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Connecting Waters, Science and Sustainability

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"Connecting Waters, Science and Sustainability"

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3rd SYMPOSIUM ON
OCEAN AND FRESHWATER SYSTEMS

SOFS
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Preface

The Faculty of Fisheries and Marine Sciences & Technology at the University of Ruhuna is pleased to present the abstract volume of the Third Symposium on Ocean and Freshwater Systems (SOFS 2026), held under the theme “Connecting Waters, Science and Sustainability.”

Since its inception in 2022, SOFS has evolved into a dedicated platform for the dissemination of research in marine, coastal, and freshwater sciences. Originally established to showcase undergraduate research within the faculty, the symposium has grown into a broader academic forum that welcomes contributions from postgraduate researchers, professionals, and international collaborators. This expansion reflects the increasing importance of focused scientific dialogue on aquatic systems in addressing contemporary environmental and developmental challenges.

Distinct from broader multidisciplinary conferences, SOFS maintains its specialized emphasis on ocean and freshwater research. This focus enables deeper engagement with the scientific, ecological, and socio-economic dimensions of aquatic environments, reinforcing its position as a unique scholarly platform in Sri Lanka.

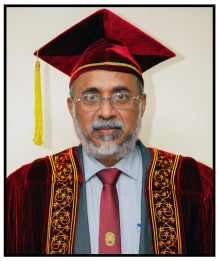
The 2026 theme, “Connecting Waters, Science and Sustainability” underscores the vital relationship between aquatic ecosystems, scientific advancement, and sustainable development. At a time when challenges such as ecosystem degradation, biodiversity loss, climate change, and resource conflicts are intensifying, scientific inquiry and knowledge exchange remain essential for fostering resilient and sustainable futures.

The abstracts compiled in this volume represent a diverse range of current research and emerging perspectives in ocean and freshwater systems. All submissions were evaluated by the Editorial Board and expert reviewers to ensure the academic quality of the work presented.

On behalf of the Editorial Board, I extend sincere gratitude to all contributors, reviewers, the organizing committee, and all stakeholders whose efforts made SOFS 2026 possible.

Prof. Upul Premarathne
Editor-in-Chief
SOFS-2026

Message from the Vice Chancellor



As a leading academic conference in aquatic sciences, the Symposium on Ocean and Freshwater Systems (SOFS) has become an important forum for scientific discussion, interdisciplinary collaboration and the dissemination of innovative research on marine and freshwater ecosystems. I would like to commend the Faculty of Fisheries and Marine Sciences and Technology for their dedication in sustaining this valuable biennial initiative, and for creating opportunities that strengthen the nation's scientific community.

As an island nation with rich marine and inland water resources, Sri Lanka depends greatly on the sustainable management of these ecosystems for food security, livelihoods, biodiversity conservation and climate resilience. In this context, scientific research and innovation play a pivotal role in addressing the complex environmental, social and economic challenges facing aquatic systems today.

SOFS 2026's theme appropriately reflects the need to integrate scientific knowledge, technological advancement and sustainable management practices to safeguard our interconnected water resources. It highlights the importance of collaborative research that transcends disciplines and promotes evidence-based solutions for the stewardship of oceans and freshwater systems.

I am particularly pleased to see the active involvement of young researchers and students, whose contributions continue to enrich this symposium. Their enthusiasm, creativity and commitment to scientific enquiry will undoubtedly help to shape a more sustainable future for our aquatic environments.

I extend my sincere appreciation to the organizing committee, authors, reviewers, partners, and sponsors whose collective efforts have made this symposium possible. I wish SOFS 2026 every success and trust that it will inspire meaningful discussions, fruitful collaborations, and impactful research outcomes.

Senior Prof. P.A. Jayantha

Vice-Chancellor
University of Ruhuna

Message from the Dean

I am honoured to announce the third Symposium on Ocean and Freshwater Systems (SOFS) of the Faculty of Fisheries and Marine Sciences & Technology at the University of Ruhuna, scheduled for 05th June 2026. SOFS is significant to our faculty and the broader fisheries and marine sciences community, and I am proud to share this moment with you all. The State Key Laboratory of Breeding Biotechnology and Sustainable Aquaculture in China co-sponsors SOFS-2026, and Sampath Bank PLC serves as the symposium's strategic partner.

The Faculty of Fisheries and Marine Sciences & Technology, founded in 2005, has spearheaded education and research in fisheries, freshwater, and marine sciences within the country's tertiary education system. SOFS is a regular event in the faculty's academic calendar, disseminating high-quality research findings from students and researchers. The faculty board recognised the theme of the third symposium: “Connecting Waters, Science, and Sustainability”. SOFS-2026 is of great importance to the faculty because the research findings of its graduates are also communicated to the scientific community. The proceedings of SOFS-2026 consist of 52 research communications, the outcomes of independent research by graduates of the faculty and researchers in the field working across the country. The quality of the abstracts in the proceedings has been maintained through peer review by expert reviewers and the editorial board panel appointed by the faculty board.

I sincerely thank the China-Sri Lanka Joint Centre for Research and Education (CSL-CER) for coordinating with the co-sponsor, the State Key Laboratory of Breeding Biotechnology and Sustainable Aquaculture. I also appreciate Sampath Bank PLC for being the strategic partner of SOFS-2026. I sincerely thank Prof. R.A. Maithreepala, Chairperson of the organising committee; Prof. Upul Premarathne, Editor-in-Chief of SOFS 2026; members of the editorial board; and all other scientific and organising committee members for their tremendous efforts towards the symposium's success. I gratefully welcome Senior Professor Pathmalal M. Manage, the keynote speaker, and Prof. Shunping He, the Guest of Honour of SOFS-2026. I also greatly appreciate the panel of expert reviewers for their excellent support in the event's success. As the Dean of the faculty, I wish to convey my sincere gratitude to the faculty academics, academic support staff, and non-academic staff for their full support and cooperation in the success of SOFS-2026. I also congratulate the faculty graduates, who are important stakeholders in SOFS-2026. I express my gratitude to Senior Professor P.A. Jayantha, the Vice-Chancellor of the University of Ruhuna, for his moral support and inspiration in the successful completion of the event.

I hope the third symposium on the ocean and freshwater systems of the Faculty of Fisheries and Marine Sciences & Technology will be a great success.

Prof. K.H.M. Ashoka Deepananda

Professor of Fisheries Biology (Chair)
Dean/ Faculty of Fisheries and Marine Sciences & Technology

Message from the Director- CSL-CER

On behalf of the China-Sri Lanka Joint Center for Education and Research (CSL-CER), led by the South China Sea Institute of Oceanology (SCSIO), Chinese Academy of Sciences and the University of Ruhuna (UoR), I extend my warmest congratulations on the third symposium on Oceans and Freshwater Systems. Organized by the Faculty of Fisheries and Marine Sciences & Technology, the State Key Laboratory of Breeding Biotechnology and Sustainable Aquaculture, China and CSL-CER, this biennial event returns under the theme "Connecting Waters, Science and Sustainability." As a long-standing key supporter, we are honored to witness its continued growth.

The CSL-CER plays a vital role in fulfilling the intergovernmental agreement for technological cooperation signed over a decade ago. Since 2010, SCSIO and UoR have built a solid foundation, establishing a real-time observation network and conducting numerous expeditions with R/V Shiyan 3 and R/V Shiyan 6. In alignment with this year's theme, we are actively broadening our scope to include sustainable fisheries and modern aquaculture. By integrating ocean modeling with aquatic ecology, we aim to provide scientific solutions for the blue economy and food security. Furthermore, we remain dedicated to nurturing talent through ANSO and UCAS scholarships. To date, over 100 Sri Lankan students have been trained at CAS institutes, forming the backbone of our future bilateral scientific collaboration.

Over the past decade, the significance of CSL-CER has been reaffirmed by being specifically mentioned in three consecutive joint statements issued by the governments of China and Sri Lanka, in 2023, 2024, and 2025. This high-level recognition underscores our role as a cornerstone of bilateral cooperation. CSL-CER will continue to serve as a vital platform for marine and aquatic sciences, remaining open to the international community to address global sustainability challenges.

I wish this third symposium great success and congratulate all the authors, organizers, and contributors for making this event a reality.

Prof. Changsheng Zhang

Director, China-Sri Lanka Joint Center for Education and Research (CSL-CER),
Deputy Director General, South China Sea Institute of Oceanology,
Chinese Academy of Sciences

Message from the Conference Chair

It is with great honor and a profound sense of responsibility that I express a few words while organizing the 3rd biannual Symposium on Ocean and Freshwater Systems (SOFS-2026) under the theme "Connecting Waters: Science and Sustainability." The technical sessions have been organized under the timely and important themes of Ocean Health vs. Climate Calamities, Aquaculture Development and Blue Economy, Freshwater Systems and Environmental Issues, and Sustainable Fisheries. These areas are highly significant as we stand at a critical juncture in understanding and managing the planet's most vital natural resources.

Sri Lanka, an island nation closely connected with the Indian Ocean and enriched with diverse inland water systems, provides a unique natural laboratory for scientific exploration and knowledge generation. The Faculty of Fisheries and Marine Sciences & Technology has consistently been at the forefront of research and innovation related to these environments. This symposium reflects the dedication and scholarly efforts of our undergraduate and postgraduate students, researchers, and academic staff. Organizing this event in collaboration with the China–Sri Lanka Joint Centre for Education and Research (CSL-CER), State Key Laboratory of Breeding Biotechnology and Sustainable Aquaculture and Sampath Bank PLC has created a valuable opportunity to strengthen academic cooperation and knowledge exchange.

