammut and Dr. Fayakun Satria) interchangeably led and directed the discussion.

3.7.1. Concept Notes of Mitigation Plan

Before the workshop, most of the representatives submitted their concept notes containing the initial perspective of the participants on the mitigation plan based on the existing conditions in their economies. A set of guidelines in formulating the concept note was shared, consisting of possible policy and regulatory intervention/reform recommendations, research direction and public discourses planning and support to prevent or reduce microplastics contamination in coastal aquaculture input chain systems based on their economies' situation. Additional brief ideas/concepts were also required for post or output phases of coastal aquaculture systems, such as post-harvest processing and market policy/certification for export-import of coastal aquaculture products. The concept note was aimed at preparing the participants to share ideas and reach a common consensus on a mitigation plan among APEC economies. It is important to note here that the concept note provided by each workshop representative is a personal judgment/expertise analysis and does not necessarily represent the view or policy of their economies.

A. Chile

A.1. Key points for a mitigation plan to reduce microplastics contamination in aquaculture (Maria Amenabar)

a) The mitigation plan should be specific about responsibility for execution and budget sources to implement it. (Specifically in Latin American economies, if the policies do not count with a specific budget and are responsible for execution, the policy will be just a symbol)

b) The mitigation plan should be divided into sections, specifically directed to each type of aquaculture activity developed in APEC economies (e.g., aquaculture based on filter feeders organisms is completely different from salmonid fish culture. Thus, the organisms are exposed to and affected differently by microplastics.

c) Aquaculture products are responsible for using different plastic items. Thus, the mitigation plan should identify the plastic items produced by different types of aquaculture activity.

d) Mitigation plans should consider control and monitoring measures to track the execution.

e) Mitigation plans should consider the development of regulations and control measures for the aquaculture sector since, historically, in Chile, they have not acted voluntarily about environmental policies.

f) Economies that import aquaculture products should demand standard conditions for the products. (That will pressure companies that export aquaculture products to act according to it).

g) Mitigation plan should declare the need for continuous research about microplastics contamination and its effects on aquaculture.

h) Mitigation plans should promote APEC economies' commitment to making public policies based on scientific evidence.

i) Mitigation plan should promote the precaution principle

j) Mitigation plans should also consider policies to reduce microplastics contamination from land-based sources, specifically those near aquaculture centers.

k) Mitigation plans should promote innovation in new materials and gear used for aquaculture, promoting longer life and stronger products to be used.

l) Mitigation plans should promote research about the relationship between antibiotic resistance and microplastics.

B. People's Republic of China

B.1. Recommendations on the Draft of the Mitigation Plan at the Workshop Microplastics Distribution in Coastal Aquaculture Input Systems and Developing a Mitigation Plan towards Seafood Safety (Dr. Fu Yu)

Mariculture is an important approach to the sustainable use of marine resources, which not only meets the demand for high-quality seafood but also has great significance for the economic and social development of coastal areas and the livelihood of coastal communities. People's Republic of China attaches great importance to the prevention of marine microplastics pollution and has formed a relatively complete policy and legal system covering the prevention and control of land-based and ship-based plastic pollution of the marine environment and vigorously carried out the 3R governance of reduction, reuse and recycling of plastics.

People's Republic of China has successively promulgated a series of laws and regulations related to the prevention and mitigation of marine microplastics pollution, such as the Marine Environmental Protection Law (enacted in 1982), the Regulations on the Prevention and Control of Land-based Pollutant Pollution and the Management of Marine Environmental Pollution (1990), and the Regulations on the Prevention and Control of Marine Environmental Pollution by Ships (2009). People's Republic of China's Fisheries Law (enacted in 1982, last amended in 2004) stipulates that governments at all levels shall take appropriate measures to protect the ecology and environment of fishery waters.

Based on People's Republic of China's existing situation and practice, to reduce the impact of microplastics on the mariculture industry at the APEC regional level, the following measures are recommended for discussion at the

Workshop Microplastics Distribution in Coastal Aquaculture Input Systems and Developing a Mitigation Plan towards Seafood Safety.

a) To establish a complete institutional system

- To strengthen the "whole life cycle" management of plastics. Strengthen the whole process management of biological substitution in the production stage of raw materials, green design in the manufacturing stage, sustainable consumption methods, waste management in a centralized recycling way, and strengthen recycling and reuse to reduce the flow of microplastics waste into the seas and oceans.
- To formulate and implement policies and regulations and formulate environmental standards on microplastics pollution mitigation.
- To use scientific and technological means to strengthen the supervision of microplastics pollution.
- To optimize the layout of mariculture production. To carry out mariculture capacity assessment, scientifically evaluate the carrying capacity of sea waters for mariculture and reasonably determine the mariculture capacity.
- To carry out water area assessment to ensure that the plastic pollutants in mariculture waters meet the standards.
- To Implement special clean-up of plastic waste in bays, estuaries, beaches and other coastal areas, and to promote the establishment of a long-term mechanism for the clean-up of marine plastic waste in coastal areas.

b) To implement supporting industrial measures

- To promote the use of recyclable and degradable fishing gear.
- To set up plastic (waste fishing gear) recycling facilities in coastal areas such as ports, wharves and aquaculture facilities.
- To promote the application of recyclable and degradable alternative materials to produce fishing gear.
- To ensure that the landed garbage can be disposed of in a timely manner, the non-recyclable garbage can be properly disposed of.

c) To improve public participation

- To publicize the hazards of plastic waste, enhance the environmental awareness of practitioners, guide fishermen to cultivate and gradually form a standardized approach to mariculture, and reduce garbage flow into the sea.
- To encourage garbage classification on board and guide garbage to be disposed of ashore.
- To give full play to the role of industry associations and civil society and encourage the public to participate actively in the clean-up of marine litter.
- To guide and encourage private capital to invest in related industries.

d) To promote research on the mechanism, monitoring, and prevention technology of marine plastic garbage and microplastics pollution.

e) To actively carry out regional and international cooperation on marine plastic waste management, share best practices, and cooperate in scientific research.

C. Indonesia

C.1. Mitigation Plan for Reducing Microplastics in Aquaculture Input Chain Systems in Indonesia (IAP Riyastini, M.Si, M.Env)

1. Policy and Regulation

a) Permit mechanism: set standards/specifications for acceptable materials for aquaculture practices.

b) Awards and punishment mechanism: implement incentives and fines for aquaculture businesses.

c) Law enforcement mechanism: community-based surveillance, indicator-based surveillance, event-based surveillance.

2. Research and Development

a) Alternative materials: the use of non-plastic materials for aquaculture infrastructure and tools/equipment.

b) Closed-loop aquaculture systems: develop more sustainable aquaculture design.

c) Waste management systems: develop more proper ways to dispose of aquaculture gear and equipment.

d) EnvironmentalHus impacts (health and economic impacts) of microplastics contamination to living beings.

e) Natural attenuation strategy

3. Public Awareness

a) “Microplastics curriculum” to schools: to raise the young generation's awareness about microplastics contamination and its implications.

b) Group community involvement in promoting sustainable aquaculture practices

c) Customary village approach to encourage local community to implement waste management practices

d) Social media utilization to disseminate information about responsible plastic use and its impact on the coastal environment

e) Policy advocacy to encourage policymakers to be in the same level of concern about microplastics reduction.

C.2. Mitigation plan for reducing microplastics in Coastal Aquaculture Input Chain Systems (Dr. Buntora Pasaribu)

1. Policy Development and Strengthening Regulations

a) Creation of Specific Policies: Formulate dedicated policies that specifically address the use, disposal, and monitoring of plastics within the aquaculture sector.

b) Regulatory Framework: Develop a comprehensive regulatory framework that limits microplastics release, specifies acceptable materials for aquaculture use, and enforces proper waste management practices.

c) Strict Enforcement Mechanisms: Strengthen monitoring and enforcement of existing regulations concerning plastic usage in aquaculture.

d) Penalties for Non-compliance: Implement penalties or fines for non-compliance with regulations to ensure adherence to the set standards.

e) Public-Private Partnerships: Foster partnerships between government bodies, private industries, and relevant stakeholders within the aquaculture supply chain to collectively address the issue.

f) Community Involvement: Engage local communities, fishermen, and aquaculture farmers to raise awareness and encourage participation in sustainable practices.

g) Alignment with Domestic Policies: Ensure the mitigation plan aligns with broader domestic environmental policies and sustainable development objectives.

h) Regular Assessment and Adaptation: Continuously evaluate the effectiveness of policies and regulatory measures and adapt them as necessary based on new scientific findings or emerging challenges.

