WORLD SEAFOOD CONGRESS 2026
CHENNAI, INDIA

CONGRESS PROCEEDINGS

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WELCOME MESSAGE FROM NATIONAL STEERING COMMITTEE CHAIR, DR. RAVISHANKAR CN

Former Director, ICAR-CIFE & ICAR-CIFT
Chairman, National Steering Committee, World Seafood Congress 2026

On behalf of the National Steering Committee, it is my honour to welcome you to the World Seafood Congress-2026 in Chennai, India. This gathering marks a historic milestone as the first time the Congress is hosted on Indian - Nation that stands at the forefront of the global "Blue Revolution." This Book of Abstracts is a testament to our shared commitment to scientific excellence and industrial progress, serving as a comprehensive roadmap for the future of the global seafood trade.

The Congress theme, “Sustainable Solutions for Inclusive Growth – Building a safer, fair and resilient global seafood trade,” reflects the urgent need to balance a rapidly expanding industry with the preservation of our aquatic ecosystems and the empowerment of the people who depend on them. The research curated within this volume addresses the critical challenges of our time: from ensuring rigorous seafood safety and integrity to implementing climate-resilient aquaculture practices. We believe that by bridging the gap between cutting-edge research and commercial application, we can build a seafood economy that is not only profitable but profoundly responsible.

India’s fisheries and aquaculture sectors have demonstrated strong growth and resilience, with record seafood export performance supported by advancements in aquaculture practices, Genetic improved programmes, nutrition and feed technologies, aquatic animal health management, improved standards, modern processing and packaging technologies, value addition, and providing qualified and skilled human resource at all levels. India’s dynamic Fisheries and Aquaculture sector provides the perfect backdrop for this exchange of ideas. As we look toward the ambitious goal of doubling our seafood export earnings, we recognise that innovation is our most valuable resource.

The abstracts presented here-covering everything from blockchain traceability to the valorisation of seafood by-products-showcase the ingenuity required to navigate a complex, post-pandemic marketplace. Contents include: The role of the blue economy in developing countries, Blue foods-safety and nutrition challenges for developing countries, the Future of the global seafood trade, Ethical seafood, Value addition and processing technologies, Inspection and control systems, Hazards in seafood, and Traceabilty and data tools. We are delighted to host a joint UNIDO/FAO panel on seaweed - the blue food of the future
as well as an exciting workshop supported by our colleagues at the Bay of Bengal Program, on the challenges facing the marine ingredients sector.

This event is expected to attract a diverse group of National and International Participants including industry professionals, regulators, policymakers, academia, and NGOs. It will serve as a platform for knowledge sharing and collaboration, aiming to drive the future of the global seafood industry. May the insights found here spark the partnerships and breakthroughs needed to ensure "Blue Foods" remain a safe, sustainable, and inclusive pillar of global food security.

I extend my deepest gratitude to the International Association of Fish Inspectors (IAFI), Department of Fisheries, Government of India, other government Institutions, PDA Ventures Pvt. Ltd., and the global community of researchers, administrators, and policy makers who have contributed to this mega event. I wish to compliment Dr. Ian Goulding, Dr. C.K. Murthy and Ms. Nazeeba Zarin for their significant efforts in planning and executing WSC 2026.

On behalf of the National Steering Committee, it is my great privilege to welcome you once again to the World Seafood Congress 2026, scheduled to be held in Chennai from 8-11 February 2026 and wishing everyone a productive and inspiring Congress!

WELCOME FROM IAFI PRESIDENT, DR.IAN GOULDING

On behalf of the International Association of Fish Inspectors it gives me great pleasure to welcome you to the World Seafood Congress 2026, being held at the Chennai Trade Centre, Chennai, India.

IAFI is recognised by the UN Social and Economic Affairs Committee as representing stakeholders in the global supply chain for aquatic food and feed products, of both plant and animal origin. In this respect, in promoting the biennial World Seafood Congress, IAFI aims to bring together parties engaged in ensuring that blue foods are safe, sustainable and equitable. We seek to sustain dialogue between governments, the fish and seafood harvesting, processing and marketing industries, academia, public and private organizations and other diverse disciplines. The Congress provides all of these sectors with a great opportunity to exchange information, ideas and methodologies, and for interaction with fellow professionals to foster understanding and strengthen collaboration.

The World Seafood Congress has its roots in the FAO Technical Conference on Fish Inspection and Quality Control, held in Halifax, Canada in 1969. The historical city of Chennai joins a long list of distinguished hosts including Halifax, Canada (1999), Vancouver, Canada (2001), The Hague, Netherlands (2003), Sydney, Australia (2005), Dublin, Ireland (2007), Agadir, Morocco (2009), Washington DC (2011), Newfoundland, Canada (2013), Grimsby, UK (2015), Reykjavik, Iceland (2017), Penang, Malaysia (2019) and Peniche, Portugal 2023. We are delighted to bring the Congress for the first time to the Indian sub-continent, with its vibrant, dynamic and globally integrated seafood sector.

Whilst IAFI has its roots in fish quality control, and particularly in the safety of fishery and aquaculture products, our remit has expanded considerably over recent years, as globalisation of our food supply has brought additional issues of sustainability and equity to the fore. IAFI has always placed a high priority in ensuring that the seafood supply chain delivers products in a way that ensures that all participants, and especially those in developing countries, receive a fair share of the benefits of the global seafood trade, and that the environmental impacts of our business activities do not undermine the livelihoods of future generations. To this end, we especially welcome once again the participation of our UN and bilateral development partners, for whom production and distribution of fisheries and aquaculture products forms a core part of their blue economy strategies.

This year we are honoured by the presence in Chennai of a wide range of stakeholders from all around the world. Participants include producers, processors and distributors of aquatic products, trade associations, government agencies, competent authorities, NGOs, vocational training and educational and the R&D institutions. We are delighted that, for the first time, we have specialised sessions on the blue economy, human resources (including labour conditions) and on seaweed,

reflecting the emergence importance of these areas on international trade and development. All of this, along with your active participation, will make WSC2026 an exciting and fulfilling event. I wish you all a great Congress.

WELCOME FROM DR.MANUEL BARANGE

ASSISTANT DIRECTOR GENERAL AT THE FAO AND DIRECTOR OF THE FISHERIES AND AQUACULTURE DIVISION

Good morning and thank you. My name is Manuel Barange. I'm Assistant Director General at the FAO and Director of the Fisheries and Aquaculture Division.

It is my pleasure to speak to you, although virtually, at the World Seafood Congress 2026. In 1969, FAO and UNIDO convened the first International Fish Inspection and Quality Control Conference, the foundation of what is now the World Seafood Congress. I'm pleased to see that the International Association of Fish Inspectors is now leading the organisation of this important forum.

Now let me be clear, today 735 million people face hunger and almost 700 million people live in extreme poverty conditions. These are real lives, not just numbers. At the same time, our oceans and seas are under increasing pressure, but they hold enormous, untapped potential for food security and for poverty alleviation.

Let me tell you why aquatic foods matter. Global aquatic food production of aquatic animals reached 189 million tonnes in 2023. 19 million tonnes of those come from capture fisheries and 98 million tonnes come from aquaculture.

90% of this production goes directly for direct human consumption. In fact, the consumption of aquatic foods has been growing at twice the rate of population growth since the 1960s and is growing faster than the rate of consumption of any other protein sources, animal or vegetable. This means that they are having already a significant and growing role in improving nutritional outcomes.

Perhaps more importantly, aquatic foods are very rich on essential micronutrients, omega-3 fatty acids, iodine, iron and zinc, vitamins A, D and B12. Seafood is truly brain food. For example, omega-3 acids support brain development, memory and learning.

Iodine is critical for cognitive function. Let me mention 1.9 billion people currently lack sufficient iodine in their diets, a deficiency that is entirely preventable. Ocean foods, including seaweed, offer a natural and sustainable solution.

Now, what is the role of seaweed overall? Global seaweed production exceeded 37 million tonnes in 2023. This is primarily in Asia. Seaweed is nutritionally dense, climate-friendly and holds a significant potential for future growth.

Now, what about the demand in the future? The global seafood demand is projected to grow by at least 15% by the end of this decade, driven by population growth, urbanisation and rising incomes, especially in the global south. Yet aquatic foods remain underrepresented in food security and nutrition strategies. Let me talk a little bit about jobs, economics and livelihoods.

Now, seafood is one of the most traded food commodities globally. Over 45% of its products are traded internationally, and the global trade of this product exceeds 195 billion US dollars. On people, 600 million people are estimated to depend on fisheries and aquaculture for their livelihoods, particularly small-scale fisheries that employ 90% of these people and produce 40% of the global catch.

So let me tell you about three priority actions that we think the sector needs to take into consideration. First, to make better use of aquatic foods. That means reducing loss of waste and use more of the whole fish.

At times, 30 to 70% of a fish is discarded during filleting, yet these parts are the most nutrient-dense. With simple, affordable technology, byproducts can be transformed into low-cost nutritional foods. Promoting sustainable foods like seaweed will also ensure food safety and better quality and better volume of production.

Second, to support small-scale fisheries and post-harvest workers, especially women who play a critical and often overlooked role, and youth who are the future of the sector. Investing in policies that improve incomes, working conditions and recognitions, and ensure the social sustainability of the sector. And third, to scale up sustainable aquaculture.

Aquaculture must expand and intensify, depending on the region, but responsibly. Focus particularly on eco-friendly, inclusive systems that protect ecosystems while delivering nutrition and jobs. Raising awareness of the reduced environmental impact of aquaculture compared to land-based protein sources, and it's significant to feed a growing population.

FAO endorsed last year guidelines for sustainable aquaculture, primarily to follow this vision. In closing, if we are serious about ending hunger and poverty by 2030, we must recognise that oceans and seas are not only something to protect, but they are partners in development. We need to invest in sustainable ocean food systems, investing in nutrition, in livelihoods, in resilience, and in hope.

Let us turn this tide together for our oceans, for our people, and for our planet. Thank you very much.

MEET THE IAFI BOARD AT THE WSC2026

Ian Goulding, President

Ian is MD of Megapesca Lda of Portugal, fisheries consultants specialising in sanitary controls for international trade in fishery and aquaculture products. A food scientist, who originally qualified in the UK as an Environmental Health Officer, Ian started his fish QC career as a technologist developing new retail products for the UK market, as well as setting up the associated processing lines and QC systems. Since 1986 Ian has worked in developing countries, including four years working at Alexandria University, Egypt establishing a fish technology training centre. Ian is a Fellow of the Institute of Food Science and Technology (UK) and has worked on trade and market access issues in over 80 Pacific, Asian, and Latin American countries. Ian founded the IAFI Peter Howgate Award for young fish technologists and edits the popular monthly newsletter "Fishfiles Lite" on EU fisheries matters. Ian is Co-Chair of the World Seafood Congress and will give an opening address in the inaugural session.

Jayne Gallagher, President Elect

Jayne is CEO & Company Founder Honey & Fox Pty Ltd, where she advises launching, growing and scaling seafood businesses in Australia and internationally. She has particular skills in identifying and commercialising new opportunities, developing market entry strategies, building innovation ecosystems, communicating and presenting complex ideas so that they can be understood, multicultural and multilingual negotiations. She has more than two decades of experience in the seafood and agribusiness industries. Her career includes roles as General Manager at Australian Seafood CRC, and President of the International Association of Seafood Professionals. She holds an MBA (Executive) from Queensland University of Technology, a BSc from The Australian National University, executive education from Harvard Business School, and a Mini MBA in Brand Management. Jayne will give a presentation entitled "Crisis to Confidence: Proving Traceability as a Biosecurity Game-Changer"

Clare Winkel, Board Member

Clare is Executive Manager- Technical Solutions Integrity Compliance Solutions, Australia. She has worked in the food industry since 1987, in various roles from hands-on processing operations to Australian Government official. Clare now provides consulting services for multiple certification bodies, as a GFSI auditor & trainer. Clare has audited fish and food businesses in 14 countries throughout Europe, North America, South Pacific, Caribbean, Australia and New Zealand.

She has audited, trained and consulted in the seafood industry, including the wild caught, farmed, fish, shellfish and crustaceans, and including significant work in recent years on food safety issues and HACCP within the seaweed/aquatic plants sector. Clare has been recognised in auditor/trainer of the year awards by certification standards bodies (BRCGS and SQF). Clare holds a Bachelor of Science and MBA in Seafood Management. She is the Chair of the Aquatic Plant Names Committee and has contributed to the formulation of a regulatory framework for the Australian seaweed sector. She has also worked for UN agencies on seaweed sector projects in SE Asia and was a technical reviewer for the US Seaweed Hazards & Controls Guide. Clare will give presentations on "A review of Australian Regulations for the Seaweed industry" and "The Development of a USA Seaweed Guide to Food Safety Hazards".

Ivan Bartolo, Regional Representative Europe

Ivan Bartolo is a food scientist and regulatory specialist based in the UK, with qualifications in Applied Toxicology and Food Technology. He is President of the Seafood Importers and Processors Alliance (SIPA) which represents European interests in these activities, advocating on regulatory matters with the European institutions. He has over 40 years of experience in seafood safety and technical management. His background includes roles such as Regulatory Affairs Advisor at the Sea Fish Industry Authority and work in the seafood industry. Ivan will give a presentation entitled "Evaluating Levels Of Perfluoroalkyl Substances (PFAs) In Seafood on the EU Market"

Marcelo Hidalgo, Regional Representative - South America

Marcelo Hidalgo is the Chief Operating Officer of the Fishing Industry Association in Papua New Guinea (FIA PNG), where he plays a pivotal role in advancing the interests of industrial & small-scale fisheries in Papua New Guinea. He is also the founder and director of Seafoodmatter. In his more than 27 years of experience in the aquaculture and fisheries supply chain, he has been advising large retail companies, tuna fleets, seafood processing suppliers, NGOs, and governments on the application and improvement of responsible sourcing & sustainable practices, driving change across the global seafood supply value chain. Marcelo has been instrumental in developing initiatives that empower local fishing communities and enhance their livelihoods. He actively collaborates with NGOs, scientific institutions, and sustainable finance organisations to implement innovative projects that promote responsible sourcing and environmental stewardship. He has experience in farm management, standard development, strategic planning, and stakeholder engagement. He has worked in more than 60 countries assessing and auditing quality, food safety, traceability, labour conditions, and sustainability matters. In 2018, Marcelo developed the Responsible Sourcing Policy (RSP) of FIA PNG, which is an Initiative that has raised the bar in the Pacific region on accountability and transparency of the Tuna Purse Seiner Industry and Small-Scale Fisheries. He is a board member of several NGOs, including GSSI, GDST, IAFI, and MSC. Marcelo will give

a presentation entitled “Digitalization Of Fisheries Key Data Elements On Crew Welfare - An Audit Tool to Address SDG and ILOC188”

Margarida Correia, Social Media and Awards Director

Margarida Correia is a veterinarian and food safety consultant specializing in the hygiene and trade of animal products, particularly in the fisheries sector. Her qualifications include a Doctor of Veterinary Medicine (DVM) from the University of Lisbon's Faculty of Veterinary Medicine and advanced expertise in the food safety of animal products, focusing on regulatory compliance for international trade. Her professional history includes work as a consultant for the United Nations Industrial Development Organization (UNIDO) and FAO on projects improving food safety systems and industrial standards, participation in regional fish trade workshops across Africa, Asia, and Latin America, and consulting experience with Megapesca Lda in Africa, Europe, Caribbean and South American regions. will give a presentation entitled “The Nexus of Trade Facilitation and SPS Harmonisation”.

Stella Mbabazi, Regional Representative Africa

Stella Mbabazi is a fisheries and aquaculture professional currently serving as the regional Blue Economy Expert at the COMESA Secretariat in Lusaka. Her experience spans fisheries management and aquatic resource governance, Policy and programme development as well as building resilient regional fish value chains across the 21 COMESA Member states and the wider Africa. Her qualifications include a Master of Science in Zoology (Fisheries & Aquaculture) and a Bachelor of Science in Fisheries and Aquaculture from Makerere University. She has held roles as Senior Fisheries Officer and Fisheries Inspector at Uganda's Ministry of Agriculture, Animal Industry & Fisheries (MAAIF) and serves as the African Focal Point for the International Association of Fisheries Inspectors (IAFI), where she was the winner of the coveted Peter Howgate Award 2019.

LIST OF SESSION CHAIRS AND PANELLISTS

SESSION	CHAIR	CO-CHAIR	PANELLISTS
1. THE ROLE OF THE BLUE ECONOMY IN DEVELOPING COUNTRIES	Mr.Yahya Mgawe, National Task Team, FAO, Tanzania	Dr. Kuldeep Lal, Director, ICAR-CIBA, Chennai	
2.BLUE FOODS- SAFETY AND NUTRITION CHALLENGES FOR DEVELOPING COUNTRIES	Dr. P. Krishnan, Director, BOBP, Chennai	Dr.Ian Goulding, President, International Association of Fish Inspectors	
3.FUTURE OF THE GLOBAL SEAFOOD TRADE	Dr. Tarun Shridhar, DG, Indian Chamber of Food & Agriculture, and Former Secretary, Fisheries, AH & D, Govt of India, New Delhi	Ms.Jayne Gallagher CEO & Co Founder Honey & Fox Pty Ltd, Australia	
4.ETHICAL SEAFOOD - LABOUR AND STANDARDS	Ms.Clare Winkel, Executive Manager, Integrity Compliance Solutions, Australia	Dr. K. N. Raghavan IRS (R), Secretary General, Seafood Exporters Association of India, Kochi	
5.GROWTH THROUGH VALUE ADDITION AND PROCESSING TECHNOLOGIES	Dr.G. Sugumar, former Vice-Chancellor, TNJFU, Nagapattinam, TN, India	Mr.Ansen Ward, Fisheries and Aquaculture Division, Value Chain Development Team, FAO Rome	
6.INSPECTION AND CONTROL SYSTEMS TO MEET SEAFOOD TRADE REQUIREMENTS	Dr. M. Karthikeyan, former Director, MPEDA, Kochi	Dr.Esther Garrido Gamarro, Fishery Officer, FAO Rome, Italy	
7.HAZARDS IN SEAFOOD	Prof. Iddya Karunasagar, Advisor, Nitte University Mangalore	Mr.Ivan Bartolo, President, Seafood Importers and Processors Alliance, Belgium	
8. SEAWEED - THE BLUE FOOD OF THE FUTURE	Dr. A. G. Ponnaiah, former Director, ICAR- CIBA, Chennai & former Co-ordinator, INGA, WorldFish, Malaysia	Mr. Nima Bahramalian, Industrial Development Expert, Division of SME Competitiveness, Quality and Job Creation, UNIDO	

SESSION	CHAIR	CO-CHAIR	PANELLISTS
8.A. JOINT UNIDO/FAO PANEL ON SEAWEED - THE BLUE FOOD OF THE FUTURE	Mr. Nima Bahramalian, Industrial Development Expert, Division of SME Competitiveness, Quality and Job Creation, UNIDO	Dr.Esther Garrido Gamarro, Fishery Officer, FAO Rome, Italy	Mr.Jogeir Toppe, Ms.Clare Winkel Dr. A. G. Ponnaiah Dr. Shine Kumar
9. INDIAN SEAFOOD SECTOR - DEVELOPMENT PROSPECTS	Dr. K. N. Raghavan IRS (R), Secretary General, Seafood Exporters Association of India, Kochi	Dr. C. K, Murthy, Acting President, Society for Indian Fisheries and Aquaculture, Hyderabad India	
10.TRACEABILTY TOOLS FOR VALUE CHAIN EFFICIENCY	Mr.Marcelo Hidalgo Chief Executive Officer, Seafoodmatter, Netherlands	Dr. Shankar Rao, Director, Coastal Aquaculture Authority, Chennai	
10A. TRACEABILITY PANEL	Mr.Kevin Edwards, Global Dialogue On Seafood Traceability	Dr. M. Karthikeyan, former Director, MPEDA, Kochi	Mr.Marcelo Hidalgo Ms.Jayne Gallagher Dr. Shankar Rao Prof.G. Jeyasekaran
10. WORKSHOP ON FOSTERING STEWARDSHIP FOR SUSTAINABLE INDIAN MARINE INGREDIENTS	Chairs: Dr. P. Krishnan, Ms. Angela Lentisco, Dr. K.K. Lal and Dr. Naveen Namboothri		
11. CONCLUDING WSC PANEL: - ENSURING SUSTAINABLE BENEFITS FROM THE BLUE FOOD REVOLUTION	Moderators: Ms.Jayne Gallagher and Dr.Ian Goulding		Mr.Nigel Edwards Prof.Melanie Siggs Dr. K. N. Raghavan IRS Dr. Kuldeep Lal Dr.Jorn Schmidt Dr.Iddya Karunsagar

*Colours represent concurrent sessions (run in parallel)

SESSION 1. THE ROLE OF THE BLUE ECONOMY IN DEVELOPING COUNTRIES

BIOECONOMY IN THE AQUATIC FOOD SYSTEMS

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The bioeconomy refers to the production, utilization, conservation, and regeneration of biological resources - alongside the associated knowledge, science, technology, and innovation - to deliver sustainable solutions across all economic sectors. These solutions may include information, products, processes, and services that support the transition to a more sustainable economy. Put simply, the bioeconomy involves using biological resources more intelligently to produce biobased goods, processes, and services, including alternatives to fossil-based products, driven by scientific and technological advancements. Aquatic food processing generates substantial by-products, such as heads, skins, bones, scales, visceral organs, shells, and more - accounting for 30% to 70% of the total biomass, depending on the species and processing methods. If not properly managed or disposed of, these by-products can pose serious environmental risks. However, with appropriate processing, they can be transformed into value-added, marketable products through a bioeconomy approach. Because of their nutritional and bioactive properties, they can serve as raw materials for low-cost nutritious foods or high-value products in the food, pharmaceutical, cosmetic, and materials industries. Therefore, effective utilization of fish by-products offers significant social and environmental benefits, helping to reduce waste in aquatic value chains, optimize resource use, and contribute to the sustainable development of the global blue bioeconomy.

Despite their potential, scaling up from laboratory research to industrial production presents several challenges. These include difficulties in limited data, low consumer awareness, variability in raw materials and processing methods, technology and capacity gaps, and differences in cultural, dietary, and regulatory contexts across countries. To fully realise the potential of the bioeconomy in the aquatic food system, countries need comprehensive and supportive legislation that fosters innovation, investment, and sustainable growth.