The theme "Connecting Waters" highlights the reality that aquatic ecosystems do not exist in isolation. From deep-sea ecosystems to freshwater environments, and from advancements in water technology to fisheries and aquaculture, every component of the aquatic environment is interconnected. Disturbances in coastal ecosystems can influence marine biodiversity, while developments in water science directly affect the sustainability of rural watersheds and aquatic resources. As researchers and scientists, our responsibility is to bridge the gap between scientific discoveries and practical conservation strategies. This symposium serves as a platform to showcase how science, technology, and ecological wisdom can be integrated to ensure the resilience of aquatic resources against climate change and overexploitation.

To further enrich SOFS-2026, we are privileged to welcome two eminent scientists: Senior Prof. Pathmalal M. Manage, Vice Chancellor of the University of Sri Jayewardenepura, as the keynote speaker, and Prof. Shunping He from the Institute of Hydrobiology, Chinese Academy of Sciences, People's Republic of China, as the Guest of Honour. We sincerely appreciate their valuable contributions, together with the Chinese scientists delivering plenary speeches at the technical sessions.

I express my sincere gratitude to Senior Prof. P.A. Jayantha, Vice Chancellor of the University of Ruhuna, and Prof. Ashoka Deepananda, Dean of the Faculty of Fisheries and Marine Sciences & Technology, for their continuous guidance and support. I also thank the Co-chair of SOFS-2026, Prof. Yang Shang, for his valuable contributions. Moreover, State key laboratory of Breeding Biotechnology and Sustainable Aquaculture, China as well as Sampath Bank PLC as a strategic partner are highly acknowledged for their financial support. I highly appreciate all authors, reviewers, and the academic, administrative, and non-academic staff members whose dedication made this event a success.

Prof. R.A. Maithreepala
Conference Chair
SOFS-2026

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Agenda

Registration

7.30 Onwards	Registration of Participants

Inauguration Session

8.45 - 8.50	Arrival of Guests
8.50 - 9.00	Lighting of the Traditional Oil Lamp
9.00 - 9.05	University Anthem
9.05 - 9.10	Welcome Address by the Chairperson - SOFS 2026 Prof. R.A. Maithreepala
9.10 - 9.20	Address by the Dean - Faculty of FMST Prof. K.H.M.A. Deepananda
9.20 - 9.25	Address by the Director, China - Sri Lanka Joint Center for Education and Research Prof. Changsheng Zhang
9.25 - 9.35	Address by the Vice Chancellor – University of Ruhuna Snr. Prof. P.A. Jayantha
9.35 - 9.50	Address by the Guest of Honour Prof. Shunping He Institute of Hydrobiology, Chinese Academy of Sciences
9.50 - 10.00	Ceremonial Presentation of the Abstract Volume
10.00 - 11.00	Keynote Speech by Snr. Prof. Pathmalal M. Manage, Vice Chancellor, University of Sri Jayewardenepura
11.00 -11.15	Address by the Co-Chair, SOFS-2026 Prof. Yang Shang, South China Sea Institute of Oceanology, Chinese Academy of Sciences
11.15 - 11.30	Address by the representative of Sampath Bank PLC
11.30 - 11.40	Vote of Thanks by the Secretary, SOFS-2026 Dr. A.M.K.A. Bandara
11.40 - 11.45	National Anthem
11.45 - 12.45	Lunch

Technical Sessions

13.00 –17.00	Technical Sessions

Speech by the Guest of Honour

Origins and Evolution of Deep-Sea and Hadal Fishes

Fishes are the most diverse vertebrate group and inhabit environments ranging from high-altitude waters to the deepest ocean trenches. This presentation summarizes recent advances in fish evolutionary biology, with emphasis on vertebrate water-to-land transition and the origin and adaptation of deep-sea and hadal fishes. Comparative genomic studies of ancient ray-finned fishes and lungfishes revealed key genetic innovations associated with air breathing, locomotion, and terrestrial adaptation.

Systematic investigations of deep-sea and hadal fishes based on large-scale sampling expeditions and multi-omics analyses generated high-quality genomes for representative taxa from depths exceeding 7,000 m. Comparative analyses reconstructed the evolutionary history of fish colonization into deep-ocean environments and identified convergent adaptations related to high hydrostatic pressure, darkness, sensory systems, circadian rhythm, membrane organization, and DNA damage response. Studies on hadal snailfishes further revealed unique adaptive mechanisms involving skeletal remodeling, membrane composition, TMAO metabolism, and ferritin gene expansion. Furthermore, significant bioaccumulation of anthropogenic pollutants, such as heavy metals and persistent organic pollutants, was detected in these species. These findings provide important insights into the evolutionary processes and adaptive mechanisms of deep-sea vertebrates.

Prof. Shunping He

Institute of Hydrobiology
Chinese Academy of Sciences (CAS), Wuhan, China
E-mail: clad@ihb.ac.cn

Keynote Speech

Connecting Waters: Integrating Freshwater and Ocean Science for Sustainability in Sri Lanka

Senior Prof. Pathmalal M. Manage

Centre for Water Quality and Algae Research, Department of Zoology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka

1. Introduction: The Hydrological Continuum of Sri Lanka

Sri Lanka, a tropical island nation located in the Indian Ocean, possesses a distinctive hydrological and marine ecosystem network that fosters an intricate interconnection between rivers, reservoirs, wetlands, estuaries, groundwater systems, and coastal waters. They are critical for ecosystem services such as drinking water provision, irrigation, fisheries, transportation, biodiversity protection, tourism, and overall economic sustainability for millions of people. The freshwater, nutrients, sediments, and organic matter transported from terrestrial landscapes by major river basins like the Mahaweli, Kelani, Kalu, and Gin Rivers create strong ecological linkages between the land and ocean (Manage et al 2020).

However, freshwater and marine ecosystems are increasingly being compromised by rapid urbanisation, industrial expansion, agricultural intensification, deforestation, climate change, and anthropogenic pollution across Sri Lanka (Manage et al., 2020). Many river systems and coastal areas have been severely degraded by poor water quality caused by industrial effluents, untreated sewage discharge, agricultural run-off (high in fertilizers and pesticides), plastic pollution, and emerging contaminants such as antibiotics. These environmental pressures not only decimate aquatic biodiversity but also severely compromise public health, fisheries productivity, and the long-term sustainability of the nation's water resources. Consequently, integrating freshwater and ocean science for sustainability in Sri Lanka is no longer merely an academic concept, but an urgent national imperative.

2. The "Source-to-Sea" Paradigm: Linking Freshwater and Marine Environments

The conventional approach to water management often treats freshwater and marine environments as separate entities. Scientifically, however, it is essential to recognise the "ridge-to-reef" or "source-to-sea" continuum. Rivers act as conduits, carrying both vital nutrients and harmful pollutants from inland areas to the coast. For instance, the Kelani River, which flows through highly urbanised and industrialised zones, is a primary source of drinking water but also acts as a major pathway for land-based pollutants entering the Indian Ocean (Manage et al., 2020).

Extensive Water Quality Index (WQI) modeling has demonstrated that heavy metals, untreated wastewater, and solid waste from the Kelani River basin accumulate in the estuary and coastal waters, degrading habitats such as mangroves and coral reefs (Mahagamage, Manage, & Pathiratne, 2019). Therefore, the health of the ocean is fundamentally dependent on the health of the freshwater systems feeding into it. Protecting coastal marine ecosystems inherently requires upstream mitigation.

3. Contemporary Anthropogenic Threats to Sri Lanka's Water Ecosystems

To address the degradation of these interconnected ecosystems, we must confront several critical, cross-boundary water quality challenges:

3.1. Eutrophication, Cyanotoxins, and Groundwater Contamination

Excessive use of agricultural fertilizers introduces high levels of nitrogen and phosphorus into surface water bodies. This nutrient loading leads to eutrophication, triggering harmful algal blooms (HABs) in freshwater reservoirs and coastal lagoons. My extensive research over the past decades has shown that these blooms, particularly those dominated by *Microcystis* species, release potent cyanotoxins such as microcystins and cylindrospermopsin. When these nutrient-rich waters reach the ocean, they can create hypoxic "dead zones," suffocating marine life and devastating local fisheries. Furthermore, the contamination of groundwater with heavy metals, fluoride, and cyanotoxins is strongly hypothesized to be linked to the prevalence of Chronic Kidney Disease of unknown etiology (CKDu) in the dry zones of Sri Lanka, underscoring the lethal intersection of environmental pollution and public health.

3.2. Microbial Contamination and the Proliferation of Antimicrobial Resistance (AMR)

Faecal contamination from inadequate sanitation infrastructure remains a persistent issue. Pathogenic bacteria (e.g., *Escherichia coli*, *Salmonella*, and *Shigella* spp.) are routinely transported via rivers into coastal waters, rendering beaches unsafe for recreation and contaminating seafood (Manage et al., 2010; Manage & Wijesekara, 2012). More alarmingly, these aquatic environments now serve as massive reservoirs for Antimicrobial Resistance (AMR). Antibiotic residues from human medicine, veterinary practices, and aquaculture exert selective pressure on environmental bacteria, facilitating the horizontal transfer of resistance genes. Recent studies highlight the widespread occurrence of multi-drug resistant enteric pathogens in Sri Lankan coastal zones, posing a catastrophic threat to global public health frameworks.

3.3. Emerging Contaminants and Microplastics

Sri Lankan waters are now heavily burdened by emerging contaminants, most notably microplastics and persistent organic pollutants. Rivers act as primary transport mechanisms for mismanaged plastic waste, which eventually degrades into microplastics in the ocean. These particles are ingested by marine organisms, entering the food web and ultimately posing significant toxicological risks to human health.

4. Bridging the Divide: Integrating Freshwater and Ocean Science

Addressing these multifaceted crises requires a paradigm shift away from fragmented, siloed management structures. The artificial academic and regulatory separation of freshwater and marine sciences severely limits ecological restoration. Instead, we must adopt an Integrated Water Resource Management (IWRM) framework that encompasses the entire hydrological cycle. By explicitly integrating freshwater and ocean science for sustainability in Sri Lanka, we can transition from reactive pollution control to proactive ecosystem conservation. By understanding the biogeochemical fluxes and ecological dynamics across the freshwater-marine interface, we can develop targeted interventions that address pollution at its source, rather than merely managing its symptoms at the coast.