2. Research direction

a) Conduct in-depth studies to understand the sources, pathways, and accumulation of microplastics in coastal aquaculture systems, identifying critical entry points and hotspots.

b) Implement continuous monitoring programs to assess the concentration and distribution of microplastics in aquaculture areas, aiding in the development of targeted solutions.

c) Evaluate the environmental and economic impacts of microplastics contamination on aquatic ecosystems, marine life, and human health.

d) Conduct risk analyses to determine the extent of microplastics exposure and its potential consequences throughout the aquaculture input chain.

e) Invest in research and development of innovative technologies, equipment, and alternative materials that can minimize or replace the use of plastics in aquaculture practices.

f) Explore sustainable and eco-friendly packaging, gear, and infrastructure options to reduce plastic use and potential contamination.

g) Investigate and assess the efficiency of mitigation strategies such as filtration systems, waste management protocols, and containment techniques to prevent microplastics release and accumulation in aquaculture settings.

h) Analyze the potential of biological solutions or natural remediation processes to reduce or eliminate microplastics from aquaculture systems.

i) Encourage collaboration between research institutions, government agencies, industry experts, and local communities to share findings and pool resources for more effective research efforts.

j) Establish platforms for disseminating research outcomes to stakeholders, policymakers, and the public, enhancing awareness and understanding of microplastics issues in coastal aquaculture.

3. *Public discourse planning and support to prevent or reduce microplastic contamination*

a) Develop educational programs tailored to different stakeholders within the aquaculture industry, including fishermen, farmers, suppliers, and consumers, to raise awareness about the implications of microplastics contamination.

b) Utilize various communication channels such as workshops, seminars, and educational materials to disseminate information about responsible plastic use and its impact on the coastal economy.

c) Empower local communities to participate actively in clean-up initiatives, waste management practices, and sustainable solutions, considering the cultural and economic aspects of the communities involved in coastal aquaculture.

d) Establish community-based programs that integrate traditional knowledge with modern practices for reducing plastic use in the aquaculture sector.

e) Offer economic incentives or subsidies to aquaculture businesses willing to adopt eco-friendly practices, supporting the transition toward sustainable and plastic-reduced operations.

f) Facilitate access to funding, resources, or technological support for small and medium-sized aquaculture enterprises to integrate cost-effective and environmentally friendly measures.

g) Encourage responsible consumption among consumers by promoting sustainably sourced seafood and products from aquaculture systems with reduced or no microplastics contamination.

h) Develop certification or labeling systems that inform consumers about products originating from low-impact aquaculture systems, thereby driving market demand for environmentally conscious products.

i) Facilitate discussions and forums between policymakers, industry leaders, environmentalists, and local communities to collectively address and advocate for policy changes concerning microplastics reduction in aquaculture.

j) Encourage active participation and feedback from stakeholders to ensure policies and initiatives are practical and reflective of the economic landscape of coastal aquaculture.

C.3. Microplastics Contamination in Aquaculture (Dr. Romi Novriadi)

Micro-plastic pollution in aquaculture has not been paid enough attention, and the measures are only applied to the aquaculture grow-out stage and not to the whole production system. Thus, mitigating the presence of microplastics in aquaculture is essential to protect the culture system and the safety of seafood for human consumption. Below is a mitigation plan to reduce the micro-plastic pollution in aquaculture:

a) It is important to identify the pollution sources and determine the mitigation plan to reduce the pollution. The source of microplastics in aquaculture can come from external environments, such as industrial effluents (textile, automotive, packaging and food industries), domestic sewage, shipping industry, inland agriculture, garbage, and the atmospheric environment. In addition, the sources can also come from internal production, such as using fishing gears in aquaculture, feeding and packaging. Mitigation plans must focus on solving the pollution from external or internal sources. One of the mitigation plans that can be applied is using sustainable, biodegradable and reusable packaging to transport the larvae, fingerlings, feed, and post-harvest fish. Moreover, the government needs to promote the adoption of alternative materials to partially or entirely replace plastic usage in aquaculture production.

b) There is an urgent need to push the government to release the threshold limits of microplastics in the freshwater, brackish water, and marine water environments for aquaculture. From this point, governments can include the enhanced filtration system protocol for the intake and specific wastewater treatment in the regulation of good aquaculture management practices.

c) Government intervention can also be in the form of domestic standardization (SNI) for detecting microplastics from various sources of samples related to aquaculture systems.

d) Research direction needs to focus on countermeasures for microplastics pollution and the need to replace fishmeal in the diet formulation completely. As we know, several major studies have reported that microplastics have contaminated fishmeal. To produce 1 kg of fishmeal,

around 6 – 7 kg of capture-based fish are needed as the raw materials. Thus, one can estimate how much microplastics can be transferred from farmed fish to humans and the potential human health risks associated with the process.

e) Regulations are needed for monitoring and surveillance programs for microplastics in aquaculture. Aquaculture is a dynamic process, and microplastics pollution may differ under different time and environmental conditions. Thus, a proper monitoring system can become a good approach to control the pollution.

Microplastics have now entered the aquaculture environment in many ways. Therefore, cross-field cooperation involving active participation from stakeholders, farmers, governments, and researchers is important to carry out an efficient and effective mitigation plan.

C.4. Microplastics Mitigation Plan in Indonesia's Fisheries Sector (Lolita Thesiana, S.Si, M.T and Dr. Rinny Rahmania S.Pi, M.Si)

Mitigating microplastics in the fisheries sector in Indonesia is one of the crucial steps to protect fishery resources and marine environmental sustainability. Below are some microplastics mitigation plans suitable for the fisheries sector in Indonesia:

a) Education and Training:

We could train fishermen, fish farmers, and stakeholders in the fisheries sector on the impacts of microplastics and how to reduce the exposure and release of microplastics into open waters. Training materials include the application of fishing gear, more environmentally friendly fishing methods, and the maintenance/inspection of equipment and nets. Ensuring that fishing equipment, such as nets, fish sorting containers, and moorings, do not contain or generate microplastics. Damaged or microplastics-containing equipment should be promptly repaired or replaced.

b) Reduction of Plastics in Handling Captured Fish and Harvested Aquaculture Products:

Reducing the use of plastics in handling captured fish and harvested aquaculture products by promoting the use of environmentally friendly alternative packaging materials, such as paper, bamboo woven baskets, or other recyclable materials.

c) Monitoring and Research:

Regular research and monitoring are conducted to assess the level of microplastic exposure in a specific aquatic region, including sediments, captured marine organisms, and aquaculture commodities. Scientists or stakeholders can utilize the data to identify the microplastics exposure levels at various underwater locations, trace potential sources of

microplastics in those areas, and facilitate further mitigation efforts. Several recent studies to determine the levels of microplastic contamination in Indonesia's coastal and marine areas have been conducted such as looking at evidences of microplastic in water and sediment of Surakarta city river basin (Ismanto et al., 2023); microplastic contaminant in *Telescopium Telescopium*, the keystone mangrove species and their habitat at brackish water pond (Supriatna et al., 2023); spatial and temporal distribution of microplastic in surface water of tropical estuary: case study in Benoa Bay, Bali (Suteja et al., 2021); and a novel report on the occurrence of microplastic in Pekalongan River Estuary, Java Island (Ismanto et al., 2023).

d) Solid Waste Management on Vessels:

Promoting improved solid waste management practices on fishing vessels, including the segregation and storage of plastic waste generated during voyages and transporting it back to the shore for further waste management.

e) Wastewater and Solid Waste Management System at Ports:

Enhancing the waste management system at fishing ports, including waste segregation facilities, collection, and appropriate waste processing to reduce the release of microplastics into the sea. The Minister of Environment's Regulation No. 05 of 2009 regulated port Waste management. General ports and particular ports meeting the criteria specified in the Minister's regulation (fishery ports are not covered in this regulation) are obliged to provide waste management facilities originating from ship operations or activities. The criteria for general and special ports, as referred to in the Minister's regulation, are as follows:

- Ports where crude oil is loaded onto oil tanker vessels that meet one or more of the following criteria:
  - Have a priority to conduct ballasting for a maximum of 72 hours.
  - Anchor in an environmental interest area of the seaport or a working area of the seaport.
  - Have voyaged a minimum of 1200 nautical miles.
- Ports where vessels load bulk cargo other than bulk crude oil at an average rate exceeding 1000 metric tons per day.
- Ports equipped with facilities and infrastructure for ship repairs, cleaning of oil tanker cargo tanks, and cleaning of chemical tanker cargo tanks.
- Ports equipped with facilities and infrastructure to handle vessels equipped with oil sludge tanks.
- Ports handling oily bilge water and various other types of residues that cannot be discharged into the environment.
- Ports for bulk cargo loading and related activities associated with oil residues that cannot be discharged into the environment.

The Minister of Marine Affairs and Fisheries of Indonesia Regulation No. 26 of 2021 regulates waste management in fishing ports and fisheries activities concerning the Prevention of Pollution, Damage, Rehabilitation, and Enhancement of Fishery Resources and Their Environment. This regulation addresses the prevention of pollution for fisheries resources from the following activities: particular ports, as referred to in the Minister's regulation, are as follows:

- Tourism
- Utilization of small islands and surrounding waters
- Fishing, transportation, and fish processing
- Fish farming in Indonesia's Fisheries Management Area
- Fish handling and/or processing
- Offshore structures and installations
- Port management
- Salt ponds/salt production facilities
- Mineral and coal mining
- Maritime transportation
- Industry
- Electrical power generation
- Coastal and/or marine reclamation
- Leakage of solid waste and liquid waste from household/residential activities from land to marine waters
- Agriculture, plantations, and/or livestock farming
- Other activities or businesses with the potential to pollute fishery resources and the environment.

f) Fishery Product Labeling:

Promoting transparent labeling practices related to fishery products with low environmental impact, such as those that do not use plastic in their production or packaging processes.

g) Partnerships and Collaboration:

Establishing partnerships with environmental organizations, government entities, and other industries to develop and support microplastics mitigation initiatives in the fisheries sector. Examples include

- Returning fishmeal containers to the factory,
- Recycling old fish/shrimp pond paddle wheels and
- Implementing mechanisms to recycle HDPE plastic geo-membranes used in shrimp/fish ponds.

h) Regulatory Strengthening:

The government should strengthen regulations related to the use of plastic in the fisheries sector and impose sanctions for violations. Some laws do not directly address the use of plastic in the fisheries sector. For example, Indonesia Government Regulation No. 27 of 2020 concerning specific waste management already addresses handling waste generated in coastal, marine, and inland water areas. This waste

undergoes a process of sorting, collection, transportation, processing, and final treatment (controlled landfill/sanitary landfill). Furthermore, this waste can be used as a substitute for fuel (per Presidential Regulation No. 35 of 2018 on accelerating the development of waste-to-energy installations based on environmentally friendly technology). This regulation is the responsibility of the regional governments of DKI Jakarta, Tangerang City, Tangerang Selatan City, Bekasi City, Bandung City, Semarang City, Surabaya City, Surakarta City, Makassar City, Denpasar City, Palembang City, and Manado City.

i) Technological Innovation:

Promoting the development of new technologies that can assist in addressing microplastics, such as microplastics filtration systems on fishing vessels, microplastics filtration in water treatment facilities for recirculating aquaculture systems, or plastic waste recycling technologies at sea. For example:

- Membrane filter technology (microfiltration, ultrafiltration, dynamic membrane, and reverse osmosis) for microplastics filtration in water, source: https://www.sciencedirect.com/science/article/pii/S2772577422000404.
- Application of foam fractionator technology for freshwater land-based fish farming and marine aquaculture raw water (source: https://www.sciencedirect.com/science/article/pii/S0144860921000510, https://www.sciencedirect.com/science/article/abs/pii/S0144860912000799).

Various stakeholders should support this plan, including fishermen, government authorities, the fishing industry, and the community. These collective efforts will help sustain the fisheries sector and protect Indonesia's marine environment from microplastics.

D. Japan

D.1. What should we do to prevent plastic pollution by fisheries? (Assist. Prof. Nakano Haruka)

a) Promote public awareness of plastic pollution

Increasing awareness of fishermen and fish farmers on the loss of fishing gear and materials, is one of the challenges in combatting marine litter. Regular scientific workshops are recommended to improve the stakeholders' knowledge of marine litter issues and promote recycling by themselves. Also, Promotional activities using existing frameworks can be practical. For example, the Fisheries Agency of Japan has formulated "Guidelines for Promotion of Systematic Disposal of Waste

in Fisheries" to inform and instruct fishermen on properly managing and disposing of fishing gear. Furthermore, a declaration “Plastic Resource Recycling Action” by the Ministry of Agriculture, Forestry and Fisheries and a campaign called “Plastic Smart” organized by the Ministry of Environment, Japan, are good opportunities to share what kinds of actions have been done in Japan.

b) Thorough collection and proper disposal to prevent leaking of fishing gears

In order to promote the recycling of fishing gear, it is necessary not only to develop recycling technology but also to establish a comprehensive recycling system that includes the sorting and collection of used fishing gear, and the active cooperation of fishermen and fishery-related organizations is essential. For example, the development of easy-recycle fishing gears (subsection 3.1, 3.2) and several systems to avoid accidental leakage (subsection 3.3, 3.4) are recommended.

Furthermore, to control the loss of fishing gear, appropriate measures should be taken in each economy, taking into consideration the actual aquaculture situation in each economy, the diversity of materials used, and the factors contributing to the loss of fishing gear. In this regard, it should be noted that each economy has its own important aquaculture system, such as the shrimp in Indonesia; and Malaysia and the scallops in Japan. Because each aquaculture system is different, there should be a variety of mitigation measures. Therefore, rather than making uniform decisions, it is desirable to create a broad framework and accumulate best practices within that framework according to the actual aquaculture conditions in each economy. It is then desirable for the economies concerned to exchange frank opinions and build a cooperative framework.

c) Developing new technology systems

- Easy-recycle fishing gears

  Each manufacturer should develop fishing gear that is easy to recycle. For example, fishing gear made of a single material and fishing net fabrics that are prepared with quickly identifiable material is recommended. The Fisheries Agency of Japan is promoting such development.

- Fishing gear made from biodegradable plastics

  Each stakeholder should promote the development of fishing gear using environmentally friendly materials such as biodegradable plastic for gear or gear parts that do not necessarily require the highest strength or durability and can be flushed out easily by current. To advance the development of such fishing gear, Japan government should provide more support to manufacturers. Such activity contributes to minimizing the burden on the marine environment

caused by fishing gear accidentally or unavoidably loss of fishing gear into the ocean and the burden on the environment caused by fishing gear disposed of in landfills.

- Marking of fishing gear

  Marking of fishing gear is promoted all over the world. Based on the diversity of aquaculture and fishing gear in each economy/region, it is recommended to promote such marking systems.

- Marine disaster prediction system

  In Japan, fishing gear is usually lost due to harsh weather rather than intentional disposal. For example, the strong current called Kyucho (coastal trapped wave, currents relating to the Kuroshio) has sometimes washed away the set net. Scientists have revealed such phenomena, and relevant measures have been introduced based on scientific knowledge. Now, the fisheries department in each prefecture and the Japan Fisheries Research and Education Agency even have prediction systems for suddenly occurring coastal trapped waves. Such systems prevent fishermen from protecting their possessions and leaking plastics.

d) Collect scientific knowledge

- Monitor plastic pollution and its effects.