THE LEAKING BLUE BASKET: ALLOCATIVE INEFFICIENCY AND THE 'MISSING MIDDLE' IN ASIA'S FISHERIES VALUE CHAIN

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Over the past three decades Asia emerged as the fish basket of the world. However, regional analysis of eleven major fish-producing nations (Bangladesh, Cambodia, China, India, Indonesia, Malaysia, Maldives, Philippines, Sri Lanka, Thailand, and Vietnam) reveals systematic inefficiencies across aquatic food value chains, with fish loss and waste (FLW) rates ranging from 20% to 60% of total catch. This "leaking basket" syndrome results in aggregate annual economic losses exceeding USD 10 billion, representing a profound failure to translate massive production gains into stable economic returns or nutritional outcomes. The root of this "leaking basket" is not an overabundance of resources but are driven by specific infrastructure gaps as 43.5% of losses occur at landing sites due to inadequate icing and high ambient temperatures, while weak cold-chain integrity during distribution further exacerbates deterioration.

India serves as a definitive case study for this disproportional investment strategy. The nation has seen impressive production growth achieving a CAGR of 6.55% during 2014-2023. However, per capita supply in India is amongst the lowest in the world and instances of malnutrition is widespread indicating a distributional problem. An evaluation of India's fisheries sector schemes reveals a skewed disbursement in favour of production centric activities and missing the middle. In this perspective, under the Fisheries and Aquaculture Infrastructure Development Fund (FIDF) scheme, approximately 80% of total sanctioned investment (₹5,195.72 crore) was spent on large-scale fishing harbours, while critical "management" components such as cold storage, ice plants, and integrated cold chains each account for less than 1% of the total project cost pool. In case of the Pradhan Mantri Matsya Sampada Yojana (PMMSY), while it was more diversified than the FIDF scheme, the "Management" component often operated on lower fiscal thresholds compared to the capital-intensive "Production" and "Infrastructure" sectors enhancing the imbalance. Addressing these losses represents a high-return investment opportunity that enhances regional food security without the need to increase fishing pressure on already depleted stocks. The newly launched Pradhan Mantri Matsya Kisan Samridhi Sah-Yojana (PM-MKSSY), is a strategic pivot towards improving value-chain efficiency, favouring soft infrastructure and micro-enterprises.

The paper would present the key features of the aquatic food value chain in Asia and discuss strategies for their upgradation, by drawing success stories from different countries in the region.

BUILDING A BLUE FUTURE: AQUACULTURE AND FISHERIES AS DRIVERS OF SUSTAINABLE DEVELOPMENT IN COLOMBIA

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Colombia, located at the northern tip of South America and bordered by the Pacific and Atlantic oceans, possesses vast freshwater resources and significant agricultural potential, with nearly 38% of its territory classified as agricultural frontier. Within this context, aquaculture and fisheries have emerged as key drivers of rural transformation, engaging around 1.5 million people and reaching approximately 370,000 tons of fish production. While fishing has deep ancestral roots and industrial activity since the 1970s, aquaculture has developed over the past six decades, positioning itself as a strategic activity for rural development. Importantly, 95% of aquaculture producers are small-scale and subsistence farmers, while around 300,000 artisanal fishers depend directly on fisheries for their livelihoods. The evolution of fish production in Colombia from 1980 to 2023 shows a marked increase in aquaculture output while fishing production has fluctuated and declined in recent years (Figure 1). The promotion of Good Aquaculture and Fisheries Practices has fostered sustainability through public–private cooperation, international partnerships, and public financing. These initiatives have strengthened small-scale producers, boosted local economies, generated employment, and expanded exports. However, persistent challenges remain: access to licenses, business formalization, technological innovation, improved processing conditions, and the adoption strategies to address climate change. Additionally, the decline of fish stocks and aquatic resources poses a major threat to artisanal fishers, demanding urgent actions. Aquaculture and fisheries thus represent not only a source of food security and economic growth but also a pathway toward building a resilient and sustainable blue future for Colombia and the region.

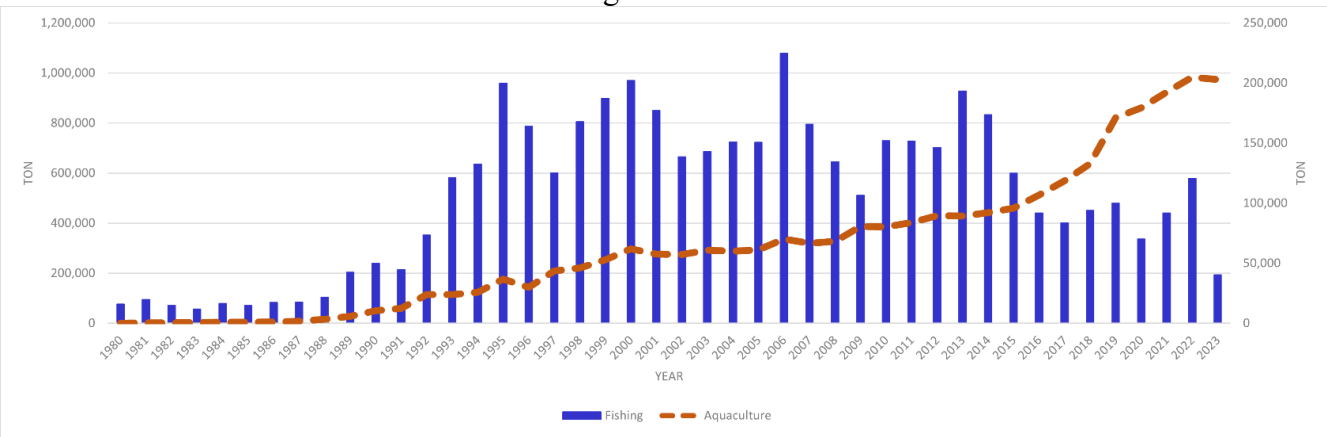

Figure 1.Fish production evolution in Colombia

MAINSTREAMING POSTHARVEST INNOVATION FOR SAFE, SUSTAINABLE, AND GLOBALLY COMPETITIVE PHILIPPINE SEAFOOD VALUE CHAINS

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The Philippines possesses vast fisheries and aquatic resources that substantially contribute to food security, national revenue, and coastal livelihoods. The postharvest sector plays a decisive role in ensuring that seafood reaches consumers safely. However, this segment is increasingly challenged by climate stressors, environmental degradation, resource depletion, market competition, and the growing demand for traceable, high-quality, safe, and responsibly sourced aquatic products. In response, the Fisheries Postharvest Research and Development Division of the National Fisheries Research and Development Institute has strengthened research efforts to modernize seafood processing and elevate competitiveness across domestic and export markets. This presentation synthesizes recent and ongoing initiatives encompassing the development and verification of innovative postharvest and processing technologies, comprehensive safety and health risk assessments of hazards in aquatic foods, integrated supply and value chain analyses of commercially important fishery commodities, climate vulnerability assessment, and efforts to address technical trade barriers through alignment with Codex standards and other international benchmarks, including recognition of locally important species. Findings underscore the heightened vulnerability of Philippine seafood value chains to climate change, but also reveal concrete opportunities to reduce postharvest losses, add value to underutilized resources, and enhance seafood safety and quality assurance for domestic and export markets. Harnessing these insights can support science-based policy development, strengthen compliance with international market requirements, and position the Philippine seafood industry toward more inclusive, sustainable, resilient, and competitive value chains, while empowering seafood producers to participate more equitably in global seafood systems.

UTILISATION, CHALLENGES AND PROSPECTS OF BY-PRODUCTS ORIGINATED FROM AQUATIC RESOURCES IN BANGLADESH

Md Jakiul Islam[1], Sujit Krishna Das[2], Mohd Hazmadi Zakaria[2] and Omar R. Peñarubia[3]
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This study examines wide range of by-products originated from aquatic resources (fresh, brackish, and marine) in Bangladesh focusing on their current utilisation, economic significance, market potential for developing high value-added co-products. It highlights the economic and environmental benefits of using bio-materials that would otherwise be wasted and also outlines the key challenges faced by seafood processors, such as dearth of technologies, inadequate infrastructure, traditional collection methods, limited market access, and lack of coordinated and long-term financing, R & D. The study also provides policy recommendations based on successful case studies to ensure sustainable fisheries management and to promote blue-circular economy. Fish scales, dried shrimp shells, pituitary glands, and fish maws show growing demand, although limited data available at national level except for scales, shrimp shells, and shark fins. Utilisation of shrimp heads and shells for making snacks, chitin, and chitosan offers major economic and environmental benefits, whereas application in nutraceuticals, pharmaceuticals, cosmeceuticals, animal feed, and bioplastics remains unexplored. This study further emphasises the need for advanced technologies, improved processing facilities, diversified products and markets to unlock the potential of by-products. Viscera and guts; and certain small pelagic fishes could support the production of high-value fishmeal and fish oil for feed mills. Collection of carp pituitary glands remains a reasonable and important alternative to synthetic hormones for local and international market. Strengthening capacity, supportive policies, and investment in R&D are the key drivers for developing high-value co-products like collagen, gelatine, chitin, fishmeal and fish oil. Effective enforcement of Wildlife Conservation Act is vital to reduce the shark and ray by-catch and continuation of conservation of marine biodiversity.

UNIDO BLUE INDUSTRY PORTS APPROACH

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Ports play a vital role in global trade and economic development, acting as gateways that connect industrial zones, special economic zones and inland corridors with international markets. For coastal developing countries, they are central to the performance of seafood value chains, supporting fisheries, aquaculture, landing operations, processing, cold chain logistics and market access. As hubs for Blue Industries, ports influence city development, community livelihoods and the broader competitiveness of aquatic food systems. In a period of significant global transitions—including climate action, energy transformation, digitalisation and the need for resilient and transparent supply chains—ports in the Global South face mounting pressures but also significant opportunities to drive sustainable seafood sector growth.

UNIDO defines Blue Industry Ports as hubs that generate economic, environmental and social impact while promoting Blue Industries and strengthening industrial development across maritime and inland trade linkages. This encompasses cargo ports, industrial fishing ports and cruise ship ports, recognising the importance of integrated infrastructure, value chain connectivity and services that support seafood quality, safety and traceability. Through its technical expertise, UNIDO assists ports in enhancing MSME competitiveness, quality infrastructure and compliance systems, trade facilitation, decarbonisation, circular economy solutions, renewable energy transitions and climate-resilient coastal planning.

By embedding industrial development, environmental stewardship and community wellbeing into port operations, Blue Industry Ports can significantly strengthen seafood value chains and enhance participation in regional and global aquatic food markets.

SESSION 2: BLUE FOODS- SAFETY AND NUTRITION CHALLENGES FOR DEVELOPING COUNTRIES

EXPLORING THE INTEGRATION OF FISH POWDER IN SCHOOL MEAL PROGRAMS IN MALAWI THROUGH A FOOD ENVIRONMENT LENS: ACCEPTABILITY, AFFORDABILITY, AND CONVENIENCE

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Fish is a powerful yet overlooked resource for school feeding in Sub-Saharan Africa. Rich in essential fatty acids, high-quality protein, and key micronutrients, fish could address persistent child malnutrition, but animal-source foods remain rare in school meal programs. In Malawi—where fish supplies 14.2% of animal protein and sustains 217,000 livelihoods—it is notably absent from school menus.

This study tested whether locally produced fish powders could be integrated into Malawi's school meals by assessing acceptability, practicality, and cost. Methods included: (1) acceptability trials with 6–13-year-old learners, (2) time assessments for fish powder preparation, (3) evaluation of ease-of-use by school volunteers, and (4) cost analyses of production and affordability for school programs.

Nearly 90% of children ate more than 75% of porridges containing pan-roasted usipa powder, with high ratings for taste, smell, and appearance across both lakeshore and inland schools. Pan-roasting improved acceptability but increased fuelwood use, time, and costs, raising sustainability concerns compared with simpler processing methods.

These results show that fish powders are not only feasible but highly acceptable for school meals. Incorporating them could improve child nutrition, enhance food security, and create new markets for local fish producers. The trade-off between preferred sensory quality and processing efficiency highlights the need for innovation in fish powder preparation.

Integrating fish into school feeding is a missed opportunity, however our evidence shows it can work. Fish powders should be actively promoted as a cost-effective, nutritious, and locally sourced ingredient in Malawi's school meal programs and beyond.

FOOD SAFETY OF FISHERY AND AQUACULTURE PRODUCTS IN MOZAMBIQUE

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Mozambique, is located on the southeast coast of Africa and bordered by the Indian Ocean, has fisheries and aquaculture as strategic sectors for food, nutritional, and socioeconomic security. Fishery products represent a primary source of animal protein, income, and livelihoods for coastal and rural populations, with artisanal fisheries contributing for more than 90% of national production and aquaculture showing increasing growth potential.
Ensuring food safety of fishery and aquaculture products is therefore essential to protect public health, enhance consumer confidence, and secure access to domestic and international markets. In Mozambique, food safety is addressed through an integrated system covering the entire value chain, from primary production to processing, transport, inspection, and certification. This system involves several national institutions, including the National Institute for Fish Inspection (INIP, IP), the National Institute for Standardization and Quality (INNOQ), the National Institute for the Development of Fisheries and Aquaculture (IDEPA), the Oceanographic Institute of Mozambique (InOM), and the Ministry of Health (MISAU), operating in coordination with local authorities.
National legislation and standards are aligned with internationally recognized frameworks such as HACCP, ISO 22000, and ISO 17025, supporting sanitary licensing, laboratory testing, and health certification for export and import. Despite notable progress, challenges remain, particularly in artisanal fisheries, including inadequate infrastructure, inconsistent application of good hygiene practices, and the high cost of maintaining laboratory accreditation.
This paper highlights current food safety measures, institutional roles, challenges, and opportunities, emphasizing the need for strengthened inspection systems, capacity building, international partnerships, and expanded adoption of food safety standards to ensure safe, sustainable, and competitive fishery and aquaculture products in Mozambique.

THE NEXUS OF TRADE FACILITATION AND SPS HARMONIZATION: THE FUTURE OF BORDER CONTROLS AND IMPLICATIONS FOR AFRICAN FISH TRADE

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The trade of fishery products across borders in Africa remains heavily shaped by non-tariff measures, particularly sanitary and phytosanitary (SPS) requirements, which often fragment regional trade and constrain market access. Based on operational experience with One Stop Border Posts (OSBPs) in Africa this paper examines how trade facilitation measures and borders are evolving and what their future role may be in facilitating safe and efficient fish trade. Complementarily, it draws on regional markets, such as the EU internal market, as an illustrative example where regulatory harmonization, mutual recognition and trade facilitation measures have demonstrably improved cross border trade.

Fishery products pose demanding SPS challenges due to the products' perishability, potential public health risks and traceability requirements. In Africa, the fisheries sector plays a critical role in providing livelihoods with fish and fishery products well positioned to meet the needs for high protein and affordable foods in the context of rising populations and growing regional demand for food products. In many African border contexts, fragmented inspection regimes and inconsistent conformity assessment practices tend to constrain market access, increase post-harvest losses and divert trade of fishery products into informal channels. While OSBPs provide an effective institutional platform for coordinated border management and are recognized under the African Continental Free Trade Agreement (AfCFTA) as key trade facilitation instruments, experience shows that their full potential in fish trade is often constrained in practice by the absence of mutual recognition or equivalence arrangements and insufficient risk based approach to border controls, thus reducing efficiency gains of the OSBP concept.

Comparative experience from other markets demonstrates that the effectiveness of integrated border controls depends not primarily on infrastructure investment and shared facilities, but on bilateral confidence in legally anchored harmonization and robust conformity assessment systems that lead to information sharing and transparent enforcement. Addressing this trust deficit requires strengthening national and regional quality infrastructure systems—an area where UNIDO's work under the ProFishBlue programme provides practical guidance to support equivalence, cooperation and mutual recognition between Member States of the SADC region, demonstrating that shifting from end-product inspection toward harmonized, process-risk based controls across the fishery value chain is essential for building trust, enabling mutual recognition, and unlocking the full trade facilitation potential of OSBPs while maintaining SPS integrity of fish products.

FISH LOSS ASSESSMENT AND VALUE CHAIN ANALYSIS ON SMALL-SCALE FISHERIES IN SOUTH SUDAN

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The Republic of South Sudan is endowed with diverse water bodies including rivers, tributaries, lakes, dams and wetland areas. The network of these water bodies has made fishing industry to become an important economic sector in the country, in terms of food security and nutrition, employment and income generation. The government of South Sudan through the financial support from The Kingdom of the Netherlands, commissioned a comprehensive study to assess losses in the context of value chain improvement. The study employed various methods including Exploratory Fish Loss Assessment Method (EFLAM), Gender Responsive Fish Loss Assessment Method (GRFLAM), Questionnaire Loss Assessment Method (QLAM), and the Value Chain Analysis for Development (VCA4D). The study was conducted from the year 2022 to 2023, covering all the ten (10) states. It was found that physical loss is about 11 percent of total catch while quality loss is about 57 percent. In monetary value, the losses can be equated to over SSP 200 billion (USD 200M)) lost income per annum. Critical fish loss hot spots have been identified, together with causes of the loss and potential solution for mitigation and value addition. From the findings, it is evident that no single approach can resolve the intertwined challenges, and thus the need for developing a Multidimensional Solution (MDS) strategy through stakeholders' consultation. Specifically, the focus should be placed on policy and regulatory frameworks, skills and knowledge, application of appropriate technologies, services and infrastructure, social and gender equity, and markets.

REDEFINING TRADITIONAL FISH SMOKING IN THE PHILIPPINES: ADOPTION OF FAO-THIAROYE PROCESSING TECHNIQUE (FTT-THIAROYE) FOR SAFER AND SUSTAINABLE SEAFOOD PROCESSING

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Fish smoking is a traditional preservation technique widely employed in the Philippines, yet conventional methods present major drawbacks related to food safety, product quality, and occupational health. A critical concern is the presence of polycyclic aromatic hydrocarbons (PAHs), which is classified as human carcinogens and tightly regulated in international markets. In this study, PAH concentrations in several smoked fish samples produced using traditional methods exceeded the 12 ng/g European Union limits for PAH4 by roughly tenfold, posing serious risks to consumer safety. Physicochemical analyses also revealed moisture contents above optimal levels for shelf stability, whereas microbiological tests showed aerobic plate counts surpassing national safety thresholds. To address these problems, the FAO-developed processing technology (FTT-Thiaroye) was adapted and optimized for the Philippine context. Production trials with milkfish, tilapia, and sardines processed using different agricultural biomass and sawdust as fuel sources demonstrated that PAH levels in FTT products consistently fell below EU regulatory limits, regardless of species or fuel type. Additional safety and quality parameters, including moisture content and microbiological stability, were maintained within optimum ranges. Refinements in design and operation were also carried out to meet local needs and industry requirements. The findings denote the transformative potential of FTT-Thiaroye in attenuating PAH contamination, improving hygienic quality, and enhancing worker safety, while ensuring compliance with both national and international food safety standards. Adoption of this technology provides a viable pathway for advancing the Philippine smoked fish industry toward greater competitiveness, higher yields, as well as improved livelihoods across the seafood value chain.

SESSION 3: THE FUTURE OF THE GLOBAL SEAFOOD TRADE

THE EVOLVING WORLD TRADE, INTERNATIONAL TRADE LAWS & PRACTICES TO BE TAKEN BY EXPORTERS/ IMPORTERS/TRADERS.

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The global trade in fishery products is increasingly shaped by geopolitical shifts, evolving trade policies, and heightened regulatory and enforcement frameworks. Key challenges encountered in India in our work as Shipping & International Trade specialists are:

- Tariffs, protectionism, and evolving world trade order - Challenges & opportunities in foreign trade.
- Changing world trade landscape, role of UN, IMO, WTO, & Law enforcement concerns.
- Domestic concerns of countries and their impact on foreign trade – Precautions to be taken to protect the value of goods & remittances for exporters.
- Changes in carriage, shipping & Bill of Lading laws in India - Need for documentation and agreements.
- Legal disputes - Challenges like legal expenses, jurisdictional issues, enforcement of law, and execution of judgment.

By identifying key legal and commercial risks, this presentation aims to provide stakeholders with actionable insights to navigate an increasingly complex global trading environment.

NOT JUST A COMMODITY: AQUATIC FOODS AS NUTRITION PATHWAYS FOR NATIONS

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As international seafood markets expand and diversify, aquatic "blue foods" are emerging as a powerful avenue for countries to manage nutrition security and climate risks to their food production, alongside ambitions to grow their blue economies. This keynote will explore how the global seafood trade can play a more deliberate role in supporting food and nutrition security across regions, recognizing that the priorities and pressures differ sharply between developed and developing country contexts.

In developed economies, the seafood sector faces rising expectations for sustainability, traceability, and responsible sourcing, as consumers demand healthier proteins and lower environmental footprints. Strategic investments in innovation, such as digital transparency tools, improved certification systems, and climate-smart, sustainable production, enable companies to secure stable supply, meet regulatory requirements, and protect brand value while contributing to global nutrition resilience.

For developing countries, blue foods represent an essential source of micronutrients, affordable protein, income, and employment. Strengthening local aquaculture and fisheries systems through improved seed, feed, aquatic animal health, cold-chain infrastructure, and market access can increase productivity, reduce losses, ensure quality, and connect small- and medium-sized producers to regional and international markets. Inclusive scientific and digital innovations, along with conducive trade partnerships, fair value chains, and inclusive procurement models, can amplify the benefits, enabling countries to improve nutrition and livelihoods for their people while expanding global supply.

From a WorldFish perspective, aligning science, policy, and market incentives across both ends of the trade system is key to improving food and nutrition security and livelihoods in the geographies we serve.

When global seafood companies, governments, and research organizations collaborate, blue foods become more than commodities: they become strategic pathways for nourishing nations, stabilizing markets, and creating shared value in an increasingly uncertain world.

MAXIMISING SOCIO-ECONOMIC VALUE FOR SMALL SCALE AQUACULTURE AND FISHERIES PRODUCERS

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Small-scale aquaculture and fisheries are the quiet engines of global food security, nutrition, and coastal prosperity—yet their potential remains largely untapped. Representing nearly half of the world's catch and supports the livelihoods of billions. These producers supply nutrient-dense seafood essential for healthy diets, which is particularly important in vulnerable communities where livelihood opportunities are limited, and nutrition sources restricted.