5. Strategic Pathways for Policy, Research, and Action

To successfully actualize the integration of freshwater and ocean science for sustainable development in Sri Lanka, I propose the following strategic actions:

i. **Promote Interdisciplinary Research:** Encourage collaborative research that bridges hydrology, oceanography, biogeochemistry, microbiology, and ecotoxicology. Understanding pollutant transport mechanisms such as the bioaccumulation of cyanotoxins and the dissemination of AMR genes from source to sea is crucial.

ii. **Implement Advanced Monitoring and Data Integration:** Establish continuous, integrated monitoring networks that track water quality parameters across the entire watershed, utilising advanced molecular diagnostics, WQI modeling, remote sensing, and GIS technologies to identify pollution hotspots and assess long-term trends.

iii. **Invest in Bioremediation and Green Technologies:** Leverage indigenous microbial isolates for the bioremediation of toxins and heavy metals in industrial effluents before they are discharged into riverine networks, thereby reducing the toxicological load on coastal ecosystems. Strengthen Policy and Governance: Implement robust, ecosystem-based management (EBM) policies that encompass the entire river basin and its associated coastal zone. Enhance regulatory frameworks to strictly control point and non-point source pollution.

iv **Foster Community Engagement:** Educate local communities, farmers, and industries about the downstream impacts of their activities. Promoting sustainable agricultural practices and proper waste management is essential to reducing land-based pollution.

6. Conclusion

The sustainability of Sri Lanka's water resources and coastal ecosystems relies on our ability to recognise and manage them as a single, interconnected continuum. By embracing cross-disciplinary research and holistic governance, we can develop evidence-based strategies to mitigate pollution, protect biodiversity, and safeguard public health. Ultimately, integrating freshwater and ocean science for sustainability in Sri Lanka is the most viable pathway to ensure a resilient and thriving blue-green economy for the future of our nation.

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Speech by the Conference Co - Chair

Advancing Aquaculture through Innovation: Overview of the State Key Laboratory of Breeding Biotechnology and Sustainable Aquaculture

The State Key Laboratory of Aquatic Organism Breeding and High-Efficiency Aquaculture is hosted by the Institute of Hydrobiology, Chinese Academy of Sciences (IHB, CAS), with the Institute of Oceanology, CAS and the South China Sea Institute of Oceanology, CAS as co-construction partners. Reorganized from the former State Key Laboratory of Freshwater Ecology and Biotechnology, the laboratory was officially approved in December 2024. Addressing the national strategic needs for food security and effective protein supply, the laboratory focuses on the grand scientific challenge of elucidating the genetic mechanisms underlying the formation and coupling of key economic traits in aquatic animals. Leveraging a big data and AI-driven "digital-intelligent" paradigm shift, we aim to dissect the genetic foundations of economically important traits-including rapid growth, disease resistance, environmental stress tolerance, superior product quality, reproductive regulation, and sex differentiation. We develop precision breeding technologies such as genomic reconstruction, genomic selection, sex control, and surrogate reproduction, and establish integrated multi-trait improvement systems to overcome critical bottlenecks like controllable sterility in aquaculture breeding. Through these efforts, we strive to cultivate elite new varieties, particularly those with coupled multi-trait advantages, thereby enhancing the contribution rate of improved germplasm in China. Guided by superior germplasm, we construct theoretical and technical frameworks for healthy and high-efficiency aquaculture, ensuring the deployment of quality varieties across diverse production scenarios, including pond culture, intensive facility-based systems, and aquatic ecological ranching. Our mission is to build a world-class innovation platform and talent cultivation hub, serving as a strategic origin for sustainable aquaculture theory and technology, and providing irreplaceable scientific and technological support for securing China's effective supply of high quality protein.

Prof. Yang Zhang

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Plenary Speeches

Technical Session I

Technical Session II

Technical Session III

Technical Session IV

Plenary Speech: Technical Session I

Integrative Analysis of Coral Plasticity and Adaptations Reveals Key Proteins Driving Resilience to Changes in Ocean Carbonate Chemistry

Xiangcheng Yuan[1,2,*], and Ellias Y. Feng[3]

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Abstract

Understanding how corals adapt to changes in seawater carbonate chemistry is crucial for developing effective coral conservation strategies. Research to date has mostly focused on short-term experiments, overlooking long-term evolutionary effects. Here, we investigated the link between short-term stress responses and long-term genetic adaptations in the coral species Porites pukoensis through experiments under varying CO_2 and alkalinity conditions. Our results showed that alkalinity enrichment significantly increased coral calcification rates by 35% - 45% compared to high CO_2 treatment, highlighting the potential of alkalinity enrichment to mitigate acidification impacts. Corals modulated relative expression levels of basic and acidic proteins in response to changes in seawater carbonate chemistry in the stress experiments. Genomic data revealed that this mechanism has been evolutionarily fixed in various organisms adapting to seawater carbonate chemistry. Additionally, both experimental and genomic results showed that extracellular matrix proteins, like collagen with von Willebrand factor type A domain, were modified in response to distinct carbonate environments. Molecular dynamics simulations and *in-vitro* experiments demonstrated that the structural stability of these proteins contributes to coral resilience under acidified conditions. This study established an integrated framework combining stress experiments, multi-omics analyses, molecular simulations, and *in-vitro* validation to identify key proteins involved in coral adaptation to acidification.

Keywords: Alkalinity enrichment, coral translation efficiency, ocean acidification, protein isoelectric point (pI)

Acknowledgement

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Plenary Speech: Technical Session II

Comparative Study on Phenotypic Traits of Tetraploid-Based Triploid Oyster in Aquaculture

Ziniu Yu*, Yuehuan Zhang, and Yanping Qin

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Abstract

Oysters are important marine bivalve species in coastal areas and China has the biggest part of oyster production in the world, accounting for 86% by weight of the world's oyster yield. Triploid is usually sterile, which is advantageous in oyster farming because it can result in superior growth. Hence, triploid hybrids with a combination of hybridization and polyploidization are expected to be more sterile than diploids because of the added complication of gametogenesis. Moreover, triploid hybrids may otherwise combine the desirable traits of two parental traits, leading to an increased growth rate, increased environmental tolerance or overall hardiness in culture conditions. To evaluate triploids performance characteristics, complete inter-ploidy hybridization between diploid and tetraploid, in Pacific oyster, Portuguese oyster and between the two species, were conducted, respectively. In Pacific oyster (*Crassostrea gigas*), the growth and survival rate of TD (Tetraploid ♂x Diploid ♀) were significantly higher, and the 100% triploid rate was stable. In Portuguese oyster (*C. angulata*), DT hybrids (Diploid♀ × Tetraploid ♂) had a higher survival rate than intra-ploidy groups during the whole life history stage in grow-out stage, and growth advantage of reciprocal triploid hybrids was evident in both DT and TD, while DT progeny was always larger than TD in the whole process except in the D larvae stage. In allotriploids, DGTA) (diploid *C. gigas* ♀ × tetraploid *C. angulata* ♂) had significant shell height, whole weight and survival advantages ($P < 0.05$), while DATG (diploid *C. angulata* ♀ × tetraploid *C. gigas* ♂,) exhibited significantly fastest growth and highest survival; These results indicate that DGTA has advantages in growth, survival and infertility in northern China while DATG performs best in southern China, which exhibits that there is a significant maternal effect of hybridization in allotriploids. All these data supported that both autotriploid and allotriploid oysters have good performance in aquaculture practice, and promise a guidance for their commercial production.

Keywords: Oyster, triploid, tetraploid, hybridization, aquaculture

Plenary Speech: Technical Session III

Immune Biological Control Technology to Important Viral Diseases in Marine Cultured Fish

Qiwei Qin[1,2,3,*], Xiaohong Huang[1,2], Jing Guang Wei[1,2], Youhua Huang[1,2], Sheng Zhou[1,2], and Shaowei Wang[1,2]

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Abstract

Groupers are representative important species being marine cultured in China and Southeast Asia countries. In 2024, the aquaculture production of grouper has exceeded 260,000 tons in China. However, under the intensive artificial conditions, the outbreaks of viral diseases have caused heavy economic losses to grouper aquaculture. Among them, Singapore grouper iridovirus (SGIV) and red-spotted grouper nervous necrosis virus (RGNNV) were identified as two important viral pathogens. To develop effective prevention and control strategies for SGIV or RGNNV, comprehensive immune-biological control technology has been established, including development of rapid diagnosis methods, vaccine preparation and evaluation, development of immune bioactive products and screening and evaluation of intestinal probiotics. These technologies cover early detection of pathogens, vaccination, and immune enhancement, that provide important technical support for the prevention and control of viral diseases in marine fish.

Keywords: Immuno-biological control technology, SGIV, RGNNV, grouper

Acknowledgement

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Plenary Speech: Technical Session IV

The Influence of Eutrophication on Seagrass-Herbivores Interaction

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Abstract

Seagrass beds are key nearshore ecosystems with important ecosystem service functions, playing a vital role in maintaining biodiversity and fishery resources production. In recent years, human activities have increased the nutrient burden on nearshore waters, altering the availability of nutrients in seawater and thus affecting the physicochemical properties of seagrass. This further changes the grazing activities of herbivores, impacting the trophic transfer efficiency of matter and energy in key food chains and the ecosystem service functions of seagrass. This study, combining field observations and simulation experiments, found that increased nutrient load significantly alters seagrass nutritional quality, chemical defense substances, and structural defenses, thereby enhancing the grazing intensity of herbivores. Simultaneously, herbivores tend to select seagrass with high nutritional quality and low chemical defense substance content. Furthermore, the effect of nitrate on seagrass palatability exhibits a threshold effect. Based on these findings, protection, management, and restoration measures for seagrass bed ecosystems are proposed.