  In order to avoid stirring up consumer anxiety, regulations should be based on scientific information. So, scientists in each economy have investigated in-situ marine plastic pollution relating to fisheries, including aquaculture. Such monitoring activities should be continued. Moreover, the knowledge of bio-toxicology should be accumulated. In toxicology experiments, we should examine how to link the laboratory conditions to the actual field.

e) Technical harmonization of plastic pollution research

Non-harmonized research, including microplastics monitoring and sample preparation, makes comparing data difficult. In Japan, the Ministry of Environment promotes a protocol for harmonizing floating microplastics monitoring in collaboration with GPML experts (Global Partnership on Marine Litter), NOAA, etc. In aquaculture, such international partnerships to harmonize techniques are also recommended.

E. Malaysia

E.1. Concept Note of policy and regulatory intervention/reform, research direction and public discourses planning and support to prevent or reduce microplastics contamination in coastal aquaculture input chain (A/Prof. Sarva Manggala Praveena, Ph.D and Zulaikha Yusof)

General concept of policy and regulatory intervention/reform in coastal aquaculture input chain systems:

a) Existing

- Fisheries Act 1985, Section 61 - To make suitable provisions with regard to the disposal of fishing gear and tackle

b) Future

- Environmental Impact Assessment

  Governments should require thorough environmental impact assessments (EIAs) for aquaculture projects. These assessments should consider the potential impacts on coastal ecosystems, water quality, and biodiversity.

- Zoning and Site Selection

  Policy interventions can establish zoning regulations to guide the location of aquaculture farms, ensuring that they do not harm sensitive coastal areas, such as mangroves or protected marine habitats.

Research direction

a) Existing

- Praveena et al. (2023) – Focusing microplastics in aquaculture products (under review)
- Yusof Shuaib et al. (2017) – focusing microplastics in coastal aquaculture products http://www.ukm.my/mjas/v21_n5/pdf/YusofShuaib_21_5_7.pdf

b) Future

- Technology and Innovation

  Investigate emerging technologies and innovations in coastal aquaculture, assessing their potential to address sustainability and regulatory challenges. This may include research on recirculating aquaculture systems, genetic improvements, and feed alternatives.

Research direction and public discourses planning and support to prevent or reduce microplastics contamination in coastal aquaculture input chain systems

a) Existing

- None

b) Future

- Sustainable Aquaculture. Studies focusing on sustainable aquaculture practices include responsible resource management, reducing environmental impacts, and promoting efficient resource utilization.

Policy Recommendation: Ensuring Food Safety from Microplastics in Coastal Agricultural Products for Export-Import

a) Standards and Guidelines:

- Incorporation of globally recognized standards, including Codex Alimentarius (e.g "Codex General Principles of Food Hygiene" and "Codex Code of Practice on Food Contaminants"), Best Aquaculture Practices (BAP) (emphasizing the BAP standards for aquaculture practices, including provisions for water quality and safety), and ASEAN Good Aquaculture Practices (ASEAN GAP) (guidelines for responsible aquaculture, environmental sustainability, and the safety of food fish production in the ASEAN region), to safeguard food safety and quality
- Comply with the World Trade Organization (WTO) Sanitary and Phytosanitary (SPS) and Technical Barriers to Trade (TBT) Agreements to promote international trade while adhering to food safety standards.
- To further enhance food safety and quality, adhere to other standards, including ISO 22000, EU Regulation 10/2011, EFSA guidelines, and relevant domestic regulations, where applicable.

b) Safety Measures:

- Adoption of Hazard Analysis and Critical Control Points (HACCP) principles to identify and mitigate the risks associated with microplastics contamination (e.g, Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Application).
- Evaluate location-based impact assessments to account for variations in microplastics accumulation and support responsible site selection for aquaculture practices.

c) Monitoring and Screening:

- Implement comprehensive water quality monitoring programs that incorporate advanced filtration systems to minimize the intake of microplastics (e.g. Best Available Practice water quality standards).
- Conduct systematic product inspection and screening procedures at various production stages to effectively detect and remove microplastics residues.
- Ensure product inspection and screening conform to the principles of the WTO TBT Agreement, promoting technical harmonization for international trade.
- Adopt the best aquaculture technology in line with the TBT Agreement's principles of non-discrimination, transparency, and trade facilitation.

d) Food Safety Testing:

- Develop and adopt standardized testing methods to accurately assess microplastics residue levels in coastal agricultural products.
- Develop testing procedures aligned with Codex and SPS Agreement principles, ensuring the safety and quality of aquaculture products regarding microplastics contamination.
- Food safety testing as a prerequisite for certification, aligning with the SPS Agreement's requirements for ensuring food safety and protecting human health.
- Integration of food safety testing into the certification process to ensure that products meet the microplastics safety standards.

e) Supply Chain Management:

- Establishment of traceability systems conforming to international standards, enabling the effective tracking and tracing of coastal agricultural products throughout the supply chain.
- Advocate for suppliers to align with food safety and quality standards, thereby promoting responsible and safe practices in the supply chain.

f) Product Certification:

- Suggest the creation of a microplastics-free certification process administered by authorized third-party certification bodies, ensuring transparency and consumer confidence.

g) Consumer Awareness:

- Clear and informative product labeling to inform consumers about the compliance of products with food safety and quality standards, with a specific focus on microplastics safety.
- Implementation of public education campaigns to raise consumer awareness about the importance of food safety, emphasizing the significance of microplastics-free products.

h) Research and Collaboration:

- Promote investment in research and development efforts to discover innovative methods for reducing microplastics contamination in aquaculture.
- Conduct a comprehensive analysis to identify potential sources of microplastics contamination.
- Analyze specific critical limits or thresholds to ensure microplastics contamination remains within safe levels and set measurable parameters that can be monitored, such as the maximum allowable microplastics concentration in water or products.
- Evaluate how microplastics can enter the aquaculture system, such as through water sources, feed, or equipment.

- Encourage data sharing and international collaboration among industry stakeholders to foster the development of best practices while prioritizing the results of testing.

i) Compliance and Enforcement:

- Establish a robust compliance and enforcement system that ensures adherence to microplastics safety standards.
- Stress the need for penalties for non-compliance to maintain accountability and transparency in the industry.

F. Peru

F.1. Mitigation Plan for Peruvian Aquaculture Activities (Dr. Ricardo Dioses)

Key characteristics of aquaculture in Peru:

a) Peru's aquaculture species are mainly three species

- *Argopecten purpuratus*
- *Litopenaeus vannamei*
- *Oncorhynchus mykiss*

b) Aquaculture areas are influenced by river input

Mitigation plan in marine debris management

a) Promotion of public policies directly addressed to marine debris.
b) Reinforcement of existing regulation in solid waste management.
c) Promotion initiatives to reduce the use of plastic and single-use plastics in inland activities.
d) Education programs dedicated to marine debris.

Mitigation plan in Sources of Microplastics

a) River clean-up activities.
b) Mapping and clean-up of sources of marine debris inputs close to aquaculture areas.
c) Installation of nets to reduce the debris intake to the sea to reduce the input ways (rivers).

Mitigation plan for aquaculture activities

a) Promote the identification of the sources of contamination in aquaculture production.
b) Evaluate the use of alternative sources of fishmeal and improve fishmeal production to reduce microplastics contamination. (Fishmeal production requires the identification of contamination sources).

c) Installation or improvement of water supply filtration systems to reduce the environmental input of microplastics.

d) Promote inland aquaculture in accordance with the possibilities of managing environmental pollution.

e) Promote the use and investigation of alternative materials and recycled materials for the aquaculture activity.

f) Identify the microplastics pollution in final aquaculture products for control and follow-up purposes.