They are pivotal to local economies: providing employment, sustaining cultural heritage, and serving as a cornerstone of women's economic empowerment through their prominent roles across harvest and post-harvest value chains. As climate pressures intensify, small-scale producers stand at the frontlines of environmental change, practicing low-impact, energy-efficient production that can enhance ecosystem resilience and support biodiversity restoration. Enabling them is not only a moral imperative, it is a strategic investment in a sustainable, climate-positive food future.

This keynote will explore how targeted empowerment through cooperative models, digital platforms, fairer trade practices, infrastructure development, knowledge sharing and access to responsible production training can unlock transformative opportunities for small-scale fishers and farmers. It will also look at how circularity and maximising value from full utilisation models can help to create greater value and prevent lost nutrition.

Successful initiatives, including those supported by the Global Seafood Alliance, demonstrate that when producers are equipped with knowledge and the tools to meet global standards, their economic power grows and communities thrive.

BLUE INDUSTRY STRATEGY FOR DEVELOPING COUNTRIES

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Developing countries hold significant potential within the Blue Economy, yet structural constraints continue to limit their ability to advance in higher-value ocean-based industries. UNIDO defines *Blue Industry* as the full spectrum of water-related productive activities that enhance sustainable and climate-resilient livelihoods, strengthen industrial value chains, and foster innovation and environmental stewardship. This paper outlines how developing countries can strategically position themselves to benefit from emerging Blue Industry opportunities by drawing on insights from UNIDO's *Blueprint for Sustainable Development*.

Key Blue Industry sectors such as blue food systems, marine biotechnology, ocean renewable energy, circular economy solutions and digital marine technologies remain underdeveloped in many regions due to fragmented policies, insufficient capacities and limited access to finance. The *Blueprint* emphasises that much of the Blue Economy's potential lies in industrial activities and highlights the importance of coordinated policy frameworks, strong governance and robust science–industry linkages to unlock this potential.

UNIDO's programme experience demonstrates that integrated approaches combining industrial policy, innovation systems, quality infrastructure and climate-resilient development can accelerate capability building and strengthen participation in global value chains. By adopting coherent Blue Industry strategies, developing countries can enhance competitiveness, support resilient coastal livelihoods and contribute more meaningfully to a sustainable Blue Economy.

GLOBAL TRADE AND MARKETS OF AQUATIC PRODUCTS AMIDST RISING UNCERTAINITIES

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Global trade in aquatic products continues to grow in 2025, with volumes increasing by an estimated 2.1 percent, reflecting steady demand across both developed and emerging markets. At the same time, trade policy developments have introduced a heightened level of uncertainty into global markets for fishery and aquaculture products. In anticipation of new or higher tariffs, many importers have adjusted procurement strategies, accelerating purchases to mitigate potential cost increases and supply disruptions.

The possibility of additional trade policy measures has further amplified uncertainty, making market conditions more volatile and creating further challenges throughout the global value chain for aquatic products, from producers and processors to traders and retailers. These dynamics are occurring alongside other contemporary challenges, including shifting consumer preferences, rising input costs, and sustainability and regulatory pressures.

This presentation will provide an overview of current global market trends for aquatic products, analyze the impacts of recent trade policy developments and other emerging challenges, and explore their implications for trade patterns, market flows, and future growth prospects in the sector.

SESSION 4: ETHICAL SEAFOOD - LABOUR AND STANDARDS

CREATING SUSTAINABLE AND SCALABLE SOLUTIONS TO FORCED LABOUR IN FISHERIES AND SEAFOOD INDUSTRY

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Fisheries and aquaculture in India provide livelihood and employment opportunities to about 30 million fishers and fish farmers at the primary level and several millions along the value chain. India is the 2nd largest fish producing country with around 8% share in global fish production. Globally, India is one of the top shrimps producing and exporting nations and 3rd largest capture fisheries producer.[1] India's fisheries sector is a powerful economic driver, with seafood exports projected to grow from $5 billion in 2020 to $18 billion by 2030[2], supporting livelihoods of millions across marine ecosystems and aquaculture value chains. This promise of economic growth requires inclusive and sustainable approaches, to protect the most vulnerable workers trapped in exploitative work in the unregulated markets of the fishery and marine ecosystem.

Every year, many workers in the fishing and seafood industry globally are lured by middlemen with false promises of good jobs and trapped in unhygienic, difficult and exploitative working conditions. Crimes ranging from illegal fishing and document fraud to labour exploitation, human trafficking and money-laundering —remain deeply embedded in this sector,[3] involving migrant and coastal labour. Such activities create unsafe, opaque and highly unequal working conditions for thousands of fishermen, many from low-income, marginalised communities and developing regions, including India.[4]

Media reports suggest that governments are identifying forced labour cases in the fishing industry in the Asian region, including in India. Given the potential for inclusive growth in the fisheries and seafood sector, sustainable and scalable solutions are critical to ensure brand reputation and market opportunities.

This paper describes a typology of labour exploitation in the fisheries sector, drawing from IJM's research and program activities in Thailand and other examples in the Asia Pacific region. It summarizes IJM's collaborative interventions with governments around the world, and how these efforts have helped contribute to progress in reducing the prevalence of forced labour. IJM comes alongside governments and their institutional arms to support efforts toward building a justice system that deters exploitation and fosters sustainable economic progress. The Indian government's efforts to address forced labour are highlighted, with a focus on India's mandatory corporate social responsibility (CSR) law as an additional lever for change.

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[1] Statement by Union Minister for Fisheries, Animal Husbandry & Dairying, Shri Rajiv Ranjan Singh in Sept 2024, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2055709

[2] See response of Minister for Fisheries, Animal Husbandry and Dairy, in Lok Sabha, Parliament of India, 4th Feb 2025.

[3] See Witbbooi et al, "Organised Crime in the Fisheries Sector threatens a sustainable Ocean Economy,", Researcp Paper, University of St. Andrews, https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/23152/Witbooi_2020_Organised_crime_in_fisheries_Nature_AAM.pdf?sequence=1

[4] Organised Crime Associated with Fisheries, https://oceanpanel.org/wp-content/uploads/2022/05/Organised-Crime-Associated-with-Fisheries.pdf

BIODIVERSITY AND SOCIAL IMPACT ASSESSMENT SHRIMP FARMS IN ANDHRA PRADESH UNDER ASC STANDARDS AND IMPACT STATEMENTS

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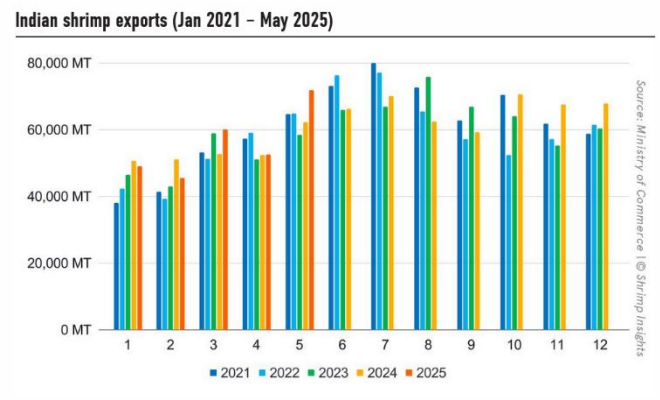
India exported India exported 1,698,170 tonnes of seafood valued at Rs 62,408.45 crore ($7.45 billion) in 2024-25. Export volumes suggest not only stable volumes but also an improved product mix and better average prices. A staggering 60% of this comes from Andhra Pradesh alone. Andhra Pradesh contributes around 32 per cent of marine seafood exports and covers 2.26 lakh acres under aquaculture. The need for traceability and certifications aligned with global standards is enhancing the credibility of Indian shrimp in discerning markets. Studies on Environmental and Social Impact Assessment were conducted in Coastal districts of Andhra Pradesh in about 70 shrimp farms selected based on their size and proximity to coastal zones under ASC standards through Independent Assessments; Results may vary due to limited sample size and selection criteria. Studies revealed that majority of farms don't have any negative impact on Native Mangrove vegetation as most of them were located away from Naturally occurring or protected Mangroves.



Majority of the farms were in Coastal Aqua zone except in Krishna and Godavari districts where farmers have converted their agriculture farms into aquaculture for higher income and due to non-availability of labour due to increased costs. Most of these farms are drawing canal water with salinity ranging from 5-30 ppt and occasionally use saline borewell water for culture. The farms under these studies also revealed that the farms were away from wildlife protected areas and away from biodiversity rich areas and don't possess High Conservation Value species as located mostly in aqua zones in coastal districts. The social Impact studies revealed that there is an overall improvement in the standard of living, earning per family through gainful employment in aqua sector from hatchery to processing and related sectors. Mostly the feedboys are from adjoining states such as West Bengal, Odisha and other regions thus providing gainful employment. Shrimp farming in Andhra Pradesh represents a sector that is future-ready, environmentally conscious, and globally competitive that captured the imagination of world seeking sustainable prosperity through blue economies. Thus, the study concludes that there could be neutral impact on biodiversity and positive impact on society with best sustainable management practices and statements are discussed.

DIGITALIZATION OF FISHERIES KEY DATA ELEMENTS ON CREW WELFARE - AN AUDIT TOOL TO ADDRESS SDG AND ILOC 188

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The Seafoodmatter benchmark labour tool developed in 2014 was updated and replaced by the FISH standard checklist based on ILO Convention 188 and with worker voice requirements (e.i, WIFI availability onboard). This paper presents analyses and shares the inclusion of innovative Key Data Elements (KDEs) in a digital platform (iFIMS) towards developing an assurance digital platform for the social accountability certification of the tuna fleet.

Objectives:

1. To develop an assurance model for our Tuna Industrial Fleet Crew's decent working and living conditions,
2. To control several Key Data Elements (KDE) of social accountability onboard supported by a digital platform.
3. To implement an auditing tool per fishing trip.

Methodology:
A checklist was developed specifically for this project based on ILOC 188 and addressing Sustainable Development Goals # 8, # 9 and # 14. A Technical Working Group (TWG) voluntarily offered to provide feedback and review the proposal including Fishing Company representatives, Crew members, and a National Fisheries Authority NFA officer.

Discussion:
There are agreements and disagreements in some proposed KDEs, the discussion and rationale assessed the practicality of the KDE, the strength of the verifiable evidence, the availability of the evidence, the sources of this information (authorities, FIAO, regulators), and also the needed resources.

Conclusion of KDE:
Fishing companies need a few documents already available to support the inclusion of these KDEs in a digital platform per fishing company initially and later per fishing vessels. The documents needed to support these 23 KDEs on Crew Welfare per fishing trip.

THE MARKET FOR ETHICAL AND SUSTAINABLE SEAFOOD - TRENDS AND OPPORTUNITIES

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This presentation will outline the need for a strategic approach to ensuring sustainable business in fisheries and aquaculture products in the current business environment. The author will draw on a background of experiences gained though senior management roles at Hilton Foods and the U.K Seafood Federation, with practical examples demonstrating how seafood industry collaboration is driving a shared agenda to address current and future challenges.
A brief analysis of the global market for seafood and its relative size to other proteins, will provide context for a growing awareness of consumer concerns over ethical and sustainability issues. In particular, the ethical aspects of human labour along the supply chain will be considered, illustrating how this can impact on investment and business processes, especially to meet market entry demands for assurance, certification, and transparency.
For operators who can meet these requirements, there is a positive outlook for Blue Foods, especially where there is leverage for through innovation to achieve health benefits and reduced carbon footprint and demonstrating leadership in ethical seafood.

ASSESSMENT OF VULNERABILITY AND FORCED LABOUR RISKS AMONG FISHERY WORKERS: EVIDENCE FROM THE PEARL CITY OF TAMIL NADU, TUTICORIN, INDIA

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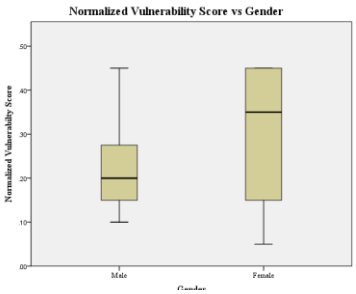

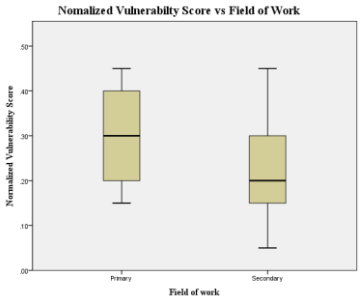

The fisheries sector, though central to livelihood and food security in coastal India, faces growing concerns of forced labour, largely influenced by socioeconomic vulnerabilities among fishery workers. This study used a random sample of 44 labours from the field of fisheries, including primary and secondary sector in 4 villages of Tuticorin district, Tamil Nadu to examine the extent of gender and job type parameters are vulnerable to forced labour, and also to study the relation between the education, age, experience and annual income with the normalized vulnerability score. In regard to this objective a pre-prepared questionnaire focussing on the parameters that supporting to build the vulnerability score were considered and survey was conducted. The result for the gender study indicate that the female labour (0.3088) exceeded that of men (0.2278), highlighting gender-based exposure to informal and unstable work. In assessment between the job types labours of primary sector showed a higher mean rank (27.07) than secondary ones (18.33), reflecting heavier workload and pressure in direct fishing operations. The correlation analysis of normalized vulnerability score with multiple variables such as age, experience, education and annual income showed a slight positive (r = 0.033), negative (r = −0.400), strong negative (r = −0.572) and slight negative (r = −0.074) correlations, that depicts a serious insight about the necessity about the awareness of major government schemes and rules, and importance of education among the labours. This study signalling an urgent need for the need of building framework, aimed at safeguarding human rights and promoting decent work within the fisheries sectors.

	Normalized Vulnerability Score	Age	Education	Annual Income	Experience
Normalized Vulnerability Score	1	0.033	-0.4	-0.572	-0.074
Age	0.033	1	-0.533	-0.046	0.655
Education	-0.4	-0.533	1	0.73	-0.482
Annual Income	-0.572	-0.046	0.73	1	-0.223
Experience	-0.074	0.655	-0.482	-0.223	1

SKILLING – NEXT REVOLUTION IN FISHERIES

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India stands at the juncture of agrarian transformation and uprising of technology led fisheries. The workforce in fisheries is 0.32% of total. Output to workforce ratio is better in fisheries (22:1) in comparison to crops (1.4:1) and livestock (4.9:1). The sector has faster growth rate contributing to significant portion of agricultural exports. Waste coastline and thrust on development of technologies for farming, identify catch, vessel and fishermen safety at sea, post-harvest management and related infrastructure leading to faster growth. Fisheries evolving from traditional to GPS/drones, intuition-based to AI-based and digital markets and carbon trading. However, over 70% of the fisheries workforce are lacking formal skilling which shows clear risk of outpacing technological progress over human preparedness and remain underprepared for this rapid shift.

Agriculture Skill Council of India (ASCI) is a skill Awarding Body under MSDE, facilitating skilling and building capacity by bridging the skill gaps, reskilling/upskilling the existing and skilling the prospective workforce, extension, schools & colleges as per NEP and other stakeholders. ASCI has developed over 170 Qualification Packs and corresponding curriculum in agriculture including fisheries. New courses like solar applications, FPOs, digital and climate resilient technologies, etc. are developed from time to time.

Under Indo-Australian project, ASCI rolled out courses in Digital Agriculture, Organic, renewable energy and GHG emissions. ASCI has trained more than 15 lakh candidates in this sector and also organised Employment Melas and apprenticeship. Skilling led to improved income levels, good management practices, higher yields and better information in comparison to pre-skilling.

Therefore, India's advantage in demographic dividend can be reaped with the skill development only.

SESSION 5: GROWTH THROUGH VALUE ADDITION AND PROCESSING TECHNOLOGIES

TOWARDS TOTAL UTILISATION OF AUSTRALIAN WILD ABALONE: A FRAMEWORK APPROACH

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The Australian Wild Harvest Abalone industry is facing profitability challenges due to a range of issues including spatial squeeze; disease; quota reduction; competition and increasing operational costs. The industry is therefore researching a range of new options for total utilisation of the catch, including emerging and potentially value-added outcomes for the traditional by-products of viscera, blood and shell.

The research has been developed to align with the principles of SDG 12.3, including using at least 50% of the target by-product for upcycling. A food byproduct utilisation framework was developed and has been tested in this (and other) case studies. The framework steps include detailed supply chain mapping; upcycled options development including market appraisals; consultation for prioritisation; food science investigation for functionality, processing and new product development and pre-feasibility assessment incorporating economic, technical, operational and regulatory considerations.

The results of the supply chain mapping, as well as functionality; new product development and processing innovations for the viscera; blood and shell will be presented. Regulatory (including food safety and novel food approvals) and operational challenges and mitigation actions will be explained, and pre-feasibility results demonstrated.

The developed food by-product utilisation framework is being applied to other seafood and food business case studies and examples of developed and evaluated sector specific extension activities and materials will conclude the presentation.

ON-BOARD PROPANE-BASED REFRIGERATION FOR SMALL FISHING BOATS: A CLEAN COOLING PATHWAY FOR QUALITY PRESERVATION, INCOME ENHANCEMENT, AND CARBON REDUCTION

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India is among the world's leading producers and exporters of fish and seafood; however, post-harvest losses and quality degradation remain persistent challenges, especially in small motorised and mechanized fishing vessels that depend largely on crushed ice for preservation. The absence of on-board refrigeration restricts fishing duration, compromises product quality, and results in significant economic and environmental losses. This presentation introduces a compact, engine-driven on-board refrigeration and flake ice production system using the natural refrigerant propane (R290), specifically designed for small fishing boats. The system employs an indirect loop R290 configuration, driven by a belt-coupled open-type compressor connected to the main engine, with auxiliary battery support. The design emphasizes mechanical simplicity, robustness, and ease of maintenance, making it suitable for harsh marine environments. Thermodynamic simulations indicate a 14–15% improvement in cooling coefficient of performance (COP) compared to conventional refrigerants. Carbon footprint analysis shows a net reduction of approximately 6.7 tonnes of CO_2 equivalent per fishing trip, primarily due to reduced ice transport, lower fuel consumption, and minimized fish wastage. Economic assessment demonstrates a rapid payback period of about four fishing trips, driven by improved fish quality, higher market value, and reduced operating costs. Beyond technical performance, the system offers broader socio-economic benefits, including enhanced fisher income, improved working conditions, skill development, and support for sustainable fishing practices. System architecture, component selection, propane safety considerations, and the field demonstration roadmap is discussed. The proposed technology represents a scalable clean cooling solution for strengthening small-scale fisheries and Indian seafood cold chain.

SENSE & DOSE FOR CHEMICAL TREATMENTS

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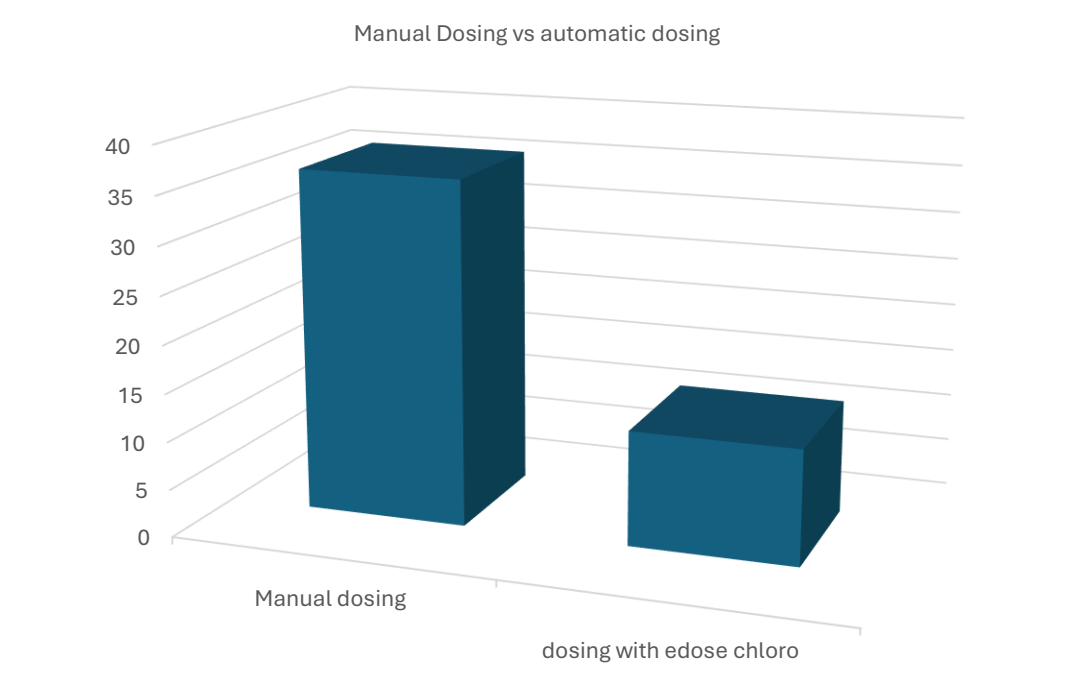
The fisheries industry relies on a range of chemical inputs throughout processing operations, including disinfectants, pH adjusters, and medicinal additives. These chemicals are essential for maintaining product safety, water quality, and effective disease control. However, traditional manual dosing methods, limited real-time monitoring, and fluctuating water conditions often result in chemical overuse, underuse, or inconsistent application. Such inefficiencies increase operational costs, negatively impact product quality, and raise environmental sustainability concerns.

Integrating sensor-based chemical monitoring with automated dosing systems presents a transformative solution to these challenges. Continuous measurement of key parameters—such as residual disinfectant levels, pH, turbidity, and chemical concentration—enables precise, demand-driven chemical application. Automated dosing improves accuracy, minimizes human error, and enhances process reliability. The implementation of smart control systems supports regulatory compliance, optimizes chemical consumption, and promotes sustainable fisheries operations.

Initiative Engineering offers a range of patented (439478), innovative solutions—including *eDose Neutra* and *eDose Chloro*—designed to deliver advanced control over critical chemical dosing processes in the fisheries industry.