Keywords: Eutrophication, seagrass, herbivore, interaction, protection and management

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Technical Session III: *Freshwater Systems and Environmental Issues*

Technical Session IV: *Sustainable Fisheries*

Technical Session I

Ocean Health Vs. Climate Calamities

The Impacts of Causeway Modifications on Water Quality in Rekawa Lagoon, Sri Lanka

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Abstract

Rekawa lagoon, a major coastal aquatic system on the southern coast of Sri Lanka that supports numerous ecosystem services, has experienced impaired ecological integrity due to construction activities near the lagoon mouth. Water exchange through the causeway has undergone several modifications and evolved from 23 pipes (30 cm diameter) in 1984, to a partial bridge (6.2 m) in 1999, then eight larger culverts (79 cm diameter) with a partial bridge in 2005, followed by a complete bridge in 2018. Although these modifications have a potential to change the water quality of the lagoon, a comprehensive scientific report in this regard is unavailable. The present study was designed to compare the water quality of lagoon in parallel to these modifications by using published historical literature together with field observations conducted in August 2024 selecting eight sampling sites (S_1-S_8) across the lagoon. Salinity, Temperature, pH, Dissolved Oxygen, Nitrate nitrogen, Orthophosphate, Total dissolved solids, Total suspended solids, Chlorophyll-a, Turbidity, Chemical oxygen demand, Secchi depth and Electrical Conductivity were measured, and the Lagoon Water Quality Index (L-WQI) was calculated. Salinity levels recorded in 1994, 2002, and 2005 were 4.81 ± 0.66 ppt, 5.7 ± 4.4 ppt, and 8.1 ± 0.6 ppt, respectively, while the value increased to 9.78 ± 0.94 ppt in 2024. Significant differences ($p < 0.05$) were observed in salinity, temperature, pH, and Secchi depth between historical water quality and present findings, demonstrating notable improvements in lagoon water quality over time. L-WQI of study sites were range from 49.42 ± 0.52 to 56.70 ± 0.12. L-WQI were significantly different ($p<0.05$) among sites, where two sites (S_2 and S_6) were classified under "critical condition", while the remaining sites were categorised as "good condition". Present findings revealed that the causeway modifications have significantly altered the water quality dynamic of Rekawa lagoon, and the L-WQI indicated that, restoration efforts have improved water quality, but specific areas are still facing localized pollution and nutrient loading. This study recommends sustainable management strategies and conservation programs to preserve ecological health, support local livelihoods, and ensure the long-term sustainability of the Rekawa Lagoon ecosystem.

Keywords: Causeway, ecological integrity, lagoon water quality index (L-WQI), Rekawa lagoon, water quality

Explainable Random Forest-Based Classification of Dolphin Behaviour from Movement Data in Low-Resource Settings

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Abstract

Animal behavior, specifically that of the intelligent and very social animals like the dolphin, is naturally complicated and cannot fully be expressed using numbers but will only act as an additional approach for ecological understanding. In relation to marine ecology, especially when focusing on the impact assessment and monitoring of dolphin habitats, proper identification of the behaviors of dolphins becomes imperative. Yet up to this point, studies related to this subject continue to use the traditional method of manual observation and video analysis, which requires much time. Movement-based variables derived from tracking and field observations provide a scalable alternative for inferring behaviors such as foraging, socializing, and fast surface movement. Nevertheless, many studies operate under low-resource conditions characterized by limited labeled datasets, class imbalance, and measurement noise. This study proposes an explainable machine learning framework for dolphin behavior classification using a Random Forest model under such constraints. The dataset consists of N = 136 movement observations of bottlenose dolphins, represented by eight numerical features describing locomotion and group dynamics, along with one categorical contextual variable. The class distribution is [insert distribution], reflecting moderate imbalance. The framework integrates standardized numerical features with encoded contextual data and applies Synthetic Minority Over-sampling Technique (SMOTE) within the training pipeline to address imbalance. A stratified 80:20 train/test split was used for validation to preserve class proportions. To enhance transparency and ecological interpretability, explainable artificial intelligence techniques (SHAP) were incorporated to quantify both global and instance-level feature contributions. The model classifies observations into three behavioral categories: Fast Surface Behavior, Foraging, and Socializing. Experimental results demonstrate strong performance, achieving an accuracy of 0.90, a Cohen's kappa of 0.85, and a macro-ROC–AUC of 0.97. Explainability analysis indicates that speed, group size, and reorientation-related variables are the most influential predictors, aligning with established ecological understanding of dolphin behavior.

Keywords: Dolphin behavior, movement-based analysis, explainable machine learning, low-resource data modeling

A Comparative Study of Dye Extraction from Seaweed: Exploring the Vibrant Potential for Fabric Dyeing

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Abstract

Rising environmental concerns over synthetic dyes and demand for eco-friendly products have increased interest in natural dyes. This study evaluates *Sargassum crassifolium* as a sustainable textile dye. Although other seaweeds have been studied, limited work has examined this species or the ratio-dependent effectiveness of mordants across fabrics. Dye was extracted from dried seaweed collected from Parei Wella Beach, Tangalle. Linen, poplin, and grey fabrics were dyed using iron (ferrous sulphate) and alum (potassium aluminum sulphate) through pre- and simultaneous mordanting methods. Color absorption was measured as red, green, and blue (RGB) brightness values from images analyzed using GIMP. Statistical analysis was conducted in MINITAB 17 using General Linear Model (GLM) and two-sample t-tests at $p = 0.05$. Pre-mordanting showed significant differences (GLM; $p < 0.05$) between iron and alum mordants, with iron producing lower brightness values [(RGB) (R = 165.67), (G = 135.22), (B = 109.56)] compared to alum [(RGB) (R = 203.11), (G = 178), (B = 152)], indicating higher dye absorption. Two-way ANOVA confirmed significant differences (GLM: $p < 0.05$) between mordants, with alum showing higher brightness values. This indicates greater absorption of red, green, and blue colors by iron mordant. No significant differences were observed among fabrics [(R; $p = 0.713$), (G; $p = 0.756$), (B; $p = 0.829$)] or interactions between fabric and mordant [(R; $p = 0.914$), (G; $p = 0.763$), (B; $p = 0.792$)]. In contrast, simultaneous mordanting showed no significant differences between iron and alum [(R; $p = 0.916$),(G; $p = 0.535$), (B; $p = 0.511$)], among fabrics [(R; $p = 0.480$), (G; $p = 0.308$), (B; $p = 0.126$)], or interactions [(R; $p = 0.467$), (G; $p = 0.731$), (B; $p = 0.701$)]. Comparative analysis revealed that pre-mordanting enhanced dye uptake, particularly with iron on linen. Red brightness differed ($p < 0.05$) between methods using iron on poplin [(Alum; (R; $p = 0.083$), (G; $p = 0.578$), (B; $p = 0.423$); Iron; (R; $p = 0.039$), (G; $p = 0.082$), (B; $p = 0.079$)]. These findings demonstrate that *Sargassum crassifolium* has strong potential as an eco-friendly dye, especially with pre-mordanting and iron treatment. Further research should assess color fastness, identify active compounds, and evaluate large-scale feasibility.

Keywords: Dye extraction, brown seaweeds, mordants, fabrics

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The authors are thankful to Tangalle coastal communities for providing research facilities and sample access. Special appreciation is extended to the sensory panelists and technical staff for their valuable support in laboratory work and data analysis.

The Role of Seagrass Meadows in Carbon Sequestration: An Estimate from Madanwella, Dondra

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Abstract

Seagrass meadows are crucial blue carbon ecosystems that play a critical role in carbon sequestration and are highly productive, supporting sustainable marine environments. This study was conducted at the Madanwella site (05°55'10"N 80°35'24" E) on the southern coast of Sri Lanka, aimed at estimating carbon sequestration in seagrass meadows, measuring phosphate and nitrogen concentrations in the meadows, and analyzing the relationship between carbon flux and associated flora. Seagrass (*Thalassia hemprichii*) samples and associated flora were collected from deep and shallow areas, and the sediment samples were collected in shallow, middle, and deep areas of the meadow using coring techniques. Soil Organic Carbon (SOC), Dry bulk density, porosity, Total Phosphate (TP), and Total Nitrogen (TN) along the vertical profile were measured by using the Loss on Ignition (LOI) method. The vegetative samples were analyzed to determine the moisture content, Organic matter (O_M), and carbon content. The highest amount of moisture (93.67 ± 1.87 %) was shown in the *Chaetomorpha sp*., and the lowest amount (48.95 ± 2.11%) was observed in *Halimeda opuntia*. The highest O_M (89.49 ± 1.39%) and carbon weight per 1g (0.37 mg) were observed in *Chaetomorpha* sp., and the lowest O_M (11.26 ± 2.74%) and carbon weight per 1g (0.04 mg) were observed in *Halimeda opuntia* compared to the seagrass. Seagrass leaves have higher moisture than the roots, (84.15 ± 0.86%), (86.31 ± 0.55%), respectively, with a carbon content of (0.09 ± 0.01) g, (0.09 ± 0.00) g, respectively. The average dry bulk density of soil in the study area was (0.98 ± 0.07) g/cm^3, with a porosity of 63%. Soil analysis revealed a vertical pattern in carbon content, with the highest accumulation near the coast, ranging from 0.5 g/cm^3 to 3.0g/cm^3. The initial SOC Stock for the study area was calculated as (0.089 ± 0.001) Mg C/ha. The nutrient analysis also showed that the coastal area has high TP (39.33 g/ kg at 12cm depth) & TN (222.07 g/kg at the surface) values, indicating strong nutrient mobility. However, through the meadow, a non-uniform vertical pattern was observed. Based on the results, the Madanwella seagrass meadow ecosystem is suggested to be a significant carbon reservoir, with a SOC stock of 0.089 ± 0.0088 mg C/ha, and a dynamic nutrient store, and it provides baseline data for future blue carbon conservation and management strategies.