G. Singapore

G.1. A review of Existing Regulatory Measures and Possible Mitigation Actions to Prevent/Reduce Microplastics Contamination in Coastal Aquaculture (Yulu Liu)

As included in our submission to the white paper, Singapore has yet to adopt specific laws or regulations on plastics or microplastics in aquaculture. Relevant sources of law and regulation can be found in its instruments in sectors including coastal and marine environmental protection, shipping, land-based pollution, and fisheries, including the following two examples.

a) Zero Waste Masterplan (2019)

The 2019 Zero Waste Masterplan aims to minimize waste in Singapore, featuring discussions on plastic waste treatment, including reducing packaging, EPR, sorting, and incineration. With 2018 data as a baseline, this 2019 Masterplan aims to reduce by 30% the per capita amount of domestic sector sent to landfills to achieve a 70% overall recycling rate and over 80% non-domestic recycling rate as well as a 30% recycling rate by 2030 (Ministry of the Environment and Water Resources and National Environment Agency, 2019). The Masterplan promotes three kinds of resilience: climate resilience, resource resilience and economic resilience, promoting climate change impact mitigation, resource security, and economic development for industries.

An example of efforts by the industry to reduce waste would be the voluntary Singapore Packaging Agreement. Over 200 companies have signed this agreement and are committed to reducing consumer plastics, as well as the supply chain. Since the agreement was introduced to the industry in 2007, the signatory companies have cumulatively reported more than 62,000 tonnes of reduction in packaging waste (National Environment Agency (2021).

b) Resource Sustainability Act (2019)

The Resource Sustainability Act (RSA) was introduced by the Ministry of the Environment and Water Resources (MEWR). It serves to build a sustainable Singapore with higher resource efficiency and climate

resilience as well as contributing to a more general domestic strategy. It targets to reduce three main sources of waste in Singapore with high generation and low recycling rates, including plastic packaging. Measures include mandatory packaging reporting to raise companies' awareness of packaging waste reduction and laying down a policy foundation to implement the EPR framework for brand owners, manufacturers, importers, and retailers for its implementation no later than 2025. A list of packaging to be reported is provided as a reference (in Annexes D and E).[1]

Other relevant sources of laws and regulations include the Environmental Protection and Management Act (1999), Marine Litter Policy Landscape (2020), and SS 670:2021 Specification for Good Aquaculture Practice.

With these instruments in place and across different sectors and covering different mandates, albeit with the possibility for reform or more policy intervention, the key action to be taken could be to enhance coordination of the implementation of existing laws and regulations.

c) Possible actions to be taken

Baseline research for the existence and level of microplastics in aquaculture products, which will require collaborative efforts to enhance data comparability and standardization, including guidelines, standards, and manuals for survey and monitoring, in Singapore and beyond.

Coordination across the implementation of different laws and regulations under different sectors and mandates.

Cooperation with other regional economies, on different platforms, APEC, ASEAN, and other regional bodies with specific mandates. We have built a regional platform and a search tool for relevant research and researchers, at https://mapla-riv.web.app/ and https://marseadata.org/

A responsible importer: as an importer of capture fisheries and aquaculture products, what actions can Singapore take, and what standards should be implemented for responsible aquaculture products? Can Singapore use its market as leverage for food security in and beyond the APEC region?

Targeted legislation: Singapore has adopted instruments on marine environmental protection, waste management, and resource management. These instruments have significant impacts on reducing the generation of waste in Singapore, yet they do not deal with plastics or microplastics in aquaculture or fisheries specifically. In the future, there might be a necessity for such legislative practices.

H. Thailand

H.1. Mitigation plan for microplastics contamination in coastal aquaculture input chain systems (Dr. Suppakarn Jandang)

a) Policy and regulation interventions/reform

Currently, Thailand has no specific legal measures to reduce/or manage plastic pollution in the aquatic food chain. However, Thailand has developed a draft of action plans on marine plastic debris (2023-2027). The draft contains a framework for actions by relevant sectors supporting the roadmap on plastic waste management to reduce the amount of plastic waste from land- and sea-based sources and the impact of marine plastic debris on the ecosystem. Thailand also works with the Net Free Seas project, which is run by the Environmental Justice Foundation (EJF). This project aims to rid Thailand's waters of deadly discarded fishing nets. Coastal communities will collect discarded nets that will be sent to make various goods, such as sports and kitchen equipment. This will protect ocean wildlife and support local villages at the same time.

b) Research direction (In general)

- Microplastics sources and pathways: Investigate the sources and pathways of Microplastics in coastal aquaculture systems. This includes how Microplastics enter aquaculture environments through water sources, feed, or other routes.
- Microplastics uptake by aquatic organisms: Study the extent to which aquaculture species ingest or absorb Microplastics. Assess the potential impacts on their health, growth, and overall aquaculture productivity.
- Bioaccumulation and trophic transfer: Examine the bioaccumulation of Microplastics in the food web, including primary producers, herbivores, and carnivores within aquaculture systems.
- Toxicity and health implications: Investigate the toxic effects of Microplastics on aquatic organisms, including their physiological responses and potential long-term health consequences.
- Risk profiling of Microplastics in aquaculture and fishery products: Assess the potential ecological risks of microplastics in aquaculture systems. Evaluate their impact on aquatic ecosystems and species. Examine the potential health risks associated with microplastics in fishery products, considering both environmental exposure and human consumption.
- Microplastics in aquaculture infrastructure: Investigate the release of Microplastics in aquaculture infrastructure, such as nets, cages, and equipment and their impact on aquaculture operations. Also,

study the effectiveness of filtration systems in removing microplastics from the aquaculture systems.

- Microplastics monitoring: Develop reliable monitoring and detection methods to quantify microplastics in aquaculture environments. This can help assess the extent of contamination and track changes over time.
- Eco-friendly materials development: It's essential to continuously innovate and improve products (e.g., aquaculture infrastructure, packaging) and collaborate with industry stakeholders to reduce Microplastics pollution in the environment
- Public discourse planning and support to prevent or reduce Microplastics contamination in coastal aquaculture input chain systems

c) Public discourse should be continuously encouraged as the understanding of microplastics contamination and available solutions evolves. Engaging stakeholders and the public is critical to building a broad support base and driving positive change in coastal aquaculture input chain systems.

- Research and Data Collection: Gather scientific data and research on the extent and impact of microplastics contamination in coastal aquaculture input chain systems and the perspectives among the key stakeholders. This information will serve as a foundation for informed discussions with the public.
- Public awareness and education: Promote awareness campaigns and education through social media, websites, brochures, workshops, etc. These campaigns should educate the public about microplastics' risks or potential consequences and the need for sustainable practices.
- Community Engagement: Engage with local communities near aquaculture sites to inform them about the risks and solicit their input. Address their concerns and provide opportunities for participation in mitigation efforts, such as monitoring programs (citizen science), organizing beach cleanups, etc.
- Industry Involvement: Engage with aquaculture industry stakeholders to encourage the adoption of best practices for reducing microplastics pollution, such as sustainable feed choices, waste management, and infrastructure improvements.
- Policy Advocacy: Provide evidence and public support to influence policymakers.
- Monitoring and Reporting: Establish a system for ongoing monitoring and reporting of microplastics contamination in aquaculture input chain systems. Get feedback from stakeholders to refine strategies as needed.

- Advocacy for Sustainable Alternatives: Promote sustainable alternatives to materials and practices contributing to microplastics contamination within the aquaculture input chain.