CO_2 REFRIGERATION SYSTEMS FOR INDIVIDUAL QUICK FREEZERS IN SEAFOOD PROCESSING INDUSTRIES

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Seafood processing industries employ various freezing technologies, such as plate freezing, blast freezing, and Individually Quick Freezing (IQF), to preserve product quality. Among these, IQF technology has gained more attention for processing high-value seafood products, such as shrimp, prawns, and squid, due to its ability to rapidly freeze individual species, prevent cluster formation, reduce drip loss, and maintain superior texture and appearance. However, due to the large temperature lifts involved, the systems used for IQF applications are highly energy intensive. In addition, use of refrigerants that have high global warming potential (GWP) affects the overall sustainability of these systems. To achieve rapid heat removal and uniform freezing, IQF systems require very low evaporator temperatures, typically at −45°C. However, achieving such low temperatures using conventional single-stage vapour compression cycles results in high energy consumption and reduced system efficiency. Though multi-stage refrigeration systems can be used for these applications with synthetic refrigerants such as R134a, R404a, R152a, or natural refrigerants such as ammonia (R717), these systems suffer several environmental and/or safety concerns. In recent years, CO_2 (R744) has gained renewed attention as a refrigerant for low-temperature applications due to its excellent thermodynamic, environmental and safety properties. Due to its low critical temperature and high critical pressure, CO_2 is best suited as a low-temperature refrigerant in cascade systems. Hence, cascade refrigeration systems with CO_2 on the low-temperature side and a suitable low GWP refrigerant such as ammonia on the high-temperature side are being promoted for refrigeration applications such as deep freezing. Due to high volumetric cooling capacity, superior heat transfer characteristics and improved performance, these systems have huge potential in seafood processing industries that use IQFs. In the present work, the current state-of-the-art of IQF used in seafood industries is discussed in detail. This is followed by a discussion on the unique properties of CO_2, that favour its use in low-temperature freezing for the seafood industry. Then, a few case studies demonstrating the performance of CO_2 systems for IQF are presented. Finally, the steps required in making these systems commercially viable in countries such as India are discussed.

SOLAR DRYING BLUE FOODS SUPPORTS WOMEN AND STRENGTHENS VALUE CHAINS, EQUITY, AND CLIMATE RESILIENCE IN INDIA

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Post-harvest innovations are critical to strengthen the equity, quality, and climate resilience of blue food systems. In coastal India, small-scale fisherwomen have adopted portable mini solar dryers in response to issues of poor hygiene in open-air drying, fish and invertebrate spoilage and contamination, and market exclusion. The initiative combined technical innovation with capacity building in species selection, hygiene, processing methods, packaging, and basic digital record-keeping and marketing. The solar dryers improved seafood quality and shelf life, reduced losses, and opened access to higher-value domestic and regional dried seafood markets, retail outlets, and institutional buyers. Women's physical workload was also reduced, and their bargaining power within value chains was increased. Beyond immediate livelihood gains, the technology also fostered more stable, climate-resilient post-harvest processes and more localized food distribution networks. This perspective highlights how small-scale co-developed innovations can advance blue food transformation goals – linking product safety, women's economic empowerment, and nutrition security. By situating post-harvest improvements within the broader blue food system, this study shows how technology can help reconfigure value chains to deliver more sustainable, equitable, and resilient outcomes.

PATHWAYS TO A SUSTAINABLE SEAFOOD COLD CHAIN IN INDIA USING NATURAL REFRIGERANTS

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India is one of the world's largest seafood producers and exporters, yet its cold chain remains energy-intensive and heavily dependent on high global warming potential (GWP) synthetic refrigerants. Due to their high moisture and protein content, seafood products are extremely perishable and require rapid freezing, strict low-temperature storage, and reliable temperature control throughout processing and distribution. These requirements are further intensified by India's tropical coastal climate, where high ambient temperatures challenge conventional refrigeration systems and contribute to significant post-harvest losses.

This presentation explores practical pathways toward a sustainable seafood cold chain in India through the adoption of natural refrigerant-based refrigeration systems, with a primary focus on carbon dioxide (CO_2). Drawing from recent literature and industrial case studies, the talk highlights the thermodynamic advantages of transcritical CO_2 systems for seafood processing applications such as blast freezing, cold storage, ice production, and refrigerated transport. CO_2 systems offer excellent heat transfer performance at low temperatures, compact equipment design, and compatibility with cascade configurations capable of achieving temperatures down to −40 °C.

The presentation also discusses how advanced performance-enhancement techniques—including parallel compression, ejector technology, and optimized gas cooler operation—can significantly improve system efficiency under high ambient coastal conditions. In addition, the potential for gas cooler heat recovery to simultaneously meet refrigeration and process heating demands, such as cleaning-in-place (CIP) and hot water generation, is emphasized as a key sustainability advantage.

Finally, implementation challenges related to cost, technical expertise, safety, and infrastructure are addressed, alongside enabling strategies such as policy support, workforce training, and pilot demonstrations. The presentation concludes by positioning natural refrigerant-based CO_2 systems as a viable, climate-resilient, and future-ready solution for strengthening India's seafood cold chain.

EFFECT OF DIFFERENT *DAGAA* PROCESSING TECHNIQUES ON THE NUTRITIONAL PROFILE AND SENSORIAL PROPERTIES

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Small fish *(Dagaa)* is a crucial protein source, but its potential is limited by substantial postharvest losses. Small-scale fisheries predominantly utilise salting, boiling, and drying for processing, yet a critical research gap exists concerning the impact of these methods on the nutritional and sensory qualities of the final product. The study investigated the effect of cooking/boiling and drying on *Dagaa* nutrition and acceptability. The boiling stage included four treatments ranging from fresh *Dagaa* (control) to salted and boiled for 3, 5, and 8 min, while the drying stage involved four treatments, including both untreated and salted-boiled samples that were sun-dried on raised platform. Collected samples were analysed for proximate and micronutrient content and sensory attributes. Fresh *Dagaa* contained a mean protein, calcium, and iron content of 16.7%, 103.25 mg/kg, and 151.52 mg/kg, respectively. An increase in boiling time significantly reduced the protein, iron, and calcium content by 11, 29, and 38 %, respectively ($P<0.05$). The salted *Dagaa* boiled for 3 min had significantly higher protein, iron, and calcium content than the other two treatments ($P<0.05$). The salted and boiled treatment had significantly higher protein, calcium, and iron content than untreated dried *Dagaa* ($P<0.05$); and exhibited better drying efficiency. The salted, boiled, sun-dried *Dagaa* treatments were the most acceptable and preferred product by final consumers. The findings will inform the optimisation of marine *Dagaa* processing techniques to maximise nutritional and organoleptic attributes retention.

SOLAR POWERED COLD CHAIN INTERVENTIONS IN SMALL-SCALE FISHERIES

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Access to reliable and affordable energy is essential for maximizing the utilization of fish and supporting the development of associated livelihoods. Energy is vital for many post-harvest activities related to processing, preservation, storage and value addition. In particular, electricity is vital for cold chain operations including ice production, refrigerated storage and freezing. In addition to helping reduce the reliance on fossil fuels and reduce greenhouse gas (GHG) emissions, using PV solar energy to improve the cold chain for small-scale fisheries will contribute to reducing fish loss and waste, assuring food safety and improving market access for fishery products; in doing so this will benefit the livelihoods of fishers, processors and traders. This is particularly the case for those small-scale fisheries (SSF) stakeholders based in locations where access to grid electricity is not possible or unreliable. Investing in solar energy also contribute to the achievement of the United Nations' Sustainable Development Goals (SDGs), as well as FAO's four betters. Specifically, it can help achieve goals related to affordable and clean energy (SDG 7), sustainable use of ocean resources for sustainable development (SDG 14), and the promotion of sustainable industries and innovation (SDG 9). This presentation draws on emerging evidence from the evolving field of renewable energy in small-scale fisheries (SSF) development. It aims to provide decision-makers, development specialists and fisheries stakeholders with an explanation of the basic principles of solar energy and defines what it is and how it can be used in cold chain applications for the benefit of SSF development. It also highlights the pros and cons of solar energy while providing technical information illustrated with case studies. The content of the presentation will be based on: Rincon, L., Ward, A., Vaskalis, I., Milani, M., Gallego, J. & Morese, M.M. 2025. Solar energy and the cold chain – A guide for small-scale fisheries interventions. Environment and Natural Resources Management Working Paper, No. 104. Rome, FAO. https://doi.org/10.4060/cd5864e

ICAR-CIFT'S SHRIMP SHELL BIOREFINERY RESEARCH AND TECHNOLOGY – A STORY OF SUCCESS AND A FUTURISTIC ROAD MAP FOR ENSURING SUSTAINABLE INDIAN SHRIMP INDUSTRY

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With the production and export of 11 and 7.41 lakhs MT respectively, India is positioned 3rd in the global shrimp production and 2nd in international trade. Shrimp shell waste accounting to 3.17 lakhs MT at an estimated waste generation of 30% will further increase as a result of India's efforts to enhance the production. Achieving sustainability in post-harvesting is the key for driving the growth of Indian shrimp industry and blue bioeconomy forward. ICAR-CIFT has marked its significant contribution through shrimp shell biorefinery technology which recovers 72% dry matter as protein and chitin derivatives and enhanced the value realization and responsible raw material utilization by 3-fold. The technology is proven successful at a scale of 2-ton/day (Longshore Technology LLP, Maharashtra; 7 employments; 500 tons/year). Further, ICAR-CIFT is working hand-in-hand with new start-ups from various Indian states to bring up the large-scale industries of 25 – 40 MT shrimp waste/day. Stepping out beyond the lab research, understanding the gaps, incubating the start-ups, collaborating and linking the key inputs suppliers, advising on the machineries, modifications and integrations in the process lines were some of the key strategies for successful implementation of CIFT's shrimp shell biorefinery technology. ICAR-CIFT's futuristic goals under this technology are developing low-cost inputs and machineries of indigenous origin, continuous refinement of process for maximizing the recovery (minerals, pigments, functional lipids at industrial scale), expanding to novel applications, down streaming tailor-made bioactive peptides from shrimp proteins, functions-specific chitosan as industrial and pharmaceutical inputs for ensuring the sustainability in Indian shrimp industry.

OPTIMIZATION OF PHASE CHANGE MATERIAL ICE RATIOS FOR ENHANCED THERMAL EFFICIENCY AND QUALITY PRESERVATION IN INDIAN MACKEREL *(RASTRELLIGER KANAGURTA):* IMPLICATIONS FOR BIOGENIC AMINE AND PROTEIN LIPID OXIDATION IN FISH SUPPLY CHAINS

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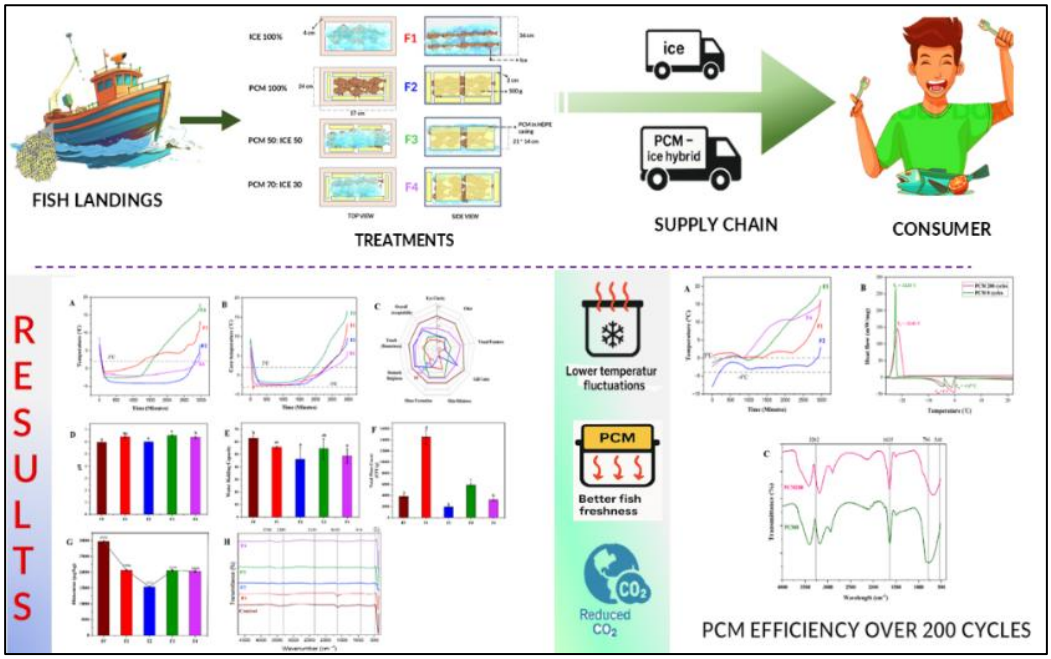
Optimizing phase change material (PCM) ice ratios provides a sustainable approach to enhance product quality and thermal efficiency in India's fish cold chain. Four cooling treatments ice (100%), PCM (100%), and hybrid PCM–ice blends (50:50 and 70:30) were evaluated using Indian mackerel (*Rastrelliger kanagurta*). The 70:30 PCM–ice blend maintained sub-2 °C for 46.5 h with minimal surface–core gradient (1.01 °C) and achieved 21 % overall energy efficiency. PCM treatments reduced total plate counts by ~86 % versus ice (1.9×10^3 vs 1.44×10^4 CFU g^{-1}) and lowered histamine accumulation by 31 % (20,594 µg kg^{-1} vs 29,735 µg kg^{-1}). Lipid oxidation decreased by ~34 % (TBARS), and FTIR spectra showed a 28 % higher Amide I/II ratio in PCM systems, indicating preserved α-helical structure and protein stability. Textural hardness reached 1.64 N in PCM 70:30, with 21 % higher resilience than PCM 100, ensuring firmness retention. Sensory analysis confirmed PCM 70:30 as the most acceptable treatment (score > 8.5/9), characterized by clear eyes, red gills, and fresh odour, while PCM 100 % performed comparably, both significantly outperforming ice-stored fish. Thermal cycling showed enthalpy stability (ΔH = 340.9 J g^{-1} after 200 cycles) and improved conductivity (0.73 W m^{-1} K^{-1}), confirming material reliability. Collectively, PCM-based super chilling minimized lipid hydrolysis, protein oxidation, and biogenic amine accumulation while enhancing sensory and microbial quality. The optimized PCM 70:30 hybrid thus offers a robust, energy-efficient, and eco-innovative alternative for sustainable tropical fish logistics.



SESSION 6: INSPECTION AND CONTROL SYSTEMS TO MEET SEAFOOD TRADE REQUIREMENTS

FOOD FRAUD IN FISHERIES AND AQUACULTURE- A JOINT FAO-IAEA REPORT

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The global fisheries and aquaculture sector, producing over 185 million tonnes of aquatic products in 2022 and valued at USD 195 billion, faces growing vulnerability to food fraud. This complexity stems from the diversity of traded species (over 12,000) and the involvement of multiple inspection authorities across international supply chains, among other things. Common fraudulent practices include species substitution, mislabelling, adulteration, counterfeiting, and misrepresentation of origin or production methods. These actions, often economically motivated, pose serious risks to public health, consumer trust, and marine conservation.

The Food and Agriculture Organization of the United Nations (FAO) and the International Atomic Energy Agency (IAEA) have worked together to provide an overview of the common food fraud cases in the aquatic sector and the health risks associated with it. The report resulting from this collaboration provides information on tools that can be used to fight food fraud for aquatic products, and international case studies illustrate the scope and impact of fraud. The report reviews regulatory frameworks as well as standards such as those set by Codex Alimentarius, FAO guidelines, and GFSI-benchmarked schemes, advocating for harmonized labelling, mandatory scientific names, and improved traceability. It emphasizes the role of consumer awareness and industry transparency in combating fraud.

In addition, the report highlights that addressing food fraud in the aquatic sector requires coordinated enforcement, technological innovation, and stakeholder collaboration to ensure authenticity, safety, and sustainability in global seafood supply chains.

ASSESSMENT OF FOOD HYGIENE KNOWLEDGE, ATTITUDES AND PRACTICES OF DAGAA VALUE CHAIN ACTORS

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The Dagaa (*Rastrineobola argentea,* and *Engraulidae spp*) value chain is one of the most complex value chains, starting at the actual fishing, processing, trading, and marketing to the end consumers. Improper handling constitutes one of the primary sources of deterioration and contamination of the end products. In this regard, evaluating knowledge, attitude, and practice (KAP) of food safety in food handling is essential to minimizee food borne diseases. A structured questionnaire, featuring both open and close-ended questions, was used alongside interviews and observations of practices and available infrastructures to assess food safety knowledge across the chain. This approach aimed to evaluate the understanding of food safety at various stages, considering both individual responses and real-time practices. The study included 255 participants involved in handling activities along the chain. The study revealed that actors along the chain had a moderate level of KAP of food safety and hygiene. Most processors don't wear PPE: 99.2% (apron), 93.7% (mask), and 95.3% (gloves), with 85% citing lack of facilities, poverty, and awareness as reasons. However, 85.1% agree that proper cleaning is crucial for food safety. The gap between awareness and practice highlights the need to enhance infrastructure, implement training programs, and multi stakeholders' involvement along the chain. Addressing these differences could lead to improved standards in food safety and hygiene among dagaa processors, ultimately benefiting consumers and the entire supply chain. The study concluded that improving food safety is possible through better knowledge supported with appropriateinfrastructure, through multidimensional solution approach

THREE MAJOR SHRIMP DISEASES IN INDIA AND PRACTICAL CHALLENGES FOR TRADE

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India's shrimp aquaculture sector, a vital contributor to the national economy and rural livelihoods, faces significant threats from disease outbreaks. Among the most impactful are White Spot Syndrome Virus (WSSV), Enterocytozoon hepatopenaei (EHP), and Running Mortality Syndrome (RMS). Each disease presents unique challenges in terms of diagnosis, management, and prevention. WSSV is a fast-spreading viral infection leading to mass mortalities, often within days of onset. EHP, a microsporidian parasite, causes growth retardation and chronic productivity losses, particularly in intensively farmed Penaeus vannamei. RMS, an emerging complex condition, is associated with multifactorial causes, including opportunistic pathogens, environmental stress, and compromised gut health, leading to unexplained mortalities. Despite advancements in diagnostics and management strategies, practical field-level challenges persist. These include delayed detection due to subclinical presentations, improper sample handling, inconsistent diagnostic capabilities, and lack of awareness among small-scale farmers. Biosecurity lapses, such as poor pond preparation, water exchange from unverified sources, movement of infected seed or broodstock, and inadequate disinfection practices, further exacerbate the spread and recurrence of these diseases.

This presentation highlights the current status, field observations, and diagnostic trends related to WSSV, EHP, and RMS in India. It also emphasizes the critical need for farmer education, standardized diagnostic protocols, and site-specific biosecurity plans to mitigate disease risks. Strengthening disease surveillance and enhancing hatchery and farm-level biosecurity compliance will be vital in sustaining India’s shrimp production and global market competitiveness.

BORDER REJECTIONS OF SEAFOOD IMPORTS: WHAT DO THEY TELL US?

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Technical regulations and standards governing international trade in agri-food products have become increasingly prevalent and complex. Many low and middle-income countries (LMICs) face persistent challenges in meeting evolving safety and quality requirements in import markets, while governments and development partners must allocate scarce resources across competing capacity-building needs. Identifying where compliance challenges are most acute, namely, the products and markets with the highest rates of non-compliance as reflected in border rejections is therefore critical. The analytical use of border rejection data is, however, constrained by several limitations. Data on import rejections are limited in terms of coverage and the markets for which these available and differ markedly in how they are collected and recorded. Differing inspection rates and regimes and reporting practices render comparisons across importing countries problematic. In addition, rejection counts alone provide an incomplete picture of compliance performance, in that they do not account for trade volumes or export structures.

Since 2008, the United Nations Industrial Development Organization (UNIDO) has systematically collected and harmonised border rejection data from five major import markets, namely Australia, China, Japan, European Union, and United States. Linking these data with import statistics enables the construction of aggregate, unit-based and relative rejection indicators over time, including proportional and high-low measures that rank exporting countries by relative compliance performance. These indicators cover all food and feed products (HS Chapters 1–23) and are compiled within UNIDO's Rejection-Import Database, which supports its Standards Compliance Analytics platform and related publications. Seafood represents a particularly important case for analysis. According to FAO, global exports of fishery and aquaculture products reached approximately US$175 billion in 2023, making seafood one of the most heavily-traded food commodities worldwide. Owing to its perishability and associated public health risks, seafood is subject to especially stringent food safety, quality, and traceability requirements and border inspection across importing markets.

Using UNIDO's harmonized border rejection dataset, this paper examines long-term global trends in seafood rejections across the five major import markets. It provides a comparative analysis of market-specific rejection patterns, assesses the relative performance of major seafood-exporting countries across destinations, and explores regional trends and dominant causes of rejection. The findings offer insights into systemic compliance challenges in global seafood trade and highlight priority areas for targeted capacity-building interventions.

ENSURING SAFER FOOD CHAINS: MULTI-CLASS VETERINARY DRUG RESIDUE ANALYSIS IN SEAFOOD USING LC–MS/MS

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Veterinary drugs are widely employed in animal husbandry to treat and prevent disease, promote growth and improve feed efficiency. However, their administration to food-producing animals can result in residues persisting in edible tissues, including fish, Shrimp and other animal products. Such residues pose potential public health risks, ranging from allergic reactions and direct toxic effects to the emergence of antimicrobial resistance in bacteria exposed to sub-therapeutic concentrations of antibiotics.

To mitigate these risks, regulatory authorities in regions such as the United States and India, FSSAI and European Union, and other countries have established Reference Point of Action (RPA for Class A analytes) and maximum residue limits (MRLs for Class B analytes) for diverse food commodities. Analytical monitoring of veterinary drug residues presents two major challenges, the wide diversity of analytes and the complexity of food matrices. Prolonged global veterinary drug usage has contributed to the persistence of residues in the food chain, necessitating robust, high-throughput analytical strategies capable of handling large sample volumes efficiently.

Advances in liquid chromatography coupled with tandem mass spectrometry (LC–MS/MS), particularly multiple reaction monitoring (MRM) approaches, have enabled the simultaneous detection of multi-class veterinary drug residues across varied matrices, including shrimp and animal tissues. These methods provide enhanced sensitivity, reproducibility, and compliance with regulatory guidelines, thereby strengthening the confidence of authorities and stakeholders in residue surveillance. Furthermore, the ability to analyse multiple classes of compounds within a single method significantly increases laboratory throughput, offering a practical solution to the growing demand for comprehensive residue monitoring in food safety programs.