Keywords: Blue carbon, seagrass meadow ecosystem, carbon stock, phosphate, nitrogen

Physicochemical Properties and Antibacterial Activity of Liquid Hand Soaps Enriched with *Avicennia marina* and *Rhizophora mucronata* Mangrove Leaf Extracts

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Abstract

The phytochemicals present in mangrove species exhibit remarkably strong antibacterial properties, emphasizing their significant potential for development in natural health care products. The present study was conducted to evaluate the physicochemical properties and antibacterial activity against *Escherichia coli (E. coli)* and *Staphylococcus aureus (S. aureus)* by liquid soaps enriched with *Avicennia marina* (AM) and *Rhizophora mucronata* (RM) mangrove leaf extracts. Extraction was done using the maceration method. In this study, 70% ethanolic extracts of both mangrove species were analyzed for the phytochemical screening and FTIR analysis to evaluate the bioactive components. The soap base was made using the hot process method and mixed with the crude extracts at two different concentrations of 1000 and ppm, 2000 ppm for each mangrove species (AM1000, AM2000 and RM1000, RM2000) separately and 50:50 combination of extracts from two species (AR1000 and AR2000) to produce different treatment formulations. The physicochemical characteristics and antibacterial activity against *E. coli* and *S. aureus* of the liquid soaps were assessed along the negative control (soap base only) and positive control (commercial liquid soap). The disc diffusion technique was used to evaluate the liquid soaps' antibacterial efficacy. Phytochemical screening of two mangrove species using FTIR analysis proved the presence of alkaloids, glycosides, saponins, diterpenes, phenols and tannins and absence of flavonoids. The pH of positive control was significantly lower (6.7 pH) than that of formulated liquid soaps which ranged from 7.8 to 8.2 pH.Viscosity of positive control was significantly higher than all the formulated liquid soaps. Significantly highest foam height was reported from AR2000 and RM2000. Compared to positive control, the highest foam retention was observed in AR2000. The density of liquid soap is not affected by the treatment.When comparing antibacterial activity, The highest inhibition zone diameter against *E. coli* was shown by positive control(16.63 ± 0.35mm) followed by AR2000(14.52 ± 0.39mm), AR1000(13.15 ± 1.06mm), RM2000 (13.57 ± 0.84mm), RM1000(13.56 ± 0.31mm). For *Staphylococcus aureus*, AR2000(15.57 ± 0.86mm) exhibit the highest inhibition zone diameter among formulated liquid soaps and the value is not statistically different from the positive control. This results indicate a superior antibacterial efficacy of AR2000 against both Gram-positive and Gram-negative bacteria when compared to the other formulated soaps. Therefore, results of this study concluded that AR2000 is the most effective formulation among formulated samples. However, it requires further optimization in formulated liquid soaps' antibacterial activity to achieve antibacterial efficacy comparable to that of commercially available liquid soaps while lowering the pH to level similar to those of liquid soaps available commercially.

Keywords: *Avicennia marina*, *Rhizophora mucronata*, phytochemicals, physicochemical properties, antibacterial activity

Leaf Damage Variability between Three Mangrove Species, Rekawa Lagoon, Sri Lanka

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Abstract

As the primary photosynthetic organs of the tree, mangrove leaves are vital to its health; consequently, studies investigating leaf damage are of significant ecological importance. Herbivory is a key ecological process influencing mangrove productivity and nutrient cycling. Quantitative and comparative assessments of leaf damage across mangrove species and developmental stages remain poorly documented. This study aimed to quantify and compare variability in herbivore-induced leaf damage assessment among *Avicennia marina, Lumnitzera racemosa*, and *Rhizophora mucronata* species , evaluate variation across three different leaf maturity stages (immature, young, and old), categorize damage types, and assess species-specific susceptibility to herbivory and disease in the Rekawa Lagoon mangrove ecosystem, Sri Lanka. In particular, limited baseline data exist on how species identity and leaf maturity interact to influence the extent and probability of foliar damage in natural mangrove forests. Addressing this study gap, is essential for understanding mangrove resilience under increasing stresses. A total of 30 trees were identified and tagged, comprising 10 trees from each of the three species, from which five leaves per maturity stage (immature, young, and old) were sampled. This yielded 15 leaves per tree and a total of 450 leaves collected between November 2024 and January 2025. High-resolution images (4032 × 3024 pixels) were analyzed using *Image J* software to quantify eight categories of damage: margin damage, necrosis, rasping, holes, fungal spots, mining, galls, and undefined damage. Leaf damage was quantified as a percentage of the total leaf area using the formula: (damaged area/total leaf area) × 100. Data were analyzed via a two-way ANOVA, which revealed significant differences ($p < 0.05$) among species and leaf maturity level. *Avicennia marina* showed the highest mean damage (13.15%), followed by *Lumnitzera racemosa* (8.34%) and *Rhizophora mucronata* (6.51%). Comparisons among maturity stages revealed that old leaves experienced greater mean damage (10.66%) than immature (9.08%) and young leaves (8.27%), suggesting cumulative exposure to herbivores and environmental stress over time. Frequency-based analysis indicated that *Rhizophora mucronata* had the highest probability of damage occurrence however, frequent test bites and high tannin, tough leaf structure resulted in the lowest mean damage. Margin damage was the most prevalent type across all three mangrove species. These findings highlight baseline data on mangrove leaf damage dynamics in Southern Sri Lanka and contribute to understanding mangrove ecosystem resilience, informing evidence-based management and conservation strategies under increasing anthropogenic and climatic pressures.

Keywords: *Avicennia marina,* herbivory, leaf damage assessment, *Lumnitzera racemosa, Rhizophora mucronata*

Factors Influencing Accumulation of Non-Biodegradable Solid Waste in Mangroves, Rekawa, Sri Lanka

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Abstract

Mangrove forests, which function as natural buffers between terrestrial and marine environments, are increasingly affected by Non Bio-Degradable Solid Waste (NBDSW) accumulation. Such accumulation disrupts biodiversity, ecological functions, and coastal protection services of mangroves however, factors influencing accumulation of NBDSW in mangroves are largely unknown. Addressing this study gap, the current study investigated the factors influencing NBDSW accumulation in the Rekawa Lagoon mangrove area, Sri Lanka. Nine potential environmental and anthropogenic factors were examined: distance from human habitation, distance from lagoon water, tidal impacts, root density (number of roots per quadrat), waste interception by root structures, vegetation cover (encompassed all plants species in the study area), types of human activity (fishing, tourism and agricultural), magnitude of human activity, and human population density Influencing factors to NBDSW accumulation. Between November 2024 to January 2025, fifty randomly selected 1 m × 1 m NBDSW accumulated quadrats were investigated to (a) identify and categorize different NBDSW types accumulated, (b) measure the abundance of each NBDSW types, (c) measure the above nine influencing factors per quadrat. Accumulated NBDSW in the quadrats included 11 different types dominated by Polyethylene Terephthalate (26%), Polyethylene (21%), Expanded Polystyrene (13%), and Glass (10%). Data were analyzed using a multiple regression model to determine the relationship between above mentioned influencing factors and the mean NBDSW abundance. The results revealed a significant relationship (R^2 = 56.7%; $p < 0.05$) between the mean NBDSW abundance and the influencing factors. Distance from human habitation (coefficient = 0.137; $P < 0.05$), distance from lagoon water (coefficient = -0.26; $P < 0.05$), tidal impacts (coefficient = 7.86; $P < 0.05$), waste interception by root structures (coefficient = -25.88; $P < 0.05$), magnitude of human activity (coefficient = 22.36; $P < 0.05$), and vegetation cover (coefficient = -7.57; $P < 0.05$) significantly influenced NBDSW accumulation. Where negative coefficients indicate a mitigating effect on NBDSW accumulation. In contrast, the human population density (coefficient = 1.16; $P > 0.05$), types of human activity (coefficient = 4.26; $P > 0.05$), and root density (coefficient = 3.94; $P > 0.05$) were not statistically significant ($p > 0.05$). These findings highlight that NBDSW accumulation in mangroves was driven by tidal impacts and human activities. The redistribution processes spread NBDSW to areas which are distance from human habitation, suggesting important insights for effective management strategies on NBDSW in mangroves.

Keywords: Expanded polystyrene, glass, non-biodegradable solid waste (NBDSW), polyethylene, polyethylene terephthalate

Temporal Variability of Sedimentation Rate and Grain Characteristics at the Pareiwella Coral Reef in Tangalle, Sri Lanka

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Abstract

Sedimentation is a key factor influencing coral reef health. Despite the recognized impact of sedimentation on coral reef health, there is a lack of site-specific information on how monsoon-driven both sedimentation rates and grain size distribution in Sri Lankan reef systems. Therefore, this study has focused on monthly sedimentation rates and grain characteristics at Pareiwella Coral Reef in Tangalle, Sri Lanka. Three Sediment traps (5cm diameter and 30cm height) were used to collect suspended sediments during the Southwest monsoon from May to September 2024 (N = 15). Dried sediment was sieved and separated based on particle size, and data were analysed using Minitab 17 statistical software. Grain characters were measured using ImageJ software. Significant monthly variations in sedimentation rates were observed (repeated measures: F value = 71.08, Degree of Freedom (DF) = 4, p = 0.0001) based on analyses of sediment weight and volume. The highest sedimentation rates were recorded in May (107.67 cm^3/month) and June (107.00cm^3/month), with corresponding mean values of 92.71 ± 1.268 g/month and 97.19 ± 1.358 g/month, respectively, followed by a notable decline in the subsequent months. The average grain size was 0.070 ± 0.0167 mm, with the largest mean value (0.086 ± 0.0241 mm) recorded in May and the smallest (0.057 ± 0.0148 mm) in June. Grain size analysis indicated finer sediments with smaller sizes in June, coinciding with peak wind speeds (m/s) retrieved from the NASA Power website, and significant differences were shown in sediment weight among sieve sizes (F = 544.95, DF = 5, p = 0.0001) and in the interaction between month and sieve sizes. The relationship between precipitation and sedimentation rate was weak (R^2 = 0.14), while wind speed showed a positive relationship with sedimentation rates. Stronger surface winds, which influence seabed dynamics and sediment transport to coastal areas, may explain the increased movement of fine sediments in June. While winnowing typically removes fine particles and leaves coarser material behind, the observed increase in finer sediment in June suggests that winnowing alone does not explain the situation at the study site. Instead, stronger wind conditions enhanced seabed disturbance. Therefore, the finer sediment composition recorded in June reflects a combination of hydrodynamic processes, including resuspension, lateral transport, and deposition. The occurrence of elevated sedimentation rates during the early Southwest monsoon at the Pareiwella coral reef indicates a strong seasonal influence that should be considered in reef management and conservation planning. This research provides a baseline for coastal sedimentation processes in the Southern Province of Sri Lanka.