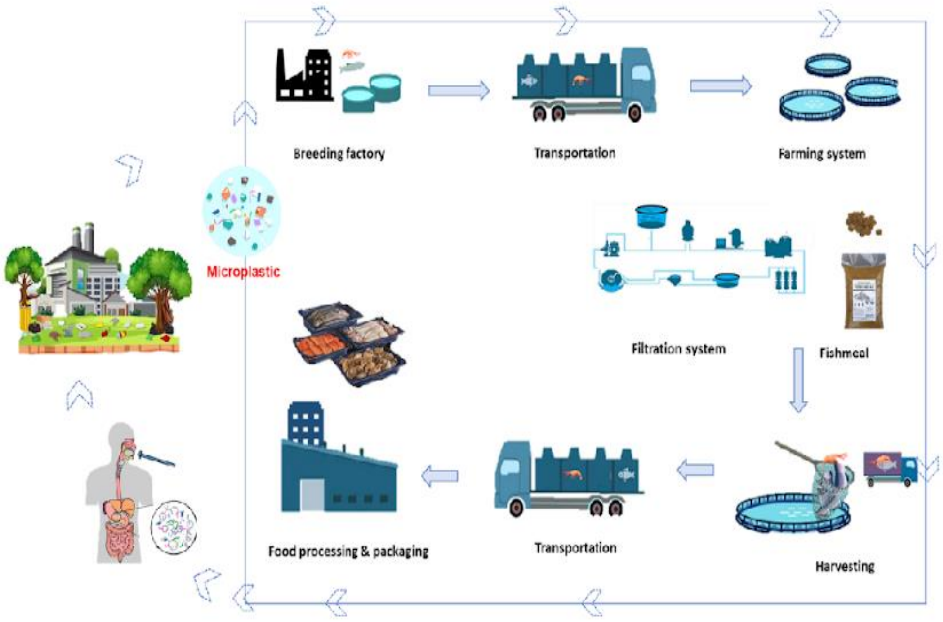

Figure 4. Scheme of microplastics cycle in the environment and aquaculture systems

I. Viet Nam

I.1. Description of Existing Regulation and Proposed Points of Mitigation Plan to Prevent and or Reduce Microplastics Contamination in the Coastal Aquaculture Input Chains (**Dang Thi Thom, Tranh Dinh Trinh and Viet Minh Trinh**)

Decision on No. 687/QD-BNN-TCTS on Approval of the marine plastic waste management action plan for the fisheries sector, 2020-2030 period. General objectives: To reduce plastic waste in fisheries production, gradually manage marine plastic waste from source to the sea, develop circular and green economy approaches, raise awareness and social responsibility of farming communities, fishermen, and plastic waste businesses, contributing to the successful implementation of the Domestic Strategy on integrated solid waste management.

Main tasks and solutions:

a) Raising awareness, knowledge and changing habits of fishing communities and relevant stakeholders;
b) Develop and complete state management documents on marine plastic waste management in the fisheries sector;
c) Reduction of plastic waste, collection, classification at source, reuse, recycling and step-by-step replacement of specialized plastic materials in the fisheries sector;

d) Scientific research, application, development, and transfer of technologies related to marine plastic waste management in the fisheries sector;
e) Strengthening international cooperation.

Targeted stakeholders: Directorate of Fisheries; People's Committees provinces and cities; Department of Agriculture and Rural Development of provinces and central-affiliated cities; Department of Planning-Finance; Education institutions and fishery research institutes; Marine sanctuaries and Associations, fishery-related unions.

Decision No. 911/QD-TTG on approving scheme for environmental protection in the fishery sector in the 2021 – 2030 period. General objectives: Control and prevent pollution in fishery activities; prevent and deal with environmental emergencies; protect and develop aquatic resources and living environment, and thus contribute to the prevention of biodiversity loss; improve climate change adaptation capacity and reduce greenhouse gas emissions; formulate and develop circular economy and green economy models in fishery activities for environmental protection and sustainable development of fishery sector.

Solutions:

a) Increase awareness of environmental protection in fishery activities of relevant parties.
b) Carry out scientific development and apply technologies to fishery activities and treatment of waste generated from fishery activities.
c) Invest in the construction of infrastructure facilities serving the treatment, collection, storage, and transport of waste in the aquatic environmental monitoring system.
d) Study mechanisms and policies on giving incentives on exploitation, use, investment, maintenance and development of aquatic natural capital; mobilize resources and encourage private sector involvement in the protection of aquatic environment.
e) Promote international cooperation in environmental protection.
f) Coverage area: fishery sector.

Decision N°687/QD-BNN-TCTS dated February 5, 2021 on approving the action plan for the management of marine plastic waste in the fishery sector, 2020 – 2030:

a) Raise awareness of relevant parties regarding reducing plastic waste in the fishery sector
b) Reduce use of materials and specialized equipment made of single-use plastic

c) Increase percentage of collection, classification, reuse, and processing of plastic waste from fishery activities
d) 100% of marine sanctuaries develop supervision plans and organize the collection, classification of plastic waste and transport to processing entities
e) Developed database on marine plastic waste in fishery
f) Raise awareness of relevant parties regarding reducing plastic waste in the fishery sector
g) Reduce use of materials and specialized equipment made of single-use plastic

Decision No. 911/QD-TTg dated July 29, 2022 on approving the scheme for environmental protection in the fishery sector in the 2021 - 2030 period:

a) Carry out investigation and assessment of actual situations and propose/formulate policies and mechanisms on giving incentives and assistance for eco-friendly fishery activities to promote circular economy and green economy;
b) Implement programs on investigation, assessment and inventory of aquatic natural capital (tangible and intangible values, etc.) serving socio-economic development;
c) Investigate and assess sources of pollution and the volume of waste generated from fishery activities and propose appropriate management solutions;
d) Improve capacity for preventing and warning of environmental emergencies in the fishery sector;
e) Carry out environmental monitoring serving management of the fishery sector (soil, water and sediment monitoring);
f) Investigate into and assess existing technologies and application of technologies to the treatment of waste generated from aquaculture, commercial fishing and processing of aquatic products, and propose technological solutions for the treatment of waste generated from fishery activities;
g) Renovate and apply waste treatment technologies to fishery activities to establish the premise for salvage and use of fishery waste and by-products in the form of public-private collaboration;
h) Study and gradually make investments in the development of advanced waste management models in fishery activities;
i) Built, updated, and operated the aquatic environment database.

Therefore, all solutions prevent or reduce microplastics contamination in coastal aquaculture input chain systems based on their economies' situation.

3.7.2. Workshop Consensus on the Mitigation Plan to Prevent and Reduce Microplastics Contamination in APEC Coastal Aquaculture Input Chains

Following the process of lesson learning during the workshop from the presentations of the invited speakers, guidance of the expert facilitators, the results of the two previous outputs of the OWFG 03 2021 (White Paper and Research Report), individual concept notes, as well as the discussion and trade-offs between the participants, the workshop participants reached a consensus regarding the recommended mitigation plan. The mitigation plan consists of three interrelated strategies, i.e., identified risks, mitigation actions, and mitigation priorities. Each strategy has specific points (issues/risks, action plans and priorities) that could be adopted by APEC and APEC economies. The recommended mitigation plan is as follows:

A. Identified Risks and Lack of Policy and Regulatory Framework Related to Microplastic Contamination in Coastal Aquaculture Input Chains

Identifying the underlying risks related to microplastics contamination in aquaculture is imperative and the first step in developing any mitigation strategies. It involves the identification of unavoidable and potentially occurring risks from which planning and actions can be devised to reduce the effects or deal with the aftermath.

The workshop participants unanimously agreed that microplastics contamination in coastal aquaculture input chains has not yet regulated in most APEC economies except Chile; People's Republic of China; and Republic of Korea. In the three economies, there are regulations partially addressing the reduction of plastic usage in feed packaging, processing, post-harvest activities, and aquaculture tools/equipment. However, these regulations primarily address the prevention of plastic/microplastics waste from aquaculture and, at the same time, do not address the risks of plastic and microplastics pollution to the aquaculture system. Therefore, the workshop identifies the primary risks to be mitigated as the following:

1) Fishmeal imported from overseas or produced domestically.

   Issue: Fishmeal-contaminated microplastics is one of the contemporary issues in aquaculture. Fishmeal comes from low-value fish and, in most of the cases, is reported to be contaminated with microplastics. The current fishmeal processing technology cannot separate the most microplastics-contaminated fish organ, the gastrointestinal tract (GIT), during fishmeal production. In addition, reports suggested that fish waste, including GIT produced by fish processing industries, is recycled back to produce fishmeal.

2) Feed packaging and processing, post-harvest, tools/equipment used in aquaculture

   Issue: The breakdown of plastic materials used in fish farming into smaller particles may contaminate many processes/stages in aquaculture, some of which will eventually enter farmed fish. Investigating and comparing the sources of microplastics in the closed-aquaculture system are highly feasible considering the compactness of a closed farming system. However, investigating and comparing microplastics contamination in semi- or open-system aquaculture are difficult and require different approaches.