ACTIONABLE LIFE CYCLE ASSESSMENT: A SPECIALIZED IMPACT MANAGEMENT PLATFORM FOR THE GLOBAL SEAFOOD SECTOR

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Providing verifiable proof of sustainability is becoming a critical requirement for the global seafood sector. This industry, encompassing both rapid-growth aquaculture and capture fisheries, faces intense "compliance driven" export demands and pressure for sustainability certification. Life Cycle Assessment (LCA) (ISO 14040/44) is the internationally standardized methodology for quantifying environmental impacts and providing a scientific basis for eco-labelling criteria. However, a critical gap exists between complex global LCA standards and practical implementation by producers. Traditional assessments are "resource-intensive," suffer from "data gaps" and "Low level of data quality," and must rely on generic, global emission factors. These factors are "inherently conservative and less precise," fail to capture the "region & industry specific nuances" and ultimately lead to inaccurate data. While the primary environmental hotspots are well established - feed production for aquaculture's global impacts (e.g., climate change), the on-farm stage for local eutrophication, and vessel fuel consumption for capture fisheries operators lack accessible tools to act on this information. A specialized impact management platform is necessary to bridge this gap. Such a tool moves beyond reporting by offering AI-assisted guided data mapping, offline low-bandwidth capabilities, and "practice-aware" localized data to establish an accurate, verifiable baseline. It enables a cyclical management process: Measure, Interpret, recommend (with ROI estimates), Implement, Verify and Report. This empowers producers to pinpoint hotspots, optimize key metrics like the Feed Conversion Ratio (FCR) (or its fishery equivalent, fuel use per tonne of catch), integrate "Quality & Food-Safety Linkages," and generate the "Buyer-Ready Verification Scorecards" required for global market access.

ROLE AND RESPONSIBILITIES OF NABL IN ENSURING THE QUALITY OF FOOD, ESPECIALLY SEAFOOD, FOR CONSUMERS

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Ensuring food safety and quality is critical for public health and international seafood trade. With increasing global market requirements for marine and aquaculture products, laboratories must comply with stringent regulatory requirements of the European Union (EU), Codex Alimentarius Commission, and country-specific import Maximum Residue Limits (MRLs). Reliable and competent testing systems are therefore essential.

The National Accreditation Board for Testing and Calibration Laboratories (NABL), operating in accordance with ISO/IEC 17011, accredits food testing laboratories under ISO/IEC 17025 to ensure technical competence and reliability of test results. As a signatory to ILAC and APAC Mutual Recognition Arrangements (MRAs), NABL facilitates international acceptance of test reports, reduces technical barriers to trade, and supports seamless market access for Indian seafood exports.

NABL-accredited laboratories verify compliance with residues, contaminants, microbiological and quality parameters mandated by EU, Codex and importing countries. This strengthens regulatory oversight, protects consumer health, enhances exporter confidence, and improves global credibility of marine and aquaculture products.

GROWING INTEREST IN FISHERIES SUSTAINABILITY CERTIFICATION IN INDIA

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Certification or ecolabelling is a market-based tool to promote the sustainable use of natural resources. Ecolabels are seals of approval given to products that are deemed to have fewer impacts on the environment than functionally or competitively similar products. The ecolabel itself is a tag or label placed on a product that certifies that the product was produced in an environmentally friendly way. The label provides information at the point of sale that links the product to the state of the resource and/or its related management regime.

India obtained the prestigious Marine Stewardship Council (MSC) ecolabel for its Ashtamudi Lake short-neck clam fisheries in 2014 and since then several export-oriented fisheries have moved into fishery improvement projects (FIPs) to achieve MSC certification. Some of the prominent fisheries which are in FIPs are trawl-caught coastal shrimp, squid, cuttlefish, octopus, deep sea shrimp and threadfin breams. Besides gillnet-caught blue swimming crabs and groupers are in the certification process. Some of the other fisheries planning to move towards certification are the pole and line caught-skipjack tuna and oil sardines. There have also been many fish feed manufacturers who have entered FIPs to achieve the Marin Trust certification for fish meal and marine ingredients.

Certification of Indian seafood appears poised for further growth because of the tremendous interest and support of all stakeholders that it is currently receiving. The government's support in terms of policy and regulations is also helpful in this regard. However, there is a long road ahead before Indian marine fisheries can fully meet all the standards of sustainability certification. Meanwhile, the certification initiatives are driving the research institutions and the government to urgently tackle sustainability issues in fisheries.

SEAFOOD TRACEABILITY VERIFICATION IN REAL TIME WITH RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY (REIMS), MOLECULAR SPECTROSCOPY SENSORS, AND MACHINE LEARNING

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Mislabelling of seafood species and origin identity is an important economic fraud, a food safety concern, and a sustainability issue. Verifying species identity and geographical origin is crucial to ensuring traceability in the seafood value chain. While DNA-based methods have been used for species authentication, authentication of geographical origin requires more complex analytical methods. Moreover, in a fast-moving supply chain of perishable commodities, faster turnaround times for authenticity test results are crucial. This study presents a rapid evaporative ionization mass spectrometry (REIMS) metabolite fingerprinting and machine learning method for real-time authentication of species identity of a range of commercially important seafoods. Further, REIMS metabolite fingerprinting and machine learning were used to develop an analytical method to authenticate the geographical origin of Vannamei shrimp. The method was validated by demonstrating transferability between two labs. In an independent validation set, the method achieved more than 95% accuracy in prediction. For on-field rapid authentication, a molecular spectroscopy sensor-based method was developed for species authentication of commercially important shrimps and squids. The sensor-based species authentication achieved more than 80% accuracy in an independent validation set.
Keywords: Seafood authentication, Mass Spectral Library, Ambient Mass Spectroscopy, Machine Learning

SESSION 7: HAZARDS IN SEAFOOD

THE DEVELOPMENT OF A USA SEAWEED GUIDE TO FOOD SAFETY HAZARDS

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Macroalgae, commonly known as seaweeds, are photosynthetic organisms found in marine and freshwater environments. They serve diverse purposes—from food and animal feed to biofuels, fertilizers, pharmaceuticals, and cosmetics. Growing awareness of its health benefits, sustainability, and culinary versatility of seaweed is driving increased demand in the U.S., leading to more seaweed products, restaurant offerings and cookbooks.

Like all foods, seaweed products carry potential food safety risks. However, due to the relative novelty of seaweed as a food commodity in the U.S., there is limited guidance and few seaweed-specific food safety guidelines or regulations. To support safe growth of this nutritious food, clear national guidance is needed to identify and mitigate key food safety hazards.

The *Seaweed Food Safety Guidance* document was developed to help food regulators, producers, processors and retailers to assess and manage risks associated with seaweed products in the U.S. The Guide includes 16 chapters that cover the following aspects: iodine, pathogens in the harvest area, environmental chemicals, target pathogen growth conditions, naturally occurring toxins and survival conditions and a list of known seaweed-related food safety outbreaks. The final report is located here
https://www.nyseagrant.org/Images/Uploads/PDFs/Seafood-Seaweed-FoodSafetyGuidance.docx

As domestic aquaculture expands, this emerging industry offers opportunities for sustainable food production and economic growth. The guidance document can support safe practices, regulatory compliance, and consumer confidence. Building on existing national and international resources, this guide provides a flexible framework tailored to diverse species, environments, and regulations—promoting consistency and safety across regional and national markets.

JOINT FAO/IOC/IAEA GUIDANCE ON MONITORING OF ALGAL TOXINS IN BIVALVE MOLLUSCS

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Harmful algal blooms (HABs) are naturally occurring phenomena that can severely impact aquatic ecosystems and aquaculture operations. Certain algal species produce potent toxins that can pose serious risks to human health through the consumption of contaminated seafood, especially bivalve molluscs. A variety of gastrointestinal and neurological illnesses associated with these seafood products have been reported over the years and the Food and Agriculture Organization of the United Nations (FAO), the International Atomic Energy Agency (IAEA) and Intergovernmental Oceanographic Commission of UNESCO (IOC) called for a Joint Expert Meeting on Marine Biotoxins and Harmful Algal Blooms Monitoring to develop the Joint FAO-IOC-IAEA guidance on monitoring of algal toxins in bivalve molluscs.

This guidance is intended to support the development of sampling, analysis, and management approaches for harvesting and production areas to determine the level of toxins in bivalve molluscs and the occurrence of toxic microalgae, and to comply with market requirements.

This guidance can be used as a roadmap by regional and national authorities and institutions to establish and implement monitoring and management programmes for marine toxins and HABs, or to expand or enhance existing systems. The guidance also covers aspects related to pre-harvest monitoring or post-harvest batch testing. Additionally, it includes monitoring of microalgae, which can help in managing the risk of toxins contaminating bivalve molluscs intended for human consumption.

RISK MANAGEMENT OPTIONS FOR PATHOGENIC *VIBRIO* SPP IN SEAFOOD

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Pathogenic *Vibrio* spp such as *V. parahaemolyticus,* non-O1/O139 *V. cholerae* and *V. vulnificus* are indigenous to aquatic environment and are distributed globally. According to a recent (2025) Lancet report, vibriosis cases reached a peak of 722,780 cases globally in 2024. FAO/WHO Joint Expert Meeting on Microbiological Risk Assessment (JEMRA) risk assessment on *Vibrio parahaemolyticus* indicated the levels of *V. parahaemolyticus* in seafood vary globally and their behavior in various shellfish species varies widely. Genomic studies indicate the involvement of certain Sequence Types (ST) eg VpST3 and VpST36 in outbreaks in different parts of the world. The contributing factors for increasing incidence of vibriosis seems to be those related to climate change. Increase in Sea Surface Temperature and other climate change related factors caused increase in exposure of population living in coastal areas to pathogenic *Vibrio* spp. For example, VpST3 that was noticed in India in 1996 was thought to have spread to Latin America. But more recent studies indicate that VpST3 existed in Latin America even before emergence in India, but what caused outbreaks was the emergence of climatic conditions favourable for causing outbreaks. Close monitoring of factors that lead to such exposures would be required to manage the risk.

EVALUATING LEVELS OF PERFLUOROALKYL SUBSTANCES (PFAS) IN SEAFOOD ON THE EU MARKET

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Statutory maximum levels of perfluoroalkyl substances (PFAS) have applied in the EU since 1 January 2023. They are based on an Opinion by the European Food Safety Authority published in July 2020.
Some information on PFAS levels in fishery products typically caught or harvested in the EU was available, but information on PFAS levels in imported seafood products was less easy to obtain. This made it difficult for seafood business operators to characterise the PFAS-related risk associated with their products.
To address this, the Seafood Importers and Processors Alliance (SIPA) collected PFAS data on the seafood available on the EU market, with a focus on imported seafood. SIPA used the following sources: published scientific literature, data made available by national authorities, data made available by seafood businesses and data obtained through SIPA's own targeted sampling and analysis.
This research provided new information for EU processors and importers:

- Farmed products, whether fish, crustaceans or bivalve molluscs, tend to have very low PFAS levels, but there are significant exceptions.
- Decapod crustaceans, including whiteleg shrimp (*Penaeus vannamei*), and domestic and imported mussels on the EU market show levels of PFAS well within the statutory limits. Some North Atlantic brown shrimp (*Crangon crangon*) occasionally have higher levels.
- Paphia clams imported from Vietnam may show levels of PFAS above statutory limits.
- In general, PFAS levels are encountered at levels that vary between fish groupings: white fish < pelagic fish < flatfish

PLANT EXTRACTS AS ANTIMICROBIAL POTENTIATORS AGAINST SEAFOOD-BORNE PATHOGENS

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Plant-derived antimicrobials have emerged as promising alternatives to conventional antibiotics and synthetic preservatives due to their natural origin, broad-spectrum activity, and potential for synergism with established antimicrobial agents. The present study investigated the antimicrobial efficacy and antibiotic-potentiation activity of extracts from *Acorus calamus*, *Embelia ribes*, and *Terminalia chebula.* The antimicrobial activities and plant extract-antibiotic synergism of ethanolic and aqueous plant extracts were evaluated against seafood-associated pathogenic bacteria such as the Shiga toxin-producing *Escherichia coli* (STEC)*, Vibrio parahaemolyticus, V. cholerae, Salmonella* Typhimurium, *Staphylococcus aureus,* and *Listeria monocytogenes.* The effect of plant extracts on the biofilm formation ability of *L. monocytogenes* on various surfaces was also studied. Combinations of *T. chebula* and *E. ribes*, as well as *T. chebula* and *A. calamus*, showed significant synergistic effects, compared to individual extracts. A significant improvement in the efficacy of conventional antibiotics such as kanamycin, gentamycin, ampicillin, ciprofloxacin, tetracycline, and imipenem, to which the tested pathogens were previously resistant, was observed, demonstrating a remarkable synergistic plant extract-antibiotic interaction. When applied to chilled tuna slices, the ethanolic and aqueous extracts of *E. ribes* and *T. chebula,* respectively, reduced *L. monocytogenes* counts significantly by 2-3 log units, along with marked reductions in its biofilm-forming ability on plastic and stainless-steel surfaces. The synergistic interactions between plant extracts and conventional antibiotics highlight their value in enhancing antimicrobial efficacy and combating antibiotic resistance. Plant-derived compounds can serve as sustainable options for managing seafood-associated microbial threats and their antimicrobial resistance, enhancing seafood safety and public health.

NOVEL ANALYTICAL DATA ON CADMIUM, MERCURY, LEAD, ARSENIC AND SELENIUM CONTENT IN FISH FROM TANZANIA AND MOZAMBIQUE: IMPLICATIONS FOR FOOD SAFETY

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Fish are important for food security and nutrition in many coastal communities; however, fish consumption is also a major source of metal(loid)s exposure to humans. Data on metal(loid)s content in fish from Tanzania and Mozambique marine waters are limited. This study analysed the content and assessed the risk of exposure from 17 fish species sampled off the coast of Tanzania and Mozambique by research vessel Dr. Fridtjof Nansen during an ecosystem survey in 2018. The samples were prepared according to local consumption habits (fillet, whole and dressed) and were analysed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Three metals, cadmium (Cd), mercury (Hg) and lead (Pb), and two metalloids, arsenic (As) and selenium (Se), were measured. The content varied among the species and tissues analysed. Hg content was higher in fillets from large predatory fish, while As, Se, Cd and Pb were higher in small fish that traditionally are consumed whole. The mean Se-Hg molar ratio was higher in whole and dressed small fish compared to fillets from large fish. In all analysed samples, HQ_{Cd} and HQ_{Hg} values were <1 except for *O. bartramii*, where HQ_{Cd} was marginally above 1. Thus, the consumption of the fish species, prepared to resemble the eating habits collected in this study, has no adverse health effects on humans, and the consumption of whole fish is highly recommended from a nutritional point of view. However, species diversification and the use of safe consumption limits may also be important in reducing multiple contaminant exposure.

FOUNDATIONAL AI AND DIGITAL TWINS FOR SCIENCE-BACKED, BIOSECURE, AND RESILIENT BLUE FOODS

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Global fisheries and aquaculture, now supplying more than 223 million metric tonnes of aquatic food annually, are entering a phase of rapid growth accompanied by increasing vulnerability. In 2025 we estimated ~30 million USD worth of avoidable stock loss due to deteriorating water quality, intensifying climate variability and disease threats. With escalating biosecurity concerns, and rising demands for transparent and verifiable supply chains are placing unprecedented pressure on production systems to adapt. Yet most operations continue to rely on fragmented data, delayed risk detection, and reactive management, exposing producers, markets, and regulators to systemic risks and failures. Existing solutions in industry rely on sparse IoT/hardware based sensing and reactive control, with limiting generalization across species, environments, and production systems - (open systems such as farm-ponds, cage-culture; and closed systems of RAS, BioFlocs, Tanks).

To tackle these challenges, we developed Twingills, an AI-native platform built on over 8 billion data points and 30+ AI- and science-backed models, powered by the AquaNurch Digital Twin foundational model. The platform targets the climate–water–disease nexus at a place-based scale. Client deployments demonstrate up to a 30% increase in productivity and a 50% reduction in biological asset risk across the production cycle, while supporting traceability and biosecurity compliance. By integrating environmental, biological, climatic, and operational intelligence, Twingills unifies real-time system data, advanced risk modeling, and end-to-end digital provenance from hatchery to market, enabling proactive health management and resilient aquatic food systems for safer supply chains and trusted global trade.

SESSION 8: SEAWEED - THE BLUE FOOD OF THE FUTURE

FUELING THE GLOBAL MARKET: MICROALGAL ASTAXANTHIN AS A CIRCULAR SOLUTION FOR AQUACULTURE AND HUMAN HEALTH

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The global natural astaxanthin market, valued at USD 1.5 billion in 2024, is projected to reach USD 5.86 billion by 2034, with microalgae-derived, 100% pure astaxanthin dominating 63% of this premium segment. This growth is strategically driven by two primary industries: aquaculture, which consumes 45% of the supply to enhance livestock health and pigmentation, and the nutraceutical sector, which leverages its potent antioxidant properties. This presentation will explore the immense opportunity for a circular bioeconomy model centered on *Haematococcus sp.* cultivation. We will demonstrate how integrated biorefinery processes can transform this single microalgal biomass into a dual-stream revenue source, simultaneously supplying high-value feed additives for sustainable aquaculture and premium ingredients for human health products. This approach not only capitalizes on a proven multi-billion-dollar market but also establishes a scalable, sustainable framework that aligns with global goals for resource efficiency and nutritional security, offering a compelling investment in the future of food and health.

A REVIEW OF AUSTRALIAN REGULATIONS FOR THE SEAWEED INDUSTRY.

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In 2024 a comprehensive review of existing Australian regulations & industry guidelines relating to seaweed products, was undertaken. This review included: human consumption food safety, animal food safety, product labelling & claims, bioproducts, novel food requirements, pharmaceutical & cosmetic requirements & bio-stimulants in agriculture. The purpose of the review was to identify gaps & inconsistencies to identify areas requiring harmonization, clarification or change.

In addition to identifying and reviewing all available regulations, 127 interviews were undertaken with state/federal government staff, seaweed industry stakeholders & product users including seaweed growers, harvesters, processors, sellers, animal feeders, stock feed manufacturers, seaweed pharmaceutical manufacturers & researchers.

Despite compliance guidelines & regulations being in place, significant knowledge gaps remain in the area of seaweed processing & its effect on chemical & microbiological hazards that may be present in the final product. The unique composition of seaweed means that its response to processing methods may differ, & therefore, applying findings from other food industries could lead to inaccurate conclusions. National regulations should be reviewed to ensure consistency in definitions within the existing regulations & the limits for the relevant contaminants should be added to the existing requirements.

The current classification of seaweed products by FSANZ, under the Novel Foods process is a very real impediment to growing the seaweed bio-products industry in Australia. The current Novel Foods Assessment process should be reviewed to include a mutual recognition of products already approved within the EU & USA along with recognition of indigenous use of seaweed species.

INTEGRATED SEAWEED VALORIZATION AS A BLUE ECONOMY PATHWAY: TECHNOLOGY, SAFETY, AND COASTAL LIVELIHOODS IN INDIA

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Seaweeds are increasingly recognized as "blue foods" owing to their nutritional richness, ecosystem services, and potential to strengthen coastal livelihoods. In coastal regions of India, particularly the Gulf of Mannar (GoM), seaweed harvesting and cultivation are traditionally practiced by fisherwomen. However, seaweed utilization remains largely confined to raw biomass supply, constrained by inconsistent availability of quality planting material, limited value addition, quality and safety concerns, and weak livelihood integration. The present work documents an end-to-end integrated valorization framework for tropical seaweeds**,** spanning tissue culture–based biomass production, decentralized processing, quality assurance, and food safety validation**.**

At the upstream level, tissue culture and micropropagation protocols were standardized for native green and red seaweeds (*Ulva lactuca* and *Gracilaria* spp.) to ensure rapid, uniform, and disease-free biomass production. An optimized growth medium enabled a fourfold biomass increase of *U. lactuca* within 10 days**,** demonstrating productivity comparable to fast-growing exotic species such as *Kappaphycus alvarezii*, while *Gracilaria* spp. showed a fourfold increase within five weeks (20–25% weekly growth)**.** These protocols provide reliable native seedstock for sustainable cultivation and reduced dependence on wild harvesting. Downstream valorization encompassed improved drying systems for quality retention, production of liquid seaweed biostimulants, granulated seaweed formulations, semi-refined carrageenan and seaweed gel extraction, and systematic utilization of post-extraction residues. Low-cost, backyard-scale processing units were developed using simple equipment, enabling decentralized adoption by fisherwomen self-help groups. Residue valorization ensured a zero-waste, circular bioeconomy approach**.**

To address food safety, an extensive assessment of heavy metals (HMs) and pesticide residues (PRs) was conducted in raw and processed edible seaweeds (*U. lactuca, Caulerpa racemosa,* and *K. alvarezii*) collected seasonally from four GoM locations (Thoothukudi, Erwadi, Mandapam, and Rameswaram) during 2022–2023. While Cr, As, Pb, and Hg were prevalent, thermal processing (boiling, steam-cooking, microwave cooking) reduced HMs by up to 100% and PRs by up to 99%**,** with boiling being most effective. Bio-digestion and bio-absorption studies, coupled with human health risk assessment (THQ, TTHQ, HQ, LCR), indicated no non-carcinogenic or carcinogenic risk (values <1 and within acceptable limits)**.** Maximum allowable consumption limits confirmed the safety of regular seaweed intake.

UNLOCKING THE NUTRITIONAL POWER OF SEAWEED: A LATIN AMERICAN PERSPECTIVE

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Global algae production has grown more than 3.5 times in volume, from 10.6 million tonnes in 2000 to 37.8 million tonnes in 2022, with seaweed making up over 99.8% of the total. About 97% of seaweed is farmed. Latin America and the Caribbean contribute only about 1.4% of global production, mostly from wild harvests. Some seaweed species, such as yuyo (*C. chamissoi*) and cochayuyo (*P. columbina*) are endemic to Peru and have been consumed dating back to pre-Inca times.

Roughly 85% of seaweed is used for human consumption, the remainder goes into feed, fertilizers, and cosmetics. Although long overlooked, seaweed's role in food security and nutrition is increasingly recognized. It can be produced sustainably with a low carbon footprint and offers key nutrients like minerals, vitamins, quality proteins, essential fatty acids, and unique carbohydrates.