Keywords: Pareiwella coral reef, grain characteristics, sedimentation rate, sediment trap, southwest monsoon

Biodiversity of Macroinvertebrates in Kalamatıya Lagoon: A Bird Sanctuary in Hambantota, Sri Lanka

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Abstract

Macroinvertebrates (MI) are bioindicators, and their diversity reflects ecosystem conditions. Kalamatiya lagoon is a bird sanctuary and a popular ecotourism site in Hambantota. This research was carried out to evaluate MI biodiversity and water quality, which are important for sustaining birds' feeding niches in the sanctuary. Benthic samples were collected monthly from June to August 2025 at eight locations (L1-L8) representing the whole lagoon area, using an Ekman grab. Meanwhile, floating aquatic plants were uprooted from the same location to collect benthic epifauna. A multi-parameter probe was used to measure water quality parameters (pH, temperature, and conductivity). The diversity parameters and relevant indices were calculated after identifying MI using standard taxonomic keys and photographic guides. The Kruskal-Wallis test in IBM SPSS Statistics software (version 25) was performed to compare the locations statistically. *Neriteron auriculata, Penaeus indicus, Thiara winteri, and Urothemis signata* were common MI across all locations. *Sesarma bocourti, Corbicula moltkiana*, and *Filopaludina penisularis* were observed only at L5, L3, and L1, respectively, where the land is closer. *Stenomelania offachiensis* and *Theodoxus flaviatilis* were present only at L6 and L8, respectively, in the middle of the lagoon. The most dominant species at each location were *Thiara winteri*, followed by *Penaeus indicus* and *Urothemis signata*. The presence of both sensitive species (*Ameletus* sp., *Brachycentrus* sp.) and tolerant species (*Chironomus* sp., *Melanoides tuberculata*) across the locations suggests a moderate ecological balance. The Shannon diversity index ranged from 1.62 ± 0.05 at L6 to 2.15 ± 0.04 at L2. Family Biotic Index (FBI) ranged from 4.62 ± 0.11 at L7 to 5.28 ± 0.12 at L5, indicating overall good to fair water quality. Ephemeroptera (E), Plecoptera (P), and Tricoptera (T) (EPT index, 2.00 ± 0.00) and Average Score Per Taxa (ASPT, 5.16 ± 0.00) were highest at L6, in the middle of the lagoon, which indicated better water quality. However, possible organic pollution and localized environmental stresses at locations closer to the land are indicated by the presence of species in the family Chironomidae. Therefore, the ratio between EPT/Chironomidae (C) varied between 0.20 ± 0.10 and 1.05 ± 0.00 at those locations. The presence of 26 MI species provides sustainable food niches for birds and maintains a moderately healthy ecological status in the Kalamatiya lagoon.

Keywords: Macroinvertebrates, bio-indicator, water quality, diversity indices, species diversity

Technical Session II

Aquaculture Development & Blue Economy

Friends in Fear, Foes in Peace: Intraspecific Behavioral Changes in Response to Alarm Cues in African Jewel Cichlid (*Hemichromis bimaculatus* Gill, 1862)

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Abstract

Group-living conspecifics often engage in complex social interactions that can be either cooperative or competitive a phenomenon observed across multiple taxa, including fishes. However, the effects of environmental stressors on these behavioral dynamics remain poorly understood. This preliminary study examined how shared stress affects intraspecific interactions, using the African jewel cichlid (*Hemichromis bimaculatus*), a territorial species with flexible social responses, as a model. Ten *H. bimaculatus* (four males, six females) were housed in an aquarium (60 × 40 × 40 cm^3) containing two clay pots as territorial sites. In Experiment A, behaviors were recorded under non-stressed conditions and following a 5-minute acute alarm stimulus (sudden water turbulence). Activity was quantified as the frequency of intraspecific interactions (chasing, biting), stress was estimated via opercular beat rate (OBR), and social-cohesion was assessed through grouping probability and nearest-neighbor distance (NND) from photographic method. All trials (n) were independent 10-minute assays, with trial order randomized (day/evening) controlling temporal effects. In Experiment B, a single unfamiliar heterospecific (*Dawkinsia filamentosa* or *Rasbora dandia*) was introduced in two separate 6-minute trials under non-stressed conditions to assess redirected aggression. Analyses were performed in R. Under non-stressed conditions, *H. bimaculatus* exhibited high intraspecific aggression (16.10 ± 7.26 interactions min^{-1}, n = 10), with strong territoriality observed. Alarm cue exposure significantly reduced aggression (1.20 ± 1.69 interactions min^{-1}, n = 10; t = 5.29, $p < 0.0005$), increased stress (OBR: stressed 61.57 ± 11.28 min^{-1}, n = 7 vs. non-stressed 45.40 ± 16.56 min^{-1}, n = 10; t = −2.24, $p < 0.05$), and promoted social-cohesion, with grouping probability rising (0.30 ± 0.15, n = 10 vs. 0.86 ± 0.13, n = 7; Fisher's Exact Test $p < 0.05$) and NND decreasing (3.32 ± 1.53 cm, n = 10 vs. 1.34 ± 0.44 cm, n = 7; t = 3.85, $p < 0.005$). Generalized linear model (Negative Binomial GLM) indicated that OBR positively predicted grouping ($\beta = 0.339$, $p = 0.099$) and negatively predicted interaction frequency ($\beta = -0.051$, $p = 0.003$). In experiment B, the introduction of unfamiliar intruders reduced intraspecific aggression while eliciting predominantly interspecific attacks (67–84% of interactions), consistent with a 'dear-enemy' effect. Overall, *H. bimaculatus* demonstrated behavioral plasticity: conspecifics functioned as competitors under stable conditions but exhibited socially cohesive, socially buffered responses under stress. These context-dependent shifts highlight the capacity of fishes to employ adaptive and flexible social strategies in response to external environmental factors.

Keywords: Behavioral plasticity; social-cohesion; social buffering; dear-enemy effect, Cichlid

Evaluation of Antibacterial and Antioxidant Activities of *Cyclea peltata* Leaf Extracts Against *Vibrio parahaemolyticus* Using *Artemia* sp. Model

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Abstract

Vibrio parahaemolyticus is a major aquatic pathogen causing vibriosis in aquatic organisms, leading to significant economic losses in aquaculture. Although synthetic antibiotics have long been used for disease control, their overuse has accelerated the development of antibiotic-resistant pathogens. Consequently, plant-based phytotherapeutic compounds are being explored as sustainable alternatives. This study evaluates the in vivo survival of brine shrimp *(Artemia* sp.) treated with hot water (reflux extraction) and cold ethanolic (maceration) leaf extracts of medicinal plant *Cyclea peltata* after being challenged with *V. parahaemolyticus*, aiming to identify the most effective extraction method. Phytochemical screening and FTIR analysis showed the presence of alkaloids, flavonoids, tannins, saponins, glycosides, and quinones with varying compositions among leaf extracts. Phosphomolybdenum antioxidant assay was performed using ascorbic acid as the standard to quantify the total antioxidant capacity (TAC) of cold ethanolic leaf extract (52.95 ± 0.42 mg ascorbic acid equivalents/g) and hot water leaf extract (35.20 ± 2.92 mg ascorbic acid equivalents/g). Disk diffusion method was performed to assess the antibacterial activity of leaf extracts (50, 100, 200 & 300 mg/mL) with tetracycline (3 mg/mL) as positive control. Results were significantly different (p <0.05) for each leaf extract treatment, and 300 mg/mL hot water leaf extract produced an inhibition zone of 9.36 ± 0.12 mm, while 300 mg/mL cold ethanolic leaf extract produced an inhibition zone of 8.22 ± 0.07 mm against *V. parahaemolyticus*, revealing the antibacterial sensitivity of *V. parahaemolyticus* for *C. peltata* leaf extracts. However, the inhibition zone of positive control was substantially higher (34.90 ± 0.89 mm) than crude extracts. Cytotoxicity assay was performed for leaf extract treatments (0,1,2,3 & 4 g/L) to determine nontoxic concentration for *Artemia* sp. The relative percentage survival of the leaf extract treatments (2 g/L) was determined using a 48-hour challenge assay with 20 *Artemia* sp. nauplii challenged with *V. parahaemolyticus* (10^6 CFU/ mL). Three replicates were maintained for each treatment followed with positive and negative controls. The results showed *Artemia* treated with hot water leaf extract exhibited significantly higher survival rate (94.36 ± 3.25%) against *V. parahaemolyticus.* Although both hot water and ethanol extracts exhibited comparable *in vitro* antibacterial activity, the hot water extract resulted in significantly higher survival under challenge conditions, indicating greater biocompatibility and potential host-protective effects. These findings suggest that hot water–derived extracts of *C. peltata* have strong potential as a sustainable alternative to conventional antibiotics against *V. parahaemolyticus* infections.