3) Aquaculture environment (water, sediment and wild fish associated with the aquaculture system)

   Issue: microplastics are ubiquitous. To fully understand the distribution and level of microplastics in an aquaculture environment, any microplastics quantification efforts should consider looking at point and non-point contamination sources.

4) The absence of regulations addressing microplastics contamination in coastal aquaculture input chains

   Issue: No specific regulations for microplastics in aquaculture except for Republic of Korea (banning Styrofoam use as buoys in shellfish farming)

5) The absence of regulations addressing microplastics contamination in post-harvest processes of coastal aquaculture products

   Issue: No existing regulations to address seafood safety protocols related to microplastics contamination; Lack of metrics/standards on acceptable concentrations of microplastics in coastal aquaculture products; No existing collaboration between economies or inter-economies management authorities to prevent or reduce microplastics contamination in aquaculture.

B. Recommendation of Mitigation Action Priorities to Reduce the Level or Prevent the Identified Risks within APEC Economies

Based on the results of the whitepaper of this project and confirmation from several workshop participants, the workshop reached a conclusion that regulations governing microplastics contamination in coastal aquaculture, including the processing of aquaculture post-harvest products, are almost non-existent. These issues should be prioritized in any mitigation action to address microplastics contamination in coastal aquaculture. In addition, in terms of research direction, all participants representing APEC economies agree that extensive research in microplastics-related aquaculture within the APEC

region is needed because the results of the extensive research will aid decision-makers in developing the required policy and regulation. Therefore, in terms of priority, extensive research has to have high priority while the development of regulatory measures can follow suit (medium priority).

The identified mitigation actions and their priority are described as the following:

1) Regulating and monitoring fishmeal imported from overseas or produced domestically in relation to the content of microplastics. The list of mitigation actions below is arranged in the order of priority:
   a) Further research into the presence of microplastics in fishmeal and investigate sources of microplastics in different fish feed ingredients.
   b) Product certification for fishmeal and feed ingredients free or has low microplastics contamination.
   c) Developing guidelines for safe levels of microplastics for feed ingredients and promote/encourage the industry to take voluntary steps to quantify, declare and reduce microplastics.
   d) Explore the best available practices, technologies and options for aquaculture nutrition
   e) Developing safe production technology of fishmeal to reduce microplastics contamination.
   f) Identify types of microplastics in fishmeal and alternative/replacement ingredients.

   Based on the severity of the risks and the feasibility of carrying out the mitigation actions within a certain timeframe, the workshop participants reached a consensus to categorize the required actions into short- and long-term mitigation plans as the following:

Short-Term (< 3 years)	Long-Term (> 3 years)
● Further research into the presence of microplastics in fishmeal ● Investigate sources of microplastics in fish feed, i.e., identify specific ingredients that contribute to microplastics contamination.	● Product certification
● Identify types of microplastics in fishmeal and alternative/replacement ingredients.	● Develop guidelines for safe levels of ingredients. Safe production of fishmeal
● Promote/Encourage the industry to take voluntary steps to quantify, declare and reduce microplastics.	● Safe production of fishmeal

● Explore the best available practices, technologies and options for aquaculture nutrition.	● Promote/Encourage the industry to take voluntary steps to quantify, declare and reduce microplastics.
	● Explore the best available practices, technologies and options for aquaculture nutrition.

Several additional suggestions to accompany the identified mitigation actions are:

- Promoting the use of alternative ingredients to replace fishmeal in coastal aquaculture feed, such as the use of seafood processing by-products (controlled aquatic species) as feed ingredients known or predetermined to have less or no microplastics contaminations.
- Encouraging fishmeal processing facilities to develop or adopt safe content guidelines and product certification related to microplastics

2) Feed packaging and processing, post-harvest, tools/equipment used in coastal aquaculture.

The identified mitigation actions and their priority are described as the following:

a) Further research on microplastics distribution in fish farms, feed production and post-harvest packaging.
b) Identify types and levels of microplastics contamination in fish feed ingredients used in coastal aquaculture;
c) Certification of plastic materials used in fish production (on farm) and post-harvest, which includes encouraging fish farmers to use and input suppliers to produce microplastic-free equipment and materials;
d) In-depth investigation of sources of plastics in the supply chain of aquaculture, including different farming stages (hatchery, nursery and grow out, end to end);
e) Develop guidelines regarding the use of microplastics-free materials in coastal aquaculture;
f) Explore alternative materials that are microplastics-free;
g) Incentivize better practices; explore punitive measures.
h) Enhance public and industry awareness (education and training) regarding the risks of microplastics contamination in coastal aquaculture
i) Increasing the role of auditors/observers to enforce compliance when specific regulatory measures exist or have been enacted to prevent or reduce microplastics

contamination in coastal aquaculture operations and products.

The workshop participants also reached a consensus that most of the mitigation actions listed above can be grouped into short- and long-term mitigation actions that can be adopted by APEC or APEC economies.

Short-Term (< 3 years)	**Long-Term (> 3 years)**
Further research on microplastics in farm/feed production materials and packaging	Certification of materials used in production. Encourage suppliers to produce microplastics-free materials
Identify types of microplastics in aquaculture materials	More investigation on sources of plastics in the supply chain (end-to-end)
Explore alternative materials that are microplastics-free	Develop guidelines for the use of microplastics-free materials
Incentivize better practices; explore punitive measures	Enhance public and industry awareness (education and training). Auditing/Observer to support compliance with any legislation

Several additional suggestions to accompany the identified mitigation actions are:

- Assessing the potential role of feed packaging and processing, post-harvest, and tools/equipment used in aquaculture in microplastics contamination/residues in the marketed coastal aquaculture products.
- Educating farmers to limit the use of low-quality plastic materials for packaging, processing, post-harvest, and tools in aquaculture.

3) Coastal aquaculture environment (water, sediment and wild fish associated with the aquaculture system)

The identified mitigation actions and their priority are described as the following:

a) In-depth research on sources of microplastics contamination within coastal aquaculture environments to enable targeted interventions.
b) Developing cost-effective monitoring technology to determine the level of microplastics level in coastal aquaculture environment
c) Revisiting or modifying site selection and zoning schemes/framework to consider the risk of microplastics

exposure to coastal aquaculture operation based on the vicinity of microplastics sources.

d) Encouraging intra and inter-agency cooperation to reduce microplastics in coastal aquaculture.

The short- and long-term mitigation actions recommended by APEC or APEC economies to tackle microplastics contamination within the aquaculture environment are listed below.

Short-Term (< 3 years)	**Long-Term (> 3 years)**
Research on sources of contamination to enable targeted interventions	Technology development for monitoring
Site selection and zoning should consider the risk of exposure based on the location/vicinity of sources.	
Encourage intra and inter-agency cooperation to reduce microplastics	

Several additional suggestions to accompany the identified mitigation actions are:

- In the case of Japan, site selection and zoning for coastal aquaculture have been firmly designated in coastal areas. Such a decision was taken to avoid conflicting use of seascape and potential natural disasters.

4. CONCLUSIONS

This final report presents the current understanding of microplastics contamination in coastal aquaculture input chains from the perspective of policy, regulation, research development and public discourses. In addition, a consensus has been reached among researchers, practitioners, and government officials on a mitigation plan to prevent or reduce the potential risks of microplastics contamination in coastal aquaculture.

Despite the increasing evidence of microplastics contamination in aquaculture, no existing policies and regulations are dedicated to addressing the issue in most APEC economies. Indeed, a few economies have recently implemented regulations to address aquaculture as one of the point sources of plastic waste and microplastics pollution. However, reciprocal attention to address the high risk of microplastics contamination in aquaculture has yet to take definitive shape in the form of regulatory measures.