A recent study in Latin America identified local seaweed species and assessed their potential uses. Nutrient analyses revealed that these seaweeds are important sources of minerals such as calcium, potassium, and iron, while levels of heavy metals (lead and cadmium) were below detection limits. Seaweeds are also known for their high iodine content—a micronutrient deficient in the diets of nearly 2 billion people worldwide.

Given their nutritional profile, seaweed has significant potential to help combat malnutrition if incorporated into human diets. The study developed and tested several local recipes using seaweed, all of which were well received: 80–90% of participants rated them as "very good," while the remainder rated them as "good."

Seaweed and other algae represent unique, nutrient-rich resources with vast potential for sustainable production. The experience from Latin America demonstrates that reinvigorating the use of local seaweed varieties in traditional recipes is feasible and highly acceptable to consumers.

UNITED NATIONS GLOBAL SEAWEED INITIATIVE: TOWARDS BLUE FOOD OF THE FUTURE

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Seaweed has significant potential to contribute to sustainable food systems, nutrition, and climate resilience, yet its development as a food commodity remains constrained by regulatory, market, and production bottlenecks. Despite rapid growth in global trade—nearly doubling in value over the past decade—food-grade seaweed is governed by fragmented regulatory frameworks, limited international standards, and incomplete recognition within food and trade classification systems. At the global level, Codex Alimentarius guidance remains largely absent, creating uncertainty around food safety, quality, labeling, and market access, particularly for developing countries and small-scale producers.

This paper examines structural constraints affecting the scaling of seaweed as a food product across production, trade, and policy dimensions. It reviews evidence on the concentration of food-grade production in a limited number of species and monoculture systems, highlighting associated risks related to disease, climate shocks, and supply stability. While production technologies such as coastal mariculture and community-based farming are well established and demonstrate strong productivity gains, diversification, improved seed systems, and climate-resilient practices remain limited. In parallel, weak quality infrastructure, non-harmonized standards, and limited certification capacity increase compliance costs and restrict participation in formal food markets.

Market analysis indicates growing demand for seaweed-driven by plant-based, low-carbon food trends—but value addition remains concentrated outside producing countries, reflecting weak integration of small-scale producers into food value chains and limited market intelligence at origin. Policy analysis further reveals weak coherence across food safety, trade, climate, and coastal management frameworks, with seaweed for food largely absent from food security strategies.

Against this backdrop, the paper presents the United Nations Global Seaweed Initiative (UNGSI) as a coordinated, multi-stakeholder platform to address regulatory gaps, strengthen standards, promote inclusive value chains, and position seaweed as a strategic blue food of the future.

BLUE AGRICULTURE REVOLUTION: SCOPE, STRATEGIES, AND VALUE CHAIN DEVELOPMENT FOR SEAWEED IN INDIA

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The escalating constraints on terrestrial agriculture—driven by land degradation, freshwater scarcity, climate change, and rising food and livelihood demands—have intensified global interest in marine-based production systems. Within this emerging paradigm of blue agriculture, seaweed cultivation represents a resource-efficient, climate-resilient, and high value opportunity for sustainable development. This paper examines the global evolution of seaweed farming, highlighting dominant species, production trends, technological pathways, and expanding market applications, and situates India's seaweed sector within this broader international context. Drawing upon recent policy frameworks, scientific literature, and institutional innovations, the presentation evaluates India's current status of seaweed cultivation, biodiversity potential, and regional distribution, while identifying key constraints related to germplasm availability, cultivation technologies, processing infrastructure, and value-chain integration.

Particular emphasis is placed on the strategic transition from near shore farming to offshore and tank-based cultivation systems, as well as the role of biosecurity, hatchery development, and elite seed banks in enabling scalable growth. The presentation further underscores the multifaceted economic, social, and environmental benefits of seaweed farming, including livelihood diversification for coastal communities, women's empowerment, nutrient bio-remediation, carbon sequestration, and integration within regenerative aquaculture models.

In addition, the paper highlights the critical importance of value addition and product innovation, with case illustrations from the National Institute of Fisheries Post-Harvest Technology and Training (NIFPHATT), demonstrating how seaweed-based functional foods and agri-marine products can strengthen inclusive blue–green value chains.

The study concludes that with targeted policy support, technological advancement, and market-driven value-chain development, seaweed cultivation can serve as a cornerstone of India's blue economy, catalysing a transformative blue agriculture revolution with substantial socio economic and environmental dividends.

SESSION 8A. JOINT UNIDO/FAO PANEL: SEAWEEDS AND MACRO/ MICROALGAE AS THE BLUE FOOD OF THE FUTURE - CHALLENGES AND OPPORTUNITIES

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Background:

Seaweed has strong potential as a sustainable food source, contributing to nutrition, food security, and climate-resilient food systems. However, the development of seaweed as a food product is constrained by fragmented regulatory frameworks, weak international standards, and underdeveloped food markets. Seaweed is often governed under fisheries or aquaculture laws rather than food systems, and at the global level there is no dedicated Codex Alimentarius guidance for seaweed, except for a single species. This regulatory gap creates uncertainty for food safety, quality, labelling, and market access, particularly for developing countries and small-scale producers.

International trade in food-grade seaweed has expanded significantly, with global trade values nearly doubling over the past decade. Yet seaweed is not fully recognized as a plant-based food commodity in trade and statistical systems and is covered by only a few HS codes. Limited harmonization of food standards, testing, and certification increases compliance costs and restricts participation in global and regional food markets. Strengthening national quality infrastructure and developing science-based food standards are therefore critical to support safe, transparent, and inclusive trade.

Food production technologies for seaweed are well established, including coastal mariculture and small-scale community-based farming, which have demonstrated rapid productivity gains. However, food-grade production remains dominated by a small number of species and monoculture practices, increasing vulnerability to disease and climate shocks. Greater diversification of edible species, improved seed systems, and climate-resilient farming practices are needed to ensure stable food supply and product quality. Technology transfer and extension services remain limited, especially for smallholders and women producers.

Food markets for seaweed are growing, driven by demand for nutritious, low-carbon, and plant-based foods. Nevertheless, market development is constrained by limited consumer awareness, lack of market intelligence, and weak integration of small-scale producers into formal food value chains. Most value addition occurs outside producing countries, reducing income opportunities at origin.

Policy coherence across food safety, trade, climate adaptation, and coastal management remains weak. Although oceans are increasingly recognized in national climate strategies, seaweed for food remains marginal in food security and nutrition policies. Aligning food regulations, trade frameworks, and climate-resilient aquaculture policies—supported by targeted public and blended finance—is essential to scale sustainable seaweed food production and position it as a strategic component of future food systems.

About United Nations Global Seaweed Initiative (UNGSI):
The UNGSI is a collaborative platform that brings together Member Stats, UN entities, research institutions, industry stakeholders, and civil society to accelerate the sage and sustainable, and inclusive development of the global seaweed sector. The UNGSI is comprised of the FAO, UNIDO, UNCTAD, IOC-UNESCO, UN Global Compact, Global Seaweed Coalition, and its growing membership includes Indonesia, France, Madagascar, Chile and Brazil.

Objective of the Panel:
This panel aims to address core questions related to seaweeds and macro/microalgae as the blue food of the future:

- What are the novel products and applications for seaweeds and macro/microalgae?
- Which emerging technologies are used in the production and processing of seaweeds and macro/microalgae?
- What are the prospects and mechanisms for market development for seaweeds and macro/microalgae for human and animal nutrition?
- What are the food safety risks in the consumption of seaweed and macro/microalgae?
- What are the environmental and social impacts of seaweeds and macro/microalgae production; and what are the organisational challenges?

SESSION 9: INDIAN SEAFOOD SECTOR - DEVELOPMENT PROSPECTS

MARINE INGREDIENTS: CATALYST FOR SUSTAINABLE SEAFOOD

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Since the 1960s, Fishmeal use was primarily driven by the pig and poultry industries. From the 1980s onward, Aquaculture emerged as the major consumer, recognizing fishmeal as a superior protein and nutrient source. Today, marine ingredients — including fishmeal and fish oil — are indispensable for aquaculture and livestock nutrition, providing affordable protein, essential nutrients, and sustaining coastal employment and incomes.

Current global fishmeal production stands at roughly 5–6 million tonnes per year, of which aquaculture consumes over 80%. The global aquafeed market is projected to rise from USD 61.8 billion (2023) to USD 88.0 billion by 2028 (CAGR 7.3%). Demand for sustainable marine ingredients continues to increase as producers align with low-carbon and circular bioeconomy principles.

Seafood and fishmeal are key foreign exchange earners within India's blue economy. While the seafood sector benefits from dedicated policy frameworks, the marine ingredients subsector remains relatively underserved. The policy priorities are to a) ensure consistent product quality and traceability; b) enhance stakeholder welfare and livelihood security and c) safeguard marine biodiversity while meeting domestic protein demand.

The Indian Marine Ingredients Association (IMIA) serves as a non-profit catalyst for sustainable development in India's fishmeal and fish oil industry by collaborating with scientific and academic institutions for innovation and technology transfer, partnering with fisher organizations to secure livelihoods and promote responsible raw material sourcing and engaging with government bodies and global initiatives to align with sustainability certifications and international standards.

India's marine ingredients sector is poised for a transformative leap, with an emphasis on responsible harvesting, quality assurance, and transparency to reinforce the sustainability of global aquaculture systems while strengthening India's food and nutritional security.

WASTE TO WEALTH: REPOSITIONING VALUE STREAMS IN THE SEAFOOD SECTOR

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Every fish we consume leaves behind more than a meal—it leaves a vast, largely untapped reservoir of functional resources. Fish and shellfish processing, from both marine and freshwater systems, generates enormous quantities of residues, most of which are ignored or underutilized, resulting in substantial economic losses along the supply chain. Studies indicate that a significant fraction of potential revenue remains unrealized due to inadequate recovery and low-value disposal practices. While traditional uses—such as silage, composting, and feed—address volume management, they capture only a fraction of the intrinsic biochemical and industrial value embedded in these residues. Strategic, knowledge-driven valorisation can convert this "so called waste" into a renewable molecular inventory with high-margin potential.

Fish processing residues are uniquely rich in structurally diverse proteins, bioactive peptides, lipid fractions, minerals, and functional biopolymers—molecules rarely found in terrestrial sources. Their superior bioavailability, functional versatility, and targeted physiological properties make them ideal for high-value applications spanning nutraceuticals, clinical nutrition, biomedical and regenerative technologies, and advanced health formulations. By prioritizing fractions with the highest functional and market potential, industries can unlock unprecedented economic and functional gains.

Integrating these high-value streams with conventional low-value uses under a circular economy and biorefinery framework not only reduces environmental burdens but also positions fish processing residues as strategic bioresources. Applying these unique functional properties across high-value applications enables the industry to convert lost opportunities into sustainable, high-value outputs, supporting industrial resilience, environmental sustainability, and long-term growth of the blue bioeconomy.

ADVANCES IN PACKAGING TECHNOLOGIES FOR FISH

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Packaging plays a vital role in preserving fish and fishery products during storage, transportation, and marketing by protecting them from physical, chemical, and biological deterioration. Effective packaging safeguards seafood against moisture changes, temperature fluctuations, mechanical damage, oxidation, contamination, and microbial growth, thereby maintaining sensory attributes, quality, and safety while extending shelf life. In the seafood sector, the appropriate selection of packaging systems from primary to tertiary levels, along with ancillary materials, is essential to meet the diverse requirements of different product forms, processing conditions, and distribution systems. Recent advances in packaging technologies such as vacuum packaging, vacuum skin packaging, modified atmosphere packaging, active packaging, and intelligent packaging have significantly improved product preservation, quality monitoring, and consumer convenience. These modern packaging approaches enhance freshness, ensure food safety, support traceability, and contribute to sustainability within the seafood supply chain. With the continuous expansion of global seafood markets, innovative packaging technologies remain essential for delivering high-quality fish and fishery products to consumers and for strengthening the resilience of the seafood industry. In addition, food packaging systems must comply with national regulatory frameworks to ensure consumer safety and product integrity. In India, packaging materials used for fish and fishery products are governed by regulations prescribed by the Food Safety and Standards Authority of India, which specify requirements related to food contact materials, labelling, and hygiene. Compliance with these regulations, along with the adoption of advanced packaging technologies, supports quality assurance, consumer confidence, and market acceptance of seafood products.

Key words: Vacuum skin packaging, Oxygen scavenger, Freshness indicators, Migration

VALUE ADDITION OF FISH AND SHELLFISH FOR INTERNATIONAL AND DOMESTIC MARKETS

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Increased standardization in seafood production and processing, enabled by innovative technologies, helped seafood become increasingly perceived by consumers as a functional source of protein. As dietary habits shift towards the most convenient and healthy products, there are enormous opportunities for value-added fish and shellfish products. Value addition is a viable approach to transform raw material to high quality and convenient end products. The products range from live fish to ready-to-eat convenience products. It can be improved market forms, speciality fish products, battered and breaded fish products and Ready-to-Eat curries in retort pouches. Technology developments in fish processing offer scope for innovation, increase in productivity and shelf life, improved food safety, and a reduction in waste during processing operations. A large number of value-added and diversified products, both for export and the international market based on fish, shrimp, lobster, squid, cuttlefish, bivalves etc., have been identified. While the international market primarily focuses on IQF frozen and RTE seafood products, the domestic sector is driven by mince-based value-added products and traditional cured products, with an emerging demand for Ready-to-Cook products in consumer pack. A rapid growth in the share of value-added products in Indian seafood export is anticipated as the Government of India seeks to increase the duty-free limit on the imported ingredients. Simultaneously, the expansion of organised retail and online delivery platforms will scale up the marketing of value-added products in the domestic sector.

Key words: Value addition, convenient products, RTE curry, mince based products, export market

SESSION 10: TRACEABILTY AND DATA TOOLS FOR VALUE CHAIN EFFICIENCY

INTERNET OF THINGS WITH BLOCK CHAIN-BASED TRACEABILITY TOOL FOR IMPROVING THE SHRIMP SUPPLY CHAIN MANAGEMENT

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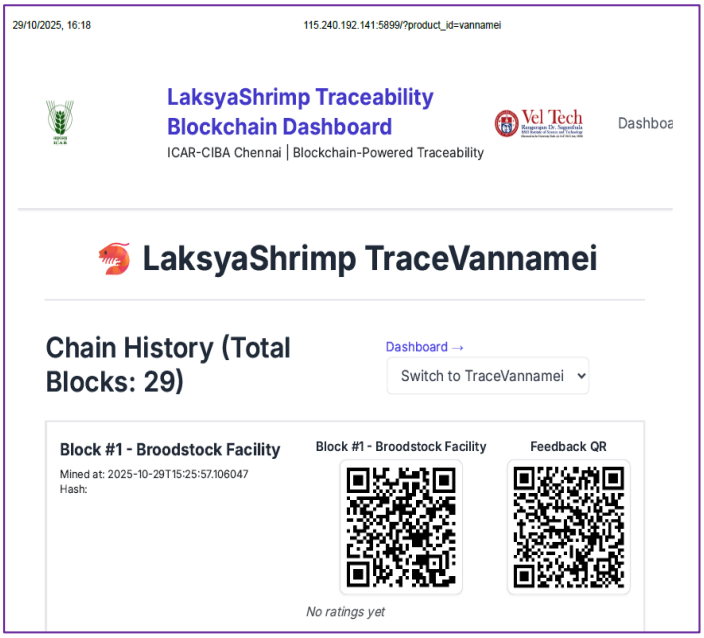
Aquaculture is currently one of the most important sources of high-quality animal protein in the world. Shrimp farming has drawn its importance within this industry due to its significant global trade potential, high economic returns, and ability to create jobs. Pacific whiteleg shrimp (*Penaeus vannamei*), black tiger shrimp (*Penaeus monodon*) and Indian white shrimp (*Penaeus indicus*) are the most often cultivated shrimp species because of their quick growth, adaptability to various habitats, and high market value. Brackishwater shrimp aquaculture has grown dramatically, but it still faces significant challenges that affect farm-level production, global competitiveness and traceability for food safety concern. There are many critical tracking events (CTEs) such as broodstock facility, hatchery, nursery, grow-out system, harvesting, processing, shipping, exporting, and retailing with respective key data elements (KDEs) which are interconnected in the entire shrimp supply chain that require close supervision and control to get the safe and certified produce with traceable value chain. Ensuring shrimp quality and safety at all stages has been a primary priority as regulatory demands for sustainability and transparency. Hence, we have developed and field tested an internet of things (IoT) with block chain-based traceability tool for each species of shrimp for improving their supply chain management. This tool is a robust, transparent, and technologically sophisticated comprehensive digital traceability system, which can monitor and record critical data points throughout the production and distribution process.



NEED FOR DIGITAL TRACEABILITY FOR INDIAN AQUATIC FOOD

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Indian fisheries and aquaculture play a pivotal role in its socio-economic development, contributing significantly to food security, livelihoods, and exports. India is one of the top three aquatic food producing countries globally and a leading exporter of aquatic food. Indian fisheries value chains are extensive and diverse, encompassing all forms of capture fisheries, aquaculture systems, post-harvest handling, processing, marketing and export. Traceability is vital for aquatic food safety to prove legality and verify sustainability, as aquatic food is the most globally traded food commodity. Issues relating to illegal fishing and mislabeling are more prominent in recent years. Many opportunities exist for aquatic food fraud as and when new and poorly managed fisheries develop.

There is an urgent need for a unified digital traceability system that facilitates real-time tracking of aquatic food product movement and transactions throughout the value chain. The National Framework on Traceability in Fisheries and Aquaculture is envisioned as a transformative initiative to standardize and implement traceability across India's capture fisheries and aquaculture sectors. The National Traceability System will adopt a phased, inclusive, and technology-driven approach to ensure that both small-scale operators and large commercial enterprises can comply without disruption. The Framework envisages that at each Critical Tracking Event (CTE), the relevant Key Data Elements (KDEs) are digitally captured, time-stamped, and linked to the product's unique identifier. The funds for the development of the Traceability System will be met by Central Government from the PM-MKSSY scheme. The project will create a centralized, secure and interoperable National Fisheries Digital Platform (NFDP) using standardized protocols, which enables customization at the state level while maintaining national-level consistency and data consolidation. The system will be hosted on a secure cloud infrastructure, ensuring scalability, cost-efficiency, and resilience against data loss. The Framework will adopt internationally recognized standards and guidelines for food traceability.

CRISIS TO CONFIDENCE: PROVING TRACEABILITY AS A BIOSECURITY GAME-CHANGER

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The detection of White Spot Syndrome Virus (WSSV) in a major Australian prawn-growing region triggered strict restrictions on the movement of uncooked prawns, placing the viability of local fisheries at risk. In response, a collaborative project was initiated to design and trial a secure, real-time traceability platform capable of enabling trade while maintaining the highest biosecurity standards.

Led by Honey & Fox and Fish Beatty Consultancy, with funding from the Fisheries Research and Development Corporation and support from industry, government, and technology partners, the project engaged directly with fishers and supply chain stakeholders to co-design a system that was both practical and powerful. Using GS1 global standards, tamper-evident packaging, QR codes, and real-time trackers integrated through Trust Provenance software, the trials successfully demonstrated transparent, tamper-proof monitoring of mock prawn consignments from harvest through to chefs.

Critically, the trial design and protocols were reviewed with state and national authorities to ensure alignment with biosecurity import controls. Outcomes confirmed that the system could provide equivalent—or superior—assurance to existing regulatory frameworks, offering a pathway for secure domestic trade in high-risk environments.

The project's implications extend well beyond Australia. It demonstrates how digital traceability can underpin regulatory compliance, reinforce consumer confidence in provenance, and contribute to global biosecurity preparedness. This approach provides a transferable model for other high-risk commodities and industries, showing how traceability systems can serve as both a safeguard and a market enabler.

At the World Seafood Congress, we will present project findings alongside a live demonstration of the technology in action, highlighting its potential to transform seafood supply chains and strengthen market access in biosecurity-sensitive environments worldwide.

ADVANCING DIGITAL TRACEABILITY IN INDIA'S SEAFOOD SECTOR THROUGH GDST ADOPTION

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Building on the GDST global context, we shall focuss on how GDST's interoperable digital traceability framework aligns with India's rapidly evolving seafood landscape. India—one of the world's leading producers and exporters of farmed shrimp—has entered a new phase of modernization with the Government of India's recent Digital Traceability Framework. This policy direction signals national recognition that future market access, regulatory compliance, and sustainability credibility depend on reliable, standardized digital data.

Indian seafood companies are already engaging with this transformation. Several GDST partners from India's shrimp sector, together with leading Indian traceability and software firms, are adopting GDST Standards to strengthen supply-chain transparency and meet the expectations of global buyers. These companies understand that providing trustworthy digital data to customers, regulators, and stakeholders is essential for demonstrating strong ESG performance and effectively addressing environmental risks, labor conditions, and product-quality concerns.

The momentum reflects a broader shift: global markets increasingly require interoperable digital traceability, and Indian exporters who implement GDST-aligned systems position themselves for competitive advantage in the US, EU, and other high-value markets. By harmonizing data capture and exchange, Indian producers and processors can reduce administrative burdens, enhance credibility, and integrate seamlessly into international value chains that are progressively adopting GDST as a best-practice standard.

We will spotlight how India's industry leaders, government initiatives, and GDST's global framework are converging to support the long-term resilience, growth, and global competitiveness of India's seafood sector.

THE GLOBAL DIALOGUE ON SEAFOOD TRACEABILITY (GDST) AND THE FUTURE OF INTEROPERABLE DIGITAL TRACEABILITY

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The Global Dialogue on Seafood Traceability (GDST) is a not-for-profit, public-benefit organization created to accelerate the global shift toward interoperable, digital seafood traceability. GDST convenes industry, civil society, and technology leaders to build and continuously evolve a common, practical, and globally applicable framework for capturing and exchanging key data across seafood supply chains. The GDST Standards—open, free, and vendor-neutral—enable interoperability across diverse digital systems, reduce the cost and complexity of compliance, and support responsible, transparent sourcing.

Today, GDST is supported by more than 120 partners worldwide, including global retailers, seafood brands, processors, logistics providers, technology companies, NGOs, and industry associations. These stakeholders recognize that standardized and verified data flows are essential to reducing fraud, enabling regulatory compliance, strengthening ESG reporting, and addressing environmental, labor, and quality risks across global seafood value chains.