Keywords: Antibacterial activity, antioxidant activity, *Cyclea peltata*, phosphomolybdenum antioxidant assay, *Vibrio parahaemolyticus*

Antibacterial and Antioxidant Potential of *Salacia reticulata* and Its' Use as a Dietary Supplement for *Oreochromis niloticus*

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Abstract

Nile tilapia (*Oreochromis niloticus*), a species of major importance in global aquaculture, is highly susceptible to bacterial infections, highlighting the urgent need for plant-based alternatives to antibiotics to mitigate the growing threat of antimicrobial resistance. This study investigated the bioactive composition and *in vitro* antimicrobial activity of *Salacia reticulata* stem and assessed its' in vivo potential as a dietary supplement to improve the health and growth performance of *Oreochromis niloticus*. The extraction was carried out using 85% ethanol via both Maceration (9.65% yield) and Soxhlet (7.52% yield) methods. Phytochemical screening proved the abundance of the bioactive compounds featuring flavonoids, alkaloids, phenols, tannins, saponins, diterpenes and terpenoids in both extracts. Simultaneously, FTIR analysis proved the availability of key functional groups such as hydroxyl and aromatic rings. Antioxidant assays revealed substantial levels of bioactive compounds, with Maceration yielding a total phenolic content (TPC) of 12.39 ± 0.66 mg GAE/g DW and a total flavonoid content (TFC) of 28.32 ± 0.86 mg GAE/g DW, while Soxhlet extraction resulted in a TPC of 11.78 ± 0.95 mg GAE/g DW and a TFC of 25.48 ± 0.87 mg GAE/g DW. Moreover, in the sensitivity assay *Vibrio parahaemolyticus* (11.58 ± 0.50 cm) and *Aeromonas hydrophila* (11.04 ± 0.74 cm) showed a significantly higher inhibition effect than *Flavobcterium columnare* (8.83 ± 1.06 cm) in the highest concentration (50 mg/mL) of crude compounds extracted by both methods. During the feeding trial of eight weeks, *S. reticulata* stem powder was used as a dietary supplement at increasing inclusion levels [2% (ED2), 4% (ED4) and 8% (ED8)]. The significant highest final body weight, specific growth rate and average daily growth were obtained from the fish group fed with ED4. Furthermore, fish fed with ED4 exhibited hematological enhancement displaying significantly higher erythrocyte count than the other groups. Therefore, this study has characterized the bioactive profile of *S. reticulata* stem extract and the usage of stem powder as an optimal dietary supplement at 4% inclusion level, promoting the growth and hematological parameters of cultured Nile Tilapia.

Keywords: *Salacia reticulata*, dietary suppliment, bioactive compounds, haematological enhancement, Nile tilapia

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AI Based Detection of *Ichthyophthirius multifiliis* in *Carassius auratus*

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Abstract

Ichthyophthirius multifiliis, commonly referred to as the causative agent for Ich or white spot disease, is one of the most important parasitic threats in freshwater aquaculture around the world. Conventional detection methods are largely based on manual visual inspection, which is very time-consuming and subjective and cannot be done continuously. Thus, automated detection methods independent of human judgments are required for rapid diagnostics. Accordingly, this work developed an AI system to detect *I. multifiliis* infection in *Carassius auratus* using the YOLOv11 architecture. A dataset of 3,004 images containing both healthy, n = 1,381, and Ich-diseased, n = 1,369, goldfish, including 254 images with mixed classes, yielding a total of 6,893 annotations (3,539 healthy, 3,354 diseased) were collected. Images were captured using GoPro Hero 10 Black and iPhone 15 Pro Max cameras under a wide range of RGB lighting conditions. The dataset was randomly divided into training, validation, and test datasets in a ratio of 70:20:10, respectively. The YOLOv11 -medium model was trained for 100 epochs using a stochastic gradient descent optimizer, with data augmentation including rotation (± 10°), translation (± 0.1), scaling (0.5), and flipping. Accordingly, the model showed excellent performance on precision at 97.9%, recall at 95.8%, an F1-score of 0.95, and mAP50 of 0.974, with class-specific mAP50, which was 0.971 for healthy fish and 0.977 for diseased fish. This resulted in mAP50-95 of 0.647 (0.659 for healthy and 0.634 for diseased fish). The confusion matrix showed that 94% of healthy fish and 97% of diseased fish were correctly classified. Only 4% diseased fish were considered as false positives, and only 3% diseased fish were classified as false negatives. Convergence during training was achieved by epoch 80 without evidence of overfitting. In conclusion, it can be established that the YOLOv11-based detection systems are reliable for the detection of *I. multifiliis* infection with >95% accuracy and recall, ensuring minimal treatment of healthy fish, while enabling early interventions.

Keywords: *Ichthyophthirius multifiliis* detection, YOLOv11 deep learning, white spot disease (Ich), goldfish *(Carassius auratus),* automated aquaculture diagnostics

Evaluation of the Antiparasitic Activity of *Hemidesmus indicus* Root Extract Against *Argulus sp.* in Ornamental Carp (*Cyprinus rubrofuscus*)

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Abstract

Parasitic infection is considered one of the major constraints in commercial fish farms owing to huge economic losses. Although there are plenty of commercial drugs available for treatment, those synthetic chemicals cause hazardous to host and the environment. Therefore, there is a trend for moving towards herbal medications. This study has focused on a well-known Sri Lankan medicinal herb called Iramusu (*Hemidesmus indicus*) as a bath treatment agent against Argulosis infection caused by *Argulus* sp. Even though, several other bioactive properties of this plant are documented, studies on its anti-parasitic properties are limited. Therefore, this study was conducted to evaluate the antiparasitic effect of *H. indicus* on *Argulus* sp. infecting ornamental carp. The crude extract from the roots was obtained using the Soxhlet extraction method, and the main functional groups of the extract were identified using the FTIR technique. During the phytochemical analysis, alkaloids, flavonoids, diterpenes, glycosides, and saponins were identified, while quinones were absent. The antiparasitic property against *Argulus* sp., was initially tested through a 32-hour toxicity assay using five concentrations of extract (0, 300, 600, 900 and 1200 ppm) in triplicates. The results showed that the minimum concentration required to achieve 100% mortality was 600 mg/L, which was then tested for the safety and effectiveness as a bath treatment for fish. Accordingly, a toxicity test with *Cyprinus rubrofuscus* var. *koi* (weight = 3.14 ± 0.92 g, length = 6.90 ± 0.36 cm) was conducted with 0 mg/ L as the control and 600 mg/L of Iramusu extract (in triplicated tanks and 10 fish per tank) to determine the crudes' toxicity to carp over 48-hour exposure period. The results showed that there were no lethal effects of the Iramusu extract on carp fish during the tested period. After confirming the absence of lethal effects on the fish, the efficacy of Iramusu extract as a short-term (0-3 hrs) and extended (0-48 hrs) bath treatment on ornamental carp fish was tested using a controlled challenge experiment. Accordingly, the experiment was conducted with non-challenged control (uninfected), challenged control (untreated), Iramusu crude extract treatment (600 mg/L), and commercial treatment/ positive control (Neguvan, 0.25 mg/L) in triplicated tanks (10 fish per tank), by exposing fish to *Argulus* sp. at 2 parasites per fish. Both short-term and extended bath treatments resulted in a significant, time-dependent reduction in parasitic counts. In short-term exposure, the commercial treatment showed higher efficacy initially, but by 3 hrs, both the commercial product and Iramusu crude extract achieved similarly low parasite count per fish, significantly lower than challenged control ($P < 0.05$). During extended exposure, the commercial treatment demonstrated more consistent antiparasitic activity overall, although the plant extract also produced substantial parasite reduction. At later time points (32 hrs), both treatments were equally effective and significantly reduced parasitic loads compared to the challenged control, confirming the antiparasitic potential of the Iramusu crude extract. Although the commercial agent acted more quickly, the Iramusu extract can be used as herbal, antiparasitic agent for ornamental carp fish, as evidenced by this research.

Keywords: Bath treatment, toxicity, *Argulus* sp., *Cyprinus rubrofuscus* var. *koi*, *Hemidesmus indicus* extract

Formulation and Evaluation of a *Sargassum crassifolium* Based Feed Additive for Enhancing Growth Performance in Koi (*Cyprinus carpio)* Fingerlings

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Abstract

Ornamental fish species are now being fed based on information derived from food fish or marine animals, which likely prioritizes beauty traits such as color production over overall nutritional needs. The present study explored the effectiveness of *Sargassum crassifolium* as a feed supplement to promote the growth performance of Koi (*Cyprinus carpio*) fingerlings. Triplicate groups of 12 *C. carpio* fingerlings (initial mean body length 4.23 ± 0.06 cm and mean body weight 1.54 ± 0.17 g) were fed three experimental diets (commercial feed, commercial feed with 5% *S. crassifolium* dry powder, and commercial feed with 2% *S. crassifolium* ethanol extract). Growth parameters including length gain, weight gain, specific growth rate (SGR) and feed conversion ratio (FCR) were investigated over 56 days. Both *S. crassifolium* supplemented diets showed better growth performance compared to the control ($p < 0.05$), and the extract-supplemented diet had the best outcomes. On day 56, fish fed with 2% *S. crassifolium* extract had the highest mean length (6.410 ± 0.157 cm) and weight (4.716 ± 0.296 g) compared to those fed with 5% *S. crassifolium* powder (6.040 ± 0.105 cm; 4.126 ± 0.358 g) and the control (5.233 ± 0.080 cm; 3.033 ± 0.157 g). The specific growth rates SGR) were 0.054 ± 0.001%, 0.045 ± 0.007%, and 0.028 ± 0.001% for the extract, powder and control groups respectively. Feed conversion ratio (FCR) values were lowest in the *S. crassifolium* extract group (2.25), followed by the *S. crassifolium* powder group (2.71), while the control group showed the highest FCR (4.34), indicating improved feed utilization in *S. crassifolium* treated fish. The results reveal that *S. crassifolium* contains bioactive compounds that can enhance the growth of Koi fingerlings, with the extract form showing greater advantages. These results demonstrate that *S. crassifolium* based feed additives offer a natural alternative to chemical additives for improving growth performance in ornamental fish aquaculture.