Both of this project's initial outputs (the White Paper and Research Report) have reconfirmed that microplastics have entered the coastal aquaculture system via multiple pathways such as fishmeal, fish feed both commercial and trash fish as well as the surrounding fish farming environment (water and sediments). The ubiquitous nature of microplastics is also observed in aquatic organisms, particularly wild fish associated with the coastal aquaculture platforms. The occurrences of microplastics within the coastal aquaculture input chains are varied. Nevertheless, it is challenging to state if the contamination level is high or low concerning its potential harmful effects on human health due to the following reasons. There is currently no agreed or regulated minimum level of microplastics in the input chains of coastal aquaculture and the resulting fish products.

On the other hand, various methods (sample collection, preservation, separation, identification and result interpretation) of microplastics quantification exist and are used by the scientific community, and each has its advantages and weaknesses. As a result, almost every research result has a certain amount of uncertainty. In order to overcome this “trust’ issue, standardized methods should be mutually agreed upon based on the accuracy level of results as well as their availability and accessibility to the scientific communities or governing authorities.

The workshop acknowledged that the existing scientific knowledge and regulatory measures to prevent or reduce microplastics contamination in aquaculture are still in their infancy. Therefore, the recommended mitigation action plans described in section 3.3.2 are grouped into short-term and long-term plans. These terms do not necessarily indicate that a short-term action has to be achieved first in order for the subsequent long-term action plan to be carried out. Instead, the terms mean how much time is required to complete one action plan. A long-term action plan can first be carried out, followed by

short-term action plans. In any case, implementing any action plan will depend on the priority and capability of the economies.

As the final conclusion, the workshop participants agreed that the OFWG 03 2021A project, through its three outputs (White Paper, Research Report and Workshop), has addressed the currently overlooked issue: the exposure of microplastics in coastal aquaculture input chains. It provides some insights, new information, and datasets ranging from the policy and regulatory stand points, scientific evidence, and perspective from APEC economy representatives. The project also provided recommendations for a mitigation plan to prevent or reduce microplastics contamination in coastal aquaculture input chains. The APEC could use these action plans as a regional organization and APEC economies to set or define the policy and regulatory direction to address the increasingly concerning issue.

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ANNEX 1. WORKSHOP AGENDA

Workshop APEC 03 2021 A - Developing a Mitigation Plan to Prevent/Reduce Microplastics in Coastal Aquaculture Input Chains Truntum Kuta Bali, 8-10 November 2023

Date/Time (Bali Time)	Activities	Remarks
1st Day –Wednesday, 8 November 2023		
08:00-09:00	Registration	Organizing Committee
09:00-10:00	Greeting Audience	Master of Ceremony
	Safety Induction	Hotel Official
	Project Summary	Project Overseer Hatim Albasri, Ph.D
	Opening Remark	Chairman of Research Organization for Earth Sciences and Maritime, National Research and Innovation Agency (BRIN) Prof. Dr. Ocky Karna Radjasa, M.Sc
	Officiate the Opening & Group Photo	
10.00-10:15	Coffee Break	
10:15-12:00	**Plenary** **Session 1** Indonesia's policy direction in preventing and reducing microplastics contamination in aquaculture	Speaker : Dr. TB Haeru Rahayu, Director General, Directorate General of Aquaculture Ministry of Marine Affairs and Fisheries
	Design principles, methods and data analysis of microplastics contamination and its associated pollutants	Speaker : Dr. Kay Ho, United States Environmental Protection Agency
	Discussion	Expert : Prof. Brian Walter Szuster University of Hawaii, Manoa – United States
12:00-13:30	Lunch Break	
13.30-15.30	- Research and best practices of microplastics prevention and monitoring in marine and coastal organisms and areas	Speaker : Dr. M. Reza Cordova, Senior Researcher, Research Center for Oceanography, The Indonesian National Research and Innovation Agency
	Research presentations on contamination level and distribution of microplastics in coastal aquaculture	Speaker : Dr. Tranh Dinh Trinh, Viet Nam National University, Ha Noi
	Discussion	Expert : Prof. Jesmond Sammut, The University of New South Wales, (UNSW) Sydney
15.30-15.45	Coffee Break	
15:45-17:00	Discussion and formulating key points of the presentation	Expert : Dr. Fayakun Satria, Secretary for Indonesian Commission on Fishing Stock Management

Date/Time (Bali Time)	Activities	Remarks
2nd Day – Thursday, 9 November 2023		
08:00-09:00	Registration	
09:00-12:00	Working Group Meetings – 1 - 3 · Drafting of microplastics mitigation plan in coastal aquaculture input chains (break out groups) · Discussion, formulating key points of the mitigation plan	Expert : 1. Prof. Brian Walter Szuster 2. Prof. Jesmond Sammut 3. Dr. Fayakun Satria
12:00-13:00	Lunch Break	
13:00-15:00	Working Group Meetings – 1 - 3 · Drafting of microplastics mitigation plan in coastal aquaculture input chains (break out groups) · Discussion, formulating key points of the mitigation plan	Expert: 1. Prof. Brian Walter Szuster 2. Prof. Jesmond Sammut 3. Dr. Fayakun Satria
15.00-15.15	Coffee Break	
15:15-17:00	Conclusion and Wrapped up Day 2	Expert: 1. Prof. Brian Walter Szuster 2. Prof. Jesmond Sammut 3. Dr. Fayakun Satria
3th Day, Friday – 10 November 2023		
08:00-09:00	Registration	
09:00-10.00	Presentation of mitigation plan summary from representatives of each working group	Presenters: Appointed group representatives Expert : Prof. Jesmond Sammut
10.00-10.15	Coffee Break	
10.15-12.30	Discussion	Expert : Prof. Jesmond Sammut
12:30-13:30	Lunch Break	
13:30-14:00	Workshop Evaluation	Organizing Committee
14.00-14.15	**Coffee Break**	
14:15-14:30	Summary of workshop recommendation of the mitigation plan to prevent and reduce microplastics in coastal aquaculture input chains+	Presenter : Project Overseer, Hatim Albasri, Ph.D.
14:30-15:00	**Closure of the event** - Closing remarks from the - Formal closure of the Workshop	Head of Bureau of Law and Overseas Cooperation Mr. Ari Prabowo

ANNEX 2. WORKSHOP SPEAKERS, EXPERT FACILITATORS AND CONTRIBUTORS

Workshop Speakers

1. Dr. TB Haeru Rahayu A.Pi, M.Sc,
   Director General, Directorate General of Aquaculture Ministry of Marine Affairs and Fisheries, Indonesia
2. Dr. Kay Ho
   United States Environmental Protection Agency, United States
3. Dr. M. Reza Cordova
   Senior Researcher, Research Center for Oceanography, The Indonesian National Research and Innovation Agency, Indonesia.
4. Assoc. Prof. Tran Dinh Trinh
   Viet Nam National University, Hanoi, Viet Nam

Expert Facilitators

1. Prof. Brian Walter Szuster, University of Hawaii, Manoa – United States
2. Prof. Jesmond Sammut, The University of New South Wales, (UNSW) Sydney, Australia
3. Dr. Fayakun Satria, Senior Researcher, Secretary for Indonesian Commission on Fishing Stock Management, Indonesia

Workshop Contributors

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   National Research and Innovation Agency, Indonesia
4. Lolita Thesiana, S.Si, M.T
   National Research and Innovation Agency, Indonesia
5. Prof. Dr. Ocky Karna Radjasa, M.Sc
   National Research and Innovation Agency, Indonesia
6. Marcus Daniel Wicaksono
   Ministry of Marine Affairs and Fisheries, Indonesia
7. Siti Annisa Mardhatillah
   Ministry of Marine Affairs and Fisheries, Indonesia
8. Yuliadi Kadarmo
   Ministry of Marine Affairs and Fisheries, Indonesia
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15. Dr. Romi Novriadi
Jakarta Technical University of Fisheries (AUP Polytechnic), Ministry Of Marine Affairs and Fisheries, Indonesia

16. Dr. Buntoro Pasaribu
Padjadjaran University, Indonesia

17. Assist. Prof. Haruka Nakano
Kyushu University, Japan

18. Assoc. Prof. Sarva Mangala Praveena B.Sc, M.Sc, Ph.D,
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