Investors aligned with the FAIRR Initiative have also identified adoption and implementation of the GDST Standards as a critical indicator of responsible corporate practice, signalling growing financial-sector expectations for digital traceability. Governments and multilaterals have increasingly echoed this alignment: Indonesia's STELINA traceability platform integrates the GDST Standard, while the EU Fisheries Control Regulation cites GDST as a best-practice model. The FAO and the UN Transparency Protocol further reinforce GDST's role in setting internationally recognized benchmarks for interoperable traceability.

We will explore how GDST's collaborative model, expanding community, and globally harmonized approach are reshaping the future of trustworthy seafood data exchange—and why interoperable digital traceability is becoming a cornerstone of responsible seafood production and trade.

SESSION 11: WORKSHOP ON FOSTERING STEWARDSHIP FOR SUSTAINABLE INDIAN MARINE INGREDIENTS

Supported by BoBP, CMFRI, NFDB and the Dakshin Foundation

in technical cooperation with:

Food and Agriculture Organization of the United Nations

Introduction

India is a major entity in the global seafood economy, supported by a dynamic aquaculture sector, strong export markets, and growing demand for marine ingredients such as aquafeeds. These sectors play an important role in supporting livelihoods, value addition, and food production systems both within India and internationally. As markets, regulatory expectations, and sustainability conversations evolve globally, FMFO and aquafeed businesses in India are increasingly navigating a complex operating environment. This includes balancing efficiency, competitiveness, traceability requirements, and long-term resource security, while responding to diverse domestic and international market signals. At the same time, there is growing recognition that closer dialogue across value chain actors can help identify shared interests, reduce fragmentation, and support more coordinated approaches to sectoral stewardship. While substantial evidence and experience exist across industry, government, and civil society, there are limited neutral platforms where these perspectives can be discussed collectively and constructively. This workshop responds to this opportunity by creating a focused, industry-facing space to exchange perspectives, surface practical insights, and explore pathways that align sustainability ambitions with business realities in India's marine ingredients sector.

Workshop Purpose

The workshop aims to convene key industry actors, regulators, and enabling organisations to:

- Initiate a structured dialogue on collective stewardship in the Indian FMFO and aquafeed sectors
- Strengthen alignment between sustainability expectations, traceability systems, and market access
- Discuss the possibilities of a longer-term multi-stakeholder coalition on marine ingredients stewardship in India.

Workshop Objectives

The workshop will aim to:

The workshop will:

1. Build shared understanding of sustainability risks, trade-offs, and opportunities within the Indian FMFO and aquafeed value chains.

2. Identify priority action areas where industry leadership can drive measurable improvements.

3. Explore the role of traceability and data systems in supporting sustainability, regulatory compliance, and market alignment.

4. Facilitate dialogue across value-chain segments, including producers, processors, feed manufacturers, exporters, and regulators.

5. Initiate a discussion on a multi-stakeholder coalition for continued engagement beyond the Congress

Key Outputs

By the end of the workshop, participants will co-develop:

- A shared framing of sustainability priorities for India's FMFO and aquafeed sectors.
- Practical recommendations on stewardship mechanisms, including traceability and data interoperability.
- Identified roles for industry, regulators, and enabling organisations in advancing collective action.
- Inputs towards a concept note for a multi-stakeholder marine ingredients coalition.

Participants

The workshop will bring together a curated group of stakeholders, including:

- Fishmeal and fish oil producers
- Aquafeed manufacturers and allied businesses
- Seafood exporters and industry associations
- Global and regional traceability initiatives
- National and international regulatory and intergovernmental organisations
- Sustainability standardisation bodies, technical partners, and civil society organisations

For further information, please contact:

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Agenda

Activity	Details	Time
Welcome & Opening Remarks	Moderator: Dr. Naveen Namboothri, Founder-Trustee, Dakshin Foundation Welcome and introduction to the workshop by BoBP-IGO and Department of Fisheries	09:10 -0930
Sector Realities & Shared Challenges	Chair: Dr. K.K. Lal, Director, ICAR-CIBA, Chennai See below for details	09.30-1015
Reimagining Sustainability in Marine Ingredients Sector	Moderator: Ms. Angela Lentisco, Fishery and Aquaculture Officer, FAO-RAP **Panellists:** Dr. M.K. Ram Mohan, Director, MPEDA Prof. G. Jeyasekaran, Safe Fish & Traceability Programme Coordinator, DoF, GoI Mr. Santhana Krishnan, Chief Executive Officer, Marine Technologies, Chennai Mr. Jogeir Toppe, Fishery Officer, Fisheries and Aquaculture Division, FAO	10:15-1100
Marine Ingredients Sector: Regional Perspectives	Moderator: Dr. P. Krishnan, Director, BOBP-IGO	1100-1120

	Current Status of Marine Ingredients in the Country: Opportunities for Regional Action - Senior Officials from Bangladesh, Maldives and Sri Lanka	
Wrap-Up & Next Steps	Priority Actions & Coalition Possibilities: Dr. Naveen Namboothri Founder-Trustee, Dakshin Foundation	1120-1145

See below for more details

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POSTER PRESENTATIONS

WSC 2026 P 01

INTEGRATED EPITOPE PREDICTION AND PEPTIDE DESIGN SYSTEM FOR VACCINE DEVELOPMENT IN AQUATIC SYSTEMS

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This novel peptide design framework enables rapid immunogenic region identification across pathogens. Its validation against aquatic pathogens highlights its utility for peptide vaccine and therapeutic development in aquatic systems. Future studies would improve its adaptability across diverse pathogens.

WSC 2026 P 02

AI-DRIVEN MICROBIOME INTELLIGENCE: TRANSFORMING SHRIMP PROBIOTIC DESIGN THROUGH OMNIBIOME AI AND NGS

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Shrimp aquaculture faces escalating challenges due to persistent disease outbreaks, indiscriminate antibiotic usage, and the pressure to minimize production cost by achieving high feed conversion ratios. Although probiotics are widely adopted as an alternative intervention, most commercial products lack ecological specificity and therefore perform inconsistently under different physicochemical water conditions, regional environments, and farming methodologies.

To address these limitations, Luminis Water Technologies integrates next-generation sequencing (NGS) with OmniBiome AI, a proprietary microbiome-intelligence platform engineered to decode complex microbial ecosystems with high precision. NGS-based metagenomic profiling of pond water and shrimp gut microbiota across life stages enables comprehensive characterization of taxonomic and functional signatures. OmniBiome AI then processes these high-dimensional datasets to identify key taxa linked to immune modulation, digestive efficiency, pathogen exclusion, and environmental resilience.

Leveraging these insights, we have established a computational–experimental pipeline for rational design of customized probiotic consortia, optimized for specific cohorts, farm conditions, and production goals. Over 1,000 bioactive strains have been isolated and curated into our proprietary biological bank. Each candidate strain undergoes in-vitro validation for antimicrobial activity, enzyme secretion, and biofilm dynamics, followed by in-vivo performance benchmarking in multiple culture systems. Trials demonstrated significant improvements in growth rate, survival, immune responsiveness, and robustness under pathogen-challenge scenarios.

Our findings show that AI-guided, NGS-powered probiotic engineering represents a transformative advancement in sustainable aquaculture health management. OmniBiome AI enables precision biological formulations that reduce antibiotic dependency, strengthen farm resilience, and advance the global One-Health agenda by aligning environmental and animal health.

WSC 2026 P 03

TRENDS IN INDIA'S SHRIMP PRODUCTION AND EXPORT GROWTH

Arjunvishwak Prabhakarsriram, Sathaiah M, Jeyashree A, Anbarassan A, Muhammed Iqshanullah A and Kalai Chezhiyan K
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Shrimp is India's top seafood export, contributing major share in export value and earnings.

- India's shrimp export quantity and trade value showed overall growth from 2000–01 to 2024–25.
- USA, Japan, and Belgium markets are stable, while China and Vietnam are more volatile.
- CDVI results show export instability, indicating the need for better market risk management.
- ARIMA forecasting suggests future growth potential in shrimp exports in upcoming years.

WSC 2026 P 04

TARGETING TRUST: A GENERATIONAL STRATEGY FOR RESILIENT SEAFOOD SAFETY COMMUNICATION

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The effectiveness of global efforts toward a resilient seafood trade depends on consumer access to trusted and credible food safety information. This study investigates the perceived reliability of information sources and preferred communication channels among 2,079 seafood consumers across four generational cohorts in Kerala, India. Data were collected between March and December 2023 through an online survey distributed via social media platforms, using convenience and snowball sampling methods. The analysis revealed a significant communication deficit, with over 70% of Gen Z (18–26 years) and Millennials (27–42 years) rated their seafood safety knowledge as poor. Behavioural data indicated that Gen Z consumers seek minimal information related to food safety. Inferential analysis of trusted sources and preferred channels highlighted clear contrasts among generations. Gen Z demonstrated significantly higher trust in social media and health professionals (doctors/ nutritionists), whereas Gen X (43–58 years) and Baby Boomers (59+) placed greater trust in online resources (websites/ blogs). Regarding preferred communication channels, Millennials showed a significant preference for product related information (QR codes/ labels/ certifications/ retail communication), identifying them as a key target for point-of-sale food safety interventions. In contrast, older groups retained a preference for print media. These findings underscore the limitations of a "one-size-fits-all" or single-channel communication approach. To enhance trust, optimize communication and encourage safer food handling practices to mitigate seafood-borne illnesses, stakeholders must adopt generation-specific strategies that prioritise digital and point-of-purchase communication channels. Such precision targeting is essential for building a resilient and inclusive seafood safety communication ecosystem.

Keywords: Seafood safety, Consumer trust, Generational cohorts, Communication channels, Food safety education, Kerala.

WSC 2026 P 05

CHALLENGES IN ADVANCING CIRCULAR ECONOMY IN FISHERIES: INSIGHTS FROM FARMERS' ADOPTION OF ORGANIC FISH SILAGE FERTILIZER IN DIPOLOG CITY, PHILIPPINES

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High volume of sardine wastes including heads, bones, and entrails is generated each year from various sardine bottling processing plants in Dipolog City, Philippines. These wastes are just often discarded with no intended use. Fish silage production is a conventional approach of harnessing the nutrients from these wastes and can be used as fertilizer. Dipolog, as an agricultural city, has a great potential to benefit from this technology. It is therefore important to assess the insights of farmers to provide a basis for its further development, as well as to evaluate its market potential. Thus, survey interviews with 252 randomly selected rice farmers were conducted to identify the opportunities and challenges in the integration of fish silage fertilizer into agricultural farming practices in Dipolog City. Results of the study showed that all of the interviewed farmers are using inorganic fertilizer such as urea and complete fertilizers. Only 22% of the farmers have tried fish silage as fertilizer, primarily for growing supplementary crops such as vegetables. One of the primary reasons is the skepticism of farmers toward the fish silage fertilizer effectiveness especially when compared to inorganic fertilizers. Also, little to none priority is given to the organic produce in the province. Other factors include the commercial unavailability of the product, and lack of awareness of fish silage and its method of production. To enhance adoption, farmers recommended product trials, government support to organic farming, and refinement of the fish silage production to enhance its effectiveness as a viable organic fertilizer.

WSC 2026 P 06

LEADERSHIP COMMITMENT TO FOOD SAFETY CULTURE IN SEAFOOD ORGANIZATIONS. AN ASSESSMENT OF EMPLOYEE PERCEPTIONS

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Food safety culture is a critical determinant of safe production practices within food and seafood organizations. Multiple dimensions—such as management and coworker support (leadership commitment), communication, self-commitment, and working environment—influence food safety culture. Among these, leadership commitment has emerged as a decisive factor in ensuring sustained compliance with safety requirements.

This study aimed to assess employee perceptions of leadership commitment to food safety in seafood manufacturing units, with particular emphasis on the role of supervisors and managers in promoting safe handling practices. The sample included food handlers from selected seafood organizations in South India. Data were collected through a structured questionnaire designed to capture employee views on management involvement, enforcement of food safety rules, and supervisory monitoring. The analysis focused on understanding how leadership actions influence employee behaviour and the overall food safety culture. Demonstrated through consistent actions, clear communication, and visible monitoring, leadership behaviours strongly shape employee attitudes and practices. Preliminary findings highlight that visible and consistent managerial involvement significantly strengthens compliance, builds mutual accountability, and reinforces collective responsibility for food safety. Conversely, gaps in enforcement, inconsistent monitoring, or lack of follow-up reduce employee trust in organizational commitment.

This research underscores the importance of leadership-driven initiatives in embedding food safety as a shared organizational value. The findings provide actionable insights for managers and policymakers to design targeted strategies that foster strong food safety cultures, ensure sustained adherence to best practices, and safeguard consumer health.

WSC 2026 P 07

METABOLIC PERSPECTIVE OF FISH AND ITS BY-PRODUCTS: AN OVERVIEW

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Since time immemorial, fish have been a primary marine resource that provides the human body with sufficient nutrients. Fish production is increasing every year, contributing to a sustainable economy, as they provide significant income and food. This review highlights the health benefits, industrial applications, and toxicity of various fish species worldwide. Fish contain various bioactive compounds; this ability makes them a more edible resource for consumption around the world. Different types of fish contain a wide range of bioactive compounds, essential macronutrients, micronutrients, vitamins, and minerals, which are essential in preventing a variety of human disorders. Fish are excellent sources of protein, peptides, and polyunsaturated fatty acids, particularly eicosapentaenoic acid, Alpha-linolenic acid, omega-6 fatty acids, and docosahexaenoic acid, omega-3 fatty acids that influence human health positively. The by-products of fish are also excellent sources for developing various nutraceutical and functional foods to fight against multiple human disorders. The by-products of fish exert significant effects against infection, viral attack, cardiovascular diseases, immune disorders, oxidative stress, inflammation, neurological diseases, and other physiological complications. Additionally, the therapeutic use of fish and their by-products unveil potential nutritional benefits to reduce the burden on public health by managing dietary issues such as food security, protein deficiency, and other nutritionally related problems.

Keywords: Fish, By-product of fish, Nutrients, Human ailments, Metabolism, Fish offal.

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ECO-SMART NUTRITION: EXPLORING MEALWORM-BASED PROTEIN REPLACEMENT FOR ENHANCED GROWTH AND HEALTH OF *ETROPLUS SURATENSIS* IN SUSTAINABLE AQUACULTURE

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In this experiment, *Tenebrio molitor* meal was evaluated as an alternative protein source to fishmeal, focusing on its influence on growth metrics, nutrient efficiency, and physiological responses of *Etroplus suratensis*. A 56-day feeding experiment was conducted using five isonitrogenous diets with replacing fishmeal using *T. molitor* meal at 0% (TM0), 15% (TM15), 30% (TM30), 60% (TM60), and 100% (TM100), each in triplicate. The findings showed notable enhancements ($p < 0.05$) in weight increase (114–201%) and specific growth rate (1.36–1.97% day^{-1}), with the optimal outcomes recorded at TM60, where the feed conversion ratio achieved 1.67 ± 0.01 in contrast to 2.09 ± 0.03 in the TM0. Broken-line regression identified 20.05 g *T. molitor* per 100 g diet as the optimal inclusion level for maximizing weight gain in *E. suratensis* juveniles. Hematological parameters such as Hb (10.4–11.7 mg/dL), RBC (2.9–3.7 × 10^6 mm^{-3}), and WBC (28.7–33.4 × 10^3 mm^{-3}) stayed within normal limits, indicating healthy physiological status. Serum biochemical markers indicated elevated total protein (4.10 ± 0.06 g/dL), albumin (1.36 ± 0.03 g/dL), and globulin (2.73 ± 0.05 g/dL) levels in TM60, whereas hepatic enzyme activities suggested enhanced metabolic capability. Total substitution (TM100) was linked to a decrease in growth efficiency (FCR 1.79 ± 0.02), emphasizing the restrictions of elevated inclusion amounts. Following an *Aeromonas hydrophila* challenge, fish fed with TM60 exhibited the highest survival probability. Kaplan–Meier analysis confirmed significant differences among groups ($\chi^2 = 67.14$, $p < 0.001$), demonstrating enhanced disease resistance with moderate mealworm inclusion. Overall, *T. molitor* meal at 60% replacement is a sustainable, nutritionally adequate protein alternative for *Etroplus* aquafeeds.

Keywords: *Tenebrio molitor*, Fishmeal replacement, *Etroplus suratensis*, Growth performance, Sustainable aquafeed

WSC 2026 P 09

SEAWEEDS AND MACRO/MICRO ALGAE BLUE FOOD OF THE FUTURE

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The seaweed is considered as the quintessential source of the affordable protein rich source for the human consumption. It can be given to the people in the world suffering with malnutrition. The countries with poor economy can also afford because of its low cost of production. Thus, concluding seaweeds and macro/micro algae- blue food of the future.

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CONSUMER ACCEPTANCE OF GREEN SEAWEED (*ULVA RETICULATA*): INSIGHTS FROM SENSORY PANEL AND E-NOSE ANALYSIS

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Rapidly growing population across countries leads to alternative food sources to meet the increasing demand for nutrition. In this context, evolution in aquaculture industry plays a key role which enables seaweed as a sustainable and nutrient rich source. Around the world seaweed is widely consumed as a vegetable but consumption of seaweed is limited due to its lack of awareness and sensory characteristics in Indian cuisine. This present study investigates the sensory attributes and consumer acceptance of raw green seaweed (*Ulva reticulata*) through combined subjective and objective methods. Subjective method involves questionnaire where 25 semi-trained panelists evaluated the visual observation involving chromatic properties, olfactory, visual morphology, odor potency, and overall acceptability. Panellist exhibited mixed perception shows seaweed as algal, unappealing, strong, unpleasant fishy odors. Odor intensity was moderate to intense; this influences the unwillingness towards the consumption of seaweed. However, objective method of sensory profiling using E-nose (Electronic nose) identify volatile compounds such as ethanethiol,2-mercaptoethanol,1-propanol, thiophene,1butanamine,1-hyroxy-2-propanone and heptadecanal with its subsequent sensory descriptors as correlated with the fishy. pungent and strong odour. Combining both methods indicates that the characteristic of seaweed leads to reduced consumer acceptance in its raw or unprocessed form. Panellists have a favourable approach towards processed products such as incorporating seaweed as a functional food ingredient in food matrices like nutritional supplements, snacks, savory, bakery products, ready to eat products and beverages.

Keywords: Sensory, subjective, E-nose, consumer acceptance, functional ingredient

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GENDER MAINSTREAMING UNDER UNIDO'S BLUE INDUSTRY FRAMEWORK: ADVANCING EQUITY IN SEAFOOD VALUE CHAIN

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Achieving equitable and sustainable seafood value chains requires addressing structural gender barriers while supporting competitiveness and compliance in global trade. The Blue Industry Framework operationalises UNIDO's mandate on inclusive and sustainable industrial development by integrating gender mainstreaming throughout project cycles, complemented by targeted measures that strengthen women's access, skills and leadership in seafood systems.

This poster presents a twin-track approach: (i) embedding gender considerations across diagnostics, policy, quality infrastructure and market linkage activities; and (ii) deploying targeted support to enhance women's participation in value chain upgrading. Operational entry points are illustrated across programmes, including SADC/PROFISHBLUE's quality infrastructure and One-Stop-Border-Post facilitation; Indonesia's seaweed and shrimp–mangrove value chains where gender-responsive training supports processing quality and sustainability markets; Cambodia, where women-led fish processing groups benefit from food safety training, improved post-harvest practices and strengthened testing and certification services; and GMAP Colombia's gender analysis, institutional capacity-building and sex-disaggregated monitoring in tilapia and shrimp value chains.

Across these cases, integrating gender into compliance processes, quality systems and trade facilitation enabled women producers and enterprises to formalise operations, meet SPS and quality requirements, and access higher-value markets. By systematically combining gender analysis with targeted measures, this work demonstrates how gender mainstreaming enhances equity, decent work, productivity and seafood trade readiness. The poster offers actionable insights for policymakers and practitioners on embedding gender equity within seafood value chain development under the Blue Industry Framework.

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PATTERNS OF LOCAL CONSUMPTION AND EXPORT OF PARROTFISHES (FAMILY: SCARIDAE) FROM THE COAST OF TAMIL NADU, INDIA - A PRELIMINARY MULTIMETHOD STUDY

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Parrotfishes (Family: Scaridae) are key herbivorous species supporting tropical reef resilience. This multimethod qualitative study evaluates their fisheries, consumption patterns, and export dynamics across seven coastal and landlocked districts in Tamil Nadu, India. Data were gathered through harbour and market surveys, semi-structured interviews (n=75) with fisherfolk, vendors, exporters, auctioneers, and consumers, alongside digital ethnography from social media, export/vendor websites, and YouTube videos.

Surveys covered fishing villages, harbours, and markets, documenting catch methods (76% via nets and traps from small, motorized boats). Interviews explored preferences and trends; digital sources quantified exports and consumer sentiments. Thematic analysis with triangulation ensured methodological robustness.

Parrotfishes weighing 400–2000 g were selectively exported to Southeast Asia and the Middle East at premium prices (3.68–7.35 USD/kg), approximately six times higher than local market rates, while smaller specimens supplied domestic demand. Local consumption predominantly featured scrambled fish or fried/roasted preparations; unexpectedly, landlocked district consumers exhibited stronger preferences than coastal residents, valuing the fish's low bone content despite its perceived blandness. Elder fisherfolk noted parrotfish exports were negligible two decades ago, indicating rapid market expansion. Functional analysis revealed 19 species grouped into 11 entities, with eight single-species entities showing high vulnerability to localized extinction—particularly concerning as these included the most heavily caught species. In conclusion, export pressures on this species surpass local consumption, thus threatening functional diversity and reef health. The results indicate a worrying trend, urging integrated management and quantitative monitoring.

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SEAWEED INFUSED NUTRACEUTICAL FUNCTIONAL BEVERAGE FOR MICRONUTRIENT SUPPLEMENTATION

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Seaweeds are rich sources of nutraceutical compounds and possess significant potential as functional food ingredients beyond their conventional use as phycocolloids. Brown seaweeds such as Padina spp. and Turbinaria ornata have gained attention due to their nutritional richness and bioactive properties. This study focuses on the development and evaluation of a seaweed-based health drink formulated as a nutrient supplement using selected brown seaweeds. The seaweeds were assessed for their nutritional composition, antioxidant potential, and sensory acceptability of the formulated beverage.
Both Padina spp. and T. ornata are known to contain appreciable levels of macronutrients, dietary fibre, essential minerals, and natural antioxidants, which contribute to their functional and health-promoting properties. Comparative observations indicate variation in nutrient composition and antioxidant potential between the two species, influencing their suitability for beverage formulation. Sensory evaluation demonstrated acceptable organoleptic characteristics, including colour, appearance, texture, flavour, and taste, highlighting the feasibility of incorporating seaweeds into palatable health drink formulations.
The findings emphasize the potential of edible seaweeds as sustainable and natural sources of macro- and micronutrients for functional beverage development. Seaweed-based health drinks represent a promising approach to nutritional supplementation and functional food innovation, supporting dietary balance and nutritional security.

Keywords: Seaweed-based health drink, Padina spp., Turbinaria ornata, nutrient supplements, antioxidants, functional beverages.

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THE EFFECTS OF PESCATOURISM ON ENHANCING AQUATIC VAQLUE CHAIN IN PALANGAN FISH FARMS

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This research investigates the influence of pesca-tourism on the aquatic value chains in the scenic geographical region of fish farms in Palangan. By examining the interplay between eco-tourism activities and the local fish farming industry against the backdrop of rugged mountain landscapes and pristine waterways, this study investigates how pesca tourism practices shape the dynamic of fish production, processing and distribution in this area.
The study investigates the integration of pesca-tourism into the aquatic value chains of Palangan fish farms, highlighting its potential to enhance economic, environmental, and social sustainability. Through geospatial analysis, stakeholder interviews, and socio-economic surveys, findings reveal that farm engaging in pesca-tourism activities achieve higher revenues, larger scale, and improved market access by diversifying products and services, such as farm-to-table experiences and cultural tourism. marketing upskilling correlates with increased farm size and production, emphasizing the importance of capacity building. Pesca tourism also fosters environmental stewardship by incentivizing sustainable aquaculture practices and raises public awareness of conservation. Socially, it supports cultural preservation and community empowerment, particularly benefiting women's economic participation.
The study recommends investing in infrastructure development, including visitor facilities and educational centers, enhancing capacity building focused on hospitality and sustainable tourism, and implementing targeted marketing strategies to promote pesca-tourism's unique value. Additionally, establishing a robust regulatory framework and fostering collaboration among government, private sectors, and local communities, are essential for sustainable growth. Ensuring community-based management and equitable benefits distribution is essential for the sustainable development of pesca tourism in Palangan.

Key words: Pesca-tourism, aquatic value chain, fish farms, Palangan

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NUTRIENT COMPOSITION OF MARINE FISH SPECIES FROM THE EAST AFRICAN COAST: IMPLICATIONS FOR FOOD AND NUTRITION SECURITY.

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Fish play a significant role in food and nutrition security along the coast of East Africa. However, there is a lack of comprehensive nutrient composition data. This study aimed to present the nutrient composition of the most commonly consumed marine fish species and assess their potential contribution to the recommended nutrient intakes (RNIs) of a healthy adult. In total, 24 commonly consumed fish species were sampled using pelagic and demersal trawls by R/V. Dr. Fridtjof Nansen during the ecosystem survey along the East African coast in 2018 and 2023. Species were categorized, according to length, into small (< 25 cm) or large (> 25 cm) fish and prepared based on local consumption practices (whole, dressed, fillets, headed, and gutted). All samples were analyzed using accredited methods. The findings revealed that small fish species typically consumed whole with bones, heads and viscera, contain higher levels of micronutrients such as calcium (908 mg/100 g), iron (2.9 mg/100 g), iodine (140 µg/100 g), zinc (2.0 mg/100 g), vitamin A (205 µg/100 g), and the fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (0.2 g/100 g and 0.6 g/100 g, respectively) when compared to larger species where only fillets are consumed. Several small fish species consumed whole were identified to contribute ≥ 15% of the RNIs of healthy adults for several essential nutrients. The data presented in this study make a valuable addition to the Tanzanian and Mozambican food composition tables and enhance the understanding of fish as a significant source of micronutrients.

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DIETARY ORGANIC ACID SALTS AS ANTIBIOTIC ALTERNATIVES FOR MITIGATING ANTIMICROBIAL RESISTANCE IN *PENAEUS VANNAMEI*

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The widespread use of antibiotics in shrimp aquaculture has accelerated antimicrobial resistance (AMR) and veterinary drug residue accumulation, threatening public health, international trade, and sector sustainability. Effective dietary alternatives to antibiotics are therefore essential for residue-free shrimp production. Although organic acids are recognized as functional feed additives, integrated and dose-dependent evidence identifying the most effective organic acid salt and its optimal inclusion level as an antibiotic alternative in *Penaeus vannamei* remains limited. This study evaluated the efficacy of different organic acid salts (OAS) and doses in improving growth, immune competence, and disease resistance in *P. vannamei*, with implications for AMR mitigation. Juvenile shrimp (~1 g) were fed thirteen experimental diets comprising a control and diets supplemented with sodium butyrate (SB), sodium fumarate (SF), sodium succinate (SS), and sodium propionate (SP) at 0.5%, 1%, and 2% inclusion levels for 60 days (triplicate). Growth performance, digestive enzyme activities, apparent nutrient digestibility, intestinal histology, innate immune responses, immune- and growth-related gene expression, and resistance to *Vibrio parahaemolyticus* challenge were assessed. Shrimp fed OAS diets showed significantly improved growth performance and feed efficiency, with SP 1% producing the highest response ($p < 0.001$). SB 2% and SP 1% produced the greatest gains in digestion, hepatopancreas health, immunity, and post-challenge survival. Upregulation of IGF-1, IGF-II, TLR, and proPO further confirmed physiological benefits. Overall, sodium propionate (1%) and sodium butyrate (2%) emerged as effective non-antibiotic dietary strategies to enhance shrimp health and disease resistance, supporting AMR mitigation and residue-free, export-compliant shrimp aquaculture.

Keywords: Sodium propionate, Sodium butyrate, Antibiotic alternatives, Growth promotor, Disease resistance, antimicrobial resistance

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DEVELOPMENT OF QUATERNISED MAGNETIC CHITOSAN BEADS FROM CRAB AND PRAWN SHELL WASTE FOR SUSTAINABLE DYE REMOVAL

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Seafood processing industries generate large volumes of crab and prawn shell waste which are often disposed, despite their high chitin content and potential as a bioadsorbent. Converting this waste into functional materials can address both environmental pollution and sustainability changes within the seafood value chain. Chitosan extracted from crab and prawn shells was functionalised into quaternised magnetic beads to check their efficiency as adsorbents for dye removal from aqueous systems.

Quaternisation was done to increase the surface charge of chitosan to improve its adsorption of anionic dye molecules, while magnetisation was done to enable separation of the adsorbent after dye removal. The beads were tested for the removal of representative dyes under laboratory conditions. Compared with unmodified chitosan, the modified chitosan showed enhanced dye removal, indicating the combined effect of chemical functionalisation and magnetisation. A main advantage of the developed bioadsorbent is the easier recovery using an external magnetic field, thereby reducing secondary waste generation and increasing reusability. This is especially useful in wastewater treatment, where separation and simplicity are crucial.

The chitosan beads contribute to an environmentally responsible approach by converting seafood processing by-product waste into functional materials for environmental remediation. The developed quaternised magnetic chitosan beads show potential for application in industrial effluent treatment supporting sustainable water management and circular economy principles within global seafood sector

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OCEAN TO DINE: A NOVEL SEAWEED-BASED INSTANT NUTRITIVE SOUP AS A NEXT-GENERATION MARINE SUPERFOOD

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Seaweeds are increasingly recognized as marine super foods due to their exceptional nutritional values and unique bioactive compounds not commonly found in terrestrial plants. The present concept introduces a novel seaweed-based instant nutritive soup, developed as a functional and therapeutic food designed to support medical recovery, immunity, and tissue repair mechanism. This instant soup integrates selected green, red, and brown seaweeds rich in sulfated polysaccharides such as fucoidan, ulvan, and agar, along with essential minerals, antioxidants, and marine-derived micronutrients. Unlike conventional soups, this formulation is designed for rapid reconstitution, easy digestion, and enhanced bioavailability, making it suitable for individuals with compromised health. The seaweed instant soup is particularly intended for post-operative patients, individuals recovering from illness or fever, elderly populations with weak digestion, anaemic individuals, post-partum women, and children with poor immunity. After consumption, the natural seaweed polysaccharide forms a gentle protective layer gently in the walls of gastrointestinal tract aiding reduction in inflammation and help the tissues to repair damaged cells. At the same time, the rich mineral and antioxidant content improves immunity, energy levels, and nutrient absorption. Bioactive compounds such as fucoidan and phlorotannins exert anti-inflammatory, antioxidant, and immunomodulatory effects, thereby accelerating cellular repair and reducing recovery time. Its novelty lies in transforming seaweed into a clinically relevant, sustainable, and plant-based instant soup, rather than a pharmaceutical product offering a simple, natural, and biocompatible solution for recovery, wellness, and daily health support.

Keywords: Seaweeds, Super-food, Anti-inflammatory, Immunomodulatory and Sustainability

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FROM CARBON IMBALANCE TO BLUE CARBON LEADERSHIP: HOW INDIA'S SHRIMP SECTOR IS RESTORING ECOSYSTEMS AND REIMAGINING GLOBAL TRADE

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The global shrimp industry faces an urgent climate challenge: for every kilogram of farmed shrimp produced, up to 13 kilograms of CO_2 are released, much of it due to the loss of mangroves—nature's most powerful blue carbon sinks. Over 250,000 hectares of mangroves have been lost worldwide to shrimp farming, driving ecosystem decline and increasing vulnerability to climate Change.

India's response is rapidly gaining momentum. Through the Mangrove Initiative for Shoreline Habitats & Tangible Incomes (MISHTI), over 26,000 hectares of coastal buffer zones—including lands previously converted for shrimp ponds—are being restored. Projects such as Small-scale Aquaculture in Mangrove Ecosystems (SAIME) in West Bengal, and community-driven restoration and the MANGREEN initiative in Tamil Nadu, demonstrate that mangrove recovery and sustainable aquaculture can coexist, supporting both carbon sequestration and resilient coastal livelihoods.

Call to Action: To catalyse a fair, sustainable, and resilient shrimp supply chain, Indian industry leaders must:

- Invest in landscape-level aquaculture improvement projects and cross-sector restoration partnerships
- Fund and participate in community-managed mangrove nurseries and restoration initiatives, with an emphasis on empowering women and local families
- Adopt and promote full-chain traceability and global ESG certifications such as ASC and Shaphari, leveraging digital platforms like Aqua Trace for transparency and buyer confidence
- Collaborate with government, NGOs, and supply chain partners to scale holistic solutions—moving beyond farm-level fixes to ecosystem-wide impact.
- Publicly report restoration metrics, community impacts, and progress toward SDG 13 (Climate Action) and SDG 14 (Life Below Water), reinforcing leadership and trust in global markets

India's shrimp sector now has the chance to move from a legacy of blue carbon loss to global leadership in blue carbon restoration and sustainable seafood

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RECIRCULATING AQUACULTURE SYSTEMS (RAS) IN INDIA: CATALYZING SUSTAINABLE DEVELOPMENTAL BENEFITS FOR HIGH-VALUE SPECIES AQUACULTURE

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This abstract provides a technical overview of the developmental benefits associated with the adoption of Recirculating Aquaculture Systems (RAS) for cultivating high-value aquatic species in India. Traditional aquaculture practices in India, primarily reliant on open-pond or cage culture, face increasing constraints from water scarcity, land availability, environmental degradation, and vulnerability to exogenous pathogens and climatic fluctuations. RAS technology offers a robust solution by enabling intensive, bio-secure, and resource-efficient aquaculture.

RAS operates as a closed-loop system, fundamentally relying on **advanced water treatment processes** including mechanical filtration for solids removal, biological filtration (nitrification) for ammonia and nitrite conversion, degassing for CO2 stripping, and oxygenation. This intricate environmental control permits **significantly higher stocking densities** and **optimized growth rates** for high-value species, transcending geographical and climatic limitations. Water reuse rates of 90-99% dramatically reduce freshwater consumption, mitigating the agricultural sector's hydrological footprint and fostering water-use efficiency in water-stressed regions of India.

From a developmental perspective, RAS directly contributes to **enhanced food security** through consistent, year-round production of high-quality protein. Its land-independent nature allows for peri-urban establishment, minimizing logistics costs and ensuring fresh product availability for burgeoning urban markets. Economically, the cultivation of high-value species in RAS yields **superior profitability and return on investment (ROI)** due to reduced feed conversion ratios (FCRs) under controlled conditions, lower disease incidence, and premium market pricing. The controlled environment also facilitates genetic selection and improved biosecurity, minimizing crop losses. Furthermore, RAS creates **skilled employment opportunities** in aquaculture engineering, water chemistry, fish health management, and system operation, contributing to rural and semi-urban socio-economic upliftment. The potential for precision farming in RAS also aligns with India's digital agriculture initiatives.

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IMPORTANCE OF DATA LOGGERS AND TRACKERS

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Data loggers popularly known as TTR (Time, Temperature recorder) play a crucial role in the seafood industry by recording temperature along with Date & Time stamp to ensure the quality and safety of seafood products during transit.

Regulatory Compliance: Data loggers provide accurate records to meet food safety regulations, such as HACCP standards. During insurance claim, report from Loggers and Trackers play a crucial role as evidence to validate damage if any due to breach in temperature. Shelf life of the product is determined based on the available data.

Improved Quality Control: Continuous monitoring ensures seafood meets safety standards.

Types of Data Loggers:

- *USB Data Loggers:* Record temperature data along with Date and Time and can generate PDF reports plus excel file. Shadow recording feature also known as Silent mode recording helps in retrieving the data even in cases where the logger was not activated.
- *NFC Data Loggers:* User friendly, all the data once downloaded are stored in particular customer account there by enhancing easy of operation and better data management.
- *Multi Use Data Loggers:* Can be programmed for interval of time, alert settings based on customer requirement. Device can be re-used multiple times. Suitable for local infrastructure monitoring and local trips.
- *Multi-Channel Data Loggers:* Monitor multiple points simultaneously, ideal for large-scale seafood processing with cold storage facility. Local Wi-fi or SIM based data is used to connect the logger's data to Cloud. Scheduler function to receive reports on pre-set interval. Temperature & Humidity with date and time stamp data stored in Cloud.
- *Real-Time Tracker:* Enables quick corrective action in case of temperature deviations specifically during transit. Can measure 5 parameters like Location, Temperature, Humidity, Light and Shock. Each tracker can have independent Alarm settings which gives Alerts for temperature breaches to ensure prompt action.

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PERFORMANCE TRADE-OFFS OF *PENAEUS MONODON* ACROSS STOCKING DENSITIES IN A NATURAL FEED-BASED PRECISION INTENSIVE SHRIMP FARMING SYSTEM

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The resurgence of *Penaeus monodon*, once the cornerstone of shrimp aquaculture before the dominance of *P. vannamei* has now renewed its commercial value by improved technologies and growing market demand for large sized premium shrimp. A 142-day study evaluated the effects of three stocking densities high (HSD, 100/m³), medium (MSD, 60/m³), and low (LSD, 30/m³) on growth, survival, feed efficiency, and water quality in six HDPE grow-out tanks (12 m diameter; 150-ton capacity). Post-larvae with an initial average body weight (ABW) of 0.012 g were stocked under semi
floc conditions. Results showed that LSD produced the highest final ABW (38.4 g), followed by MSD (37 g) and HSD (28.5 g). Survival was also greatest in LSD (98%), compared to HSD (92%) and MSD (82%). Biomass yield was highest in HSD (788.9 kg), with lower outputs from MSD (539.7 kg) and LSD (350.3 kg). FCR for shrimps reared in LSD was 1.58 which is the lowest, whereas for shrimps reared in MSD is 1.66 and 1.77 resulted in HSD. Greenhouse gas (CO_2, CH_4, N_2O) emissions remained within acceptable limits, and water quality parameters (DO, pH, salinity, temperature) were stable throughout the trial. TVC and TBC in both water and shrimp gut samples were low across all treatments. Overall, the study demonstrates that while higher stocking densities yield greater biomass, lower densities significantly enhance growth, survival, and feed efficiency, emphasizing the importance of optimizing stocking strategies for sustainable shrimp production.

Keywords: Intensive, Biomass yield, Survival, FCR, Greenhouse gas emissions.

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ASSESSING SEAFOOD SAFETY THROUGH HEAVY METAL PROFILING IN FARMED SHRIMP (*LITOPENAEUS VANNAMEI*)

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Seafood safety is a critical concern for public health, global food security, and the sustainability of aquaculture systems. Farmed shrimp, particularly *Litopenaeus vannamei*, constitutes a major component of international seafood trade and human diets, making the assessment of contaminant levels in edible tissues essential. Building on earlier findings of heavy metal enrichment in shrimp pond environments, the present study examines the implications of such contamination for seafood safety through analysis of shrimp muscle tissue. Shrimp muscle samples were subjected to standardized acid digestion followed by elemental analysis using Atomic Absorption Spectroscopy (AAS) to quantify essential and toxic metals. The analysis revealed that essential elements were largely present within expected physiological ranges, indicating acceptable nutritional quality of the shrimp muscle. Several toxic metals, including cadmium, chromium, nickel, and cobalt, were below detection limits, suggesting limited exposure to these contaminants. However, lead was detected in shrimp muscle at a concentration that exceeds the European Union maximum permissible limit for crustaceans (0.30 mg/kg), although it remains below the Codex Alimentarius maximum limit of 0.50 mg/kg. Given that shrimp muscle represents the primary route of dietary exposure, the presence of lead raises concerns regarding potential long-term health risks due to its cumulative toxicity and the absence of a safe exposure threshold. These findings highlight shrimp muscle as a critical matrix for evaluating seafood safety and regulatory compliance. The study emphasizes the importance of routine monitoring of edible shrimp tissues to minimize dietary exposure to toxic metals, ensure adherence to international food safety standards, and support sustainable aquaculture practices that protect consumer health and maintain market confidence.

Keywords: Seafood safety; heavy metals; shrimp muscle; *Litopenaeus vannamei*; lead contamination; atomic absorption spectroscopy; food safety standards; aquaculture sustainability

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PROMOTING VALUE ADDITION AND EXPORT OF TUNA VALUE CHAIN IN IRAN THROUGH INTRODUCING A SPECIAL ICE MACHINE

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This UNIDO project, funded by the Government of Japan, aims to promote inclusive and sustainable development of the yellowfin tuna value chain in Chabahar, Iran. Building on UNIDO's previous interventions, it addresses challenges such as inadequate post-harvest handling, limited product diversification, weak export capacity, and risks of overfishing. The initiative targets MSMEs, local institutions, and fishermen, while fostering collaboration with Japanese partners to support technology transfer and expand high-value export opportunities.

The project is structured around three pillars: improving quality management systems, promoting market access, and building a sustainable ecosystem. Key interventions include training on proper handling techniques, upgrading cold-chain and logistics infrastructure, enhancing quality assurance capacities, and introducing new technologies. A pilot export of fresh tuna to Japan through introducing a special ice machine will demonstrate opportunities for higher value addition. The special ice produced by the machine allows fishermen in Iran to improve quality of tuna and thereby help export tuna to foreign market.

To ensure sustainability, the project includes stock assessments, awareness-raising activities on sustainable fishing practices, and the establishment of mechanisms to monitor and manage yellowfin tuna resources. Capacity building for local institutions will strengthen long-term monitoring and regulatory capabilities.

Expected outcomes include improved competitiveness, reduced post-harvest losses, broader adoption of sustainable fishing methods, and increased access to high-value markets.

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BRIDGING THE VALUE GAP: IMPLEMENTING A FISHER-CENTRIC DIGITAL TRACEABILITY SYSTEM FOR SUSTAINABLE SEAFOOD EXPORT IN INDIA

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The Indian seafood sector, a major global supplier, currently operates at a significant economic disadvantage. The prevailing business model focuses on exporting raw, unprocessed material to international markets. Value addition, including sophisticated processing, eco-labeling, and digital traceability, is primarily executed in destination countries, allowing foreign entities to capture the premium pricing. This structure severely restricts revenue growth for Indian exporters and, critically, prevents necessary price increases for the local fishers, hindering the sector's overall profitability and sustainability. Meeting the increasing global requirement for robust, verifiable digital traceability is essential for accessing premium markets. However, implementing digital systems in the Indian context faces a critical adoption challenge. Standard digital solutions often fail because they lack direct, tangible benefits for the primary stakeholders—the fishers. Low technological awareness and a history where existing digital tools primarily serve to empower middlemen (exporters and processors) lead to deep mistrust and resistance among the fishing community, resulting in poor adoption rates. Any successful solution must fundamentally shift the benefit model to prioritize the fisher.

This paper presents a novel digital traceability system engineered specifically to overcome these adoption barriers by integrating technology within an already trusted framework. Our solution is built upon an existing, highly successful platform: a Marine Navigation System currently utilized by **over 3,000 customers** across the Indian coast. The initial success and high adoption rate of this navigation platform were achieved by seamlessly integrating **Indigenous Traditional Ecological Knowledge (TEK)** into its core functionality, making the technology immediately relevant and beneficial to the fishers' daily operations. We leverage this proven technological infrastructure and user base to implement a comprehensive digital traceability layer. By integrating capture data—such as location, time, and species—directly into the existing workflow, the system ensures that the fishers are the *primary beneficiaries* of the data, rather than just the data source. This direct benefit improved productivity, operational efficiency, and single gadget drives voluntary participation and creates a reliable, immutable digital chain of custody from the point of capture.

This fisher-centric traceability system provides a scalable and culturally appropriate model for domestic value addition. By generating verifiable, tamper-proof data at the source, the solution directly addresses the economic disadvantage faced by Indian exporters, enabling them to meet stringent international eco-labelling and traceability mandates (e.g., EU regulations, MSC standards). Ultimately, by empowering fishers with data ownership and verifiable proof of origin, this system is critical for unlocking premium pricing, fostering domestic value addition, and ensuring the long-term economic viability and environmental sustainability of the Indian seafood sector. This approach demonstrates that successful digital transformation requires not just technology, but a deep commitment to stakeholder benefit and the integration of local knowledge.

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