Keywords: *Sargassum crassifolium*, feed additive, *Cyprinus carpio*, growth performance, bioactive compounds

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Patterns of Antibiotic Usage and Associated *Vibrio* Resistance of Shrimp Hatcheries in Puttalam District, Sri Lanka

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Abstract

Shrimp hatcheries in Puttalam, Sri Lanka are essential for the production of quality seed for aquaculture operations. However, they suffer considerable production and economic losses caused by *Vibrio*-related bacterial diseases leading to high mortality. To manage these diseases, hatcheries often depend on commercial antibiotics, but their unregulated use poses serious risks including antibiotic resistance and environmental contamination. To study the patterns of antibiotic usage and the resistance towards the *Vibrio* species in shrimp hatcheries, the present study was conducted as combined with a field survey and a laboratory experiment. The survey was conducted among 23 randomly selected hatcheries in the Puttalam district using structured questionnaire to document antibiotic usage patterns, awareness of antibiotic resistance and existing health management practices. The findings indicated the widespread and frequent use of antibiotics without adherence to standardized guidelines. Limited awareness of antimicrobial resistance and potential environmental contamination were identified as key factors contributing to disease prevalence and resistance development. According to the survey results, the primary barrier to reducing antibiotic use was identified as the pressure to maintain high post larval survival (100%), followed by limited regulatory enforcement (38.10%), disease outbreaks (19.05), lack of effective alternatives (19.05) and high cost of alternatives (9.52%). In parallel, laboratory experiment was carried out to evaluate the antibiotic susceptibility of *Vibrio* sp. isolated from shrimp samples. The results showed that all tested *Vibrio* samples were resistant to Erythromycin (15 µg/10 µL), while all tested samples were sensitive to Tetracycline (30 µg/10 µL) and prohibited Chloramphenicol (30 µg/10 µL), indicating limited effectiveness of Erythromycin in controlling *Vibrio* infections in the study area. Overall, the high prevalence of vibriosis in shrimp hatcheries of the Puttalam district has led to extensive reliance on commercial antibiotics. The detection of erythromycin-resistant *Vibrio* strains indicates an emerging antimicrobial resistance issue, highlighting the necessity for standardized treatment guidelines, increased awareness, and alternative disease prevention strategies to ensure sustainable shrimp hatchery operations.

Keywords: Antibiotic resistance, Puttalam district, shrimp hatcheries, *Vibrio* species

Acknowledgements

We are thankful to shrimp hatchery owners and workers in Puttalam district who willingly participated in the survey and shared their valuable knowledge and experience.

Determination of Suitable Sites for Orange Spotted Grouper (*Epinephelus coioides*) Culture in the Southern Coastal Zone of Sri Lanka, Based on Remote Sensing Satellite Data

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Abstract

The orange-spotted grouper, *Epinephelus coioides*, is a commercially valuable species with significant demand in seafood markets. It is cultivated globally in open sea-cages and pond-based systems along coastal regions. This species typically thrives in shallow water of oceans and estuaries. Under standard aquaculture conditions, *E. coioides* generally takes eight to twelve months to reach harvestable size. Additionally, this fish is considered sensitive to various biological, chemical, and physical factors. Thus, this study focused on identifying suitable areas for cage culture of *E. coioides* in Sri Lanka's southern coastal zone using remote-sensing satellite data and key environmental parameters, including bathymetry, sea surface temperature (SST), salinity, dissolved oxygen (DO), pH, wave height, wave velocity, and chlorophyll concentration. A range of two-year data from the Copernicus Marine Environment Monitoring Service (CMEMS) was used for this purpose from 1st of May 2022 to 30th of April 2024. Each parameter was analyzed according to the first inter-monsoon, southwest monsoon, second inter-monsoon, and northeast monsoon periods in Sri Lanka. The selected time period covered eight monsoons. Selected eight-parameter data were converted into eight thematic raster layer sets. Each thematic layer set was processed and reclassified into "highly suitable", "moderately suitable", "not suitable", and integrated by weighted overlay analysis. For each parameter, tolerance ranges for ordinary fish growth were identified, and results outside these limits were classified as "not suitable". Data within the suitable range were further classified into two categories, "highly suitable" and "moderately suitable". Generated suitability maps indicated areas that are suitable for mariculture of *E. coioides* based on monsoon patterns. Selected time period consisting of the ongoing El Niño event and Indian Ocean Dipole positive phase. Based on all sets of suitability maps, Beruwala, Bentota, Balapitiya, Hikkaduwa, Galle, and Habaraduwa areas were identified as more suitable for year-round mariculture. The study concludes that there is a high potential to farm *E. coioides* from Beruwala to Hikkaduwa area spanning a 46.4 km^2 area with a corresponding coastline length of 26.24 km, without weather-prohibitive conditions, and with key parameters remaining within the optimum range in the southern coastal zone of Sri Lanka. This study guides the selection of optimal locations for year-round, uninterrupted *E. coioides* sea cage culture in Sri Lanka's southern coastal zone.

Keywords: *E. coioides*, GIS, monsoon, cage-culture, groupers

Effects of Nitrogen-Depleted *Chlorella vulgaris* on Population Dynamics of a Freshwater Copepod, *Thermocyclops* sp.

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Abstract

This study investigated the effects of nitrate availability in *Chlorella vulgaris* on the growth, population dynamics, and reproductive performance of *Thermocyclops* sp., a key freshwater copepod in aquatic food webs. Microalgae were cultured in Bold's Basal Medium under three nitrogen regimes: nitrogen-rich (10 mL/L $NaNO_3$), half-nitrogen (5 mL/L $NaNO_3$), and nitrogen-deficient (0 mL/L $NaNO_3$). Copepod population size, body length, and width were monitored daily, while environmental parameters were kept stable. Statistical analysis indicated that dietary nitrogen did not significantly influence somatic growth ($p > 0.05$). Final body length and width did not differ among treatments, as shown by the non-significant Kruskal-Wallis test results for length ($H = 0.566$, $p = 0.753$) and width ($H = 0.931$, $p = 0.628$) ($p > 0.05$). However, pronounced differences were observed at the population level. The nitrogen-starved treatment showed the highest population growth rate ($B = 0.215$, $R^2 = 0.666$), greatest final density (320 ± 195 individuals), and highest fecundity (78 ± 1 eggs per female). The half-nitrogen treatment produced intermediate results ($B = 0.168$, $R^2 = 0.515$; 166 ± 85 individuals; 62 ± 3 eggs per female), whereas the nitrogen-rich treatment yielded the lowest growth rate ($B = 0.140$, $R^2 = 0.500$), population density (93 ± 80 individuals), and fecundity (56 ± 3 eggs per female). Water quality remained stable across treatments during the experimental period. Although nitrogen availability did not affect individual body growth, nitrogen limitation in the algal diet appeared to enhance population growth and reproduction. This response may be linked to metabolic changes in nitrogen-starved *Chlorella vulgaris*, particularly increased triacylglycerol synthesis. Overall, the study demonstrates that manipulating algal nutrient conditions can significantly improve copepod production, highlighting its potential application in hatchery systems as a high-quality live feed.

Keywords: Algal feed, *Chlorella vulgaris*, copepod population dynamics, nitrogen starvation, *Thermocyclop*s sp.

Acknowledgements

We are grateful to the National Aquatic Resources Research and Development Agency (NARA), Sri Lanka, for their support through the provision of resources for this research.

Comparative Study of Extraction Methods of *Kappaphycus alvarezii* and Evaluation of their Antimicrobial Activity Against Common Fish Pathogenic Bacteria

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Abstract

Increasing antimicrobial resistance has created a need to explore new natural bioactive compounds as safe and sustainable alternatives to synthetic antibiotics. This study aimed to evaluate the antibacterial and antioxidant properties of *Kappaphycus alvarezii* seaweed extracts from maceration, Soxhlet, and sonication extraction methods, using 70% ethanol as the solvent. *K. alvarezii* was collected from a seaweed farm in Mannar in the Northern Province of Sri Lanka. The phytochemical screening and FTIR analysis showed the presence of alkaloids, flavonoids, terpenoids, saponins, glycosides, and phenolic compounds in crude extracts. The disc diffusion assay was performed against common fish pathogenic bacteria: *Aeromonas hydrophila, Vibrio parahaemolyticus, and Flavobacterium columnare*. The crude extracts were evaluated using a concentration series of 200 mg/mL, 350 mg/mL, 500 mg/mL, and 750 mg/mL, and each concentration was tested in triplicate. For the positive control, tetracycline was used, and distilled water was used as the negative control. Among those tested bacterial strains, *Vibrio parahaemolyticus* presented visible inhibition zones. The highest inhibition zones were observed at 500 mg/mL concentration of three extraction methods and among them the sonication extract showed a significant inhibition zone (11.93 ± 0.16 mm) higher than the other two methods. At 500 mg/mL, no significant difference ($p > 0.05$) was observed between the maceration (10.42 ± 0.13 mm) and Soxhlet (10.52 ± 0.15 mm) crude extracts. The phosphomolybdenum assay indicated strong reducing potential in all crude extracts, while Soxhlet and sonication crude extracts showed significantly higher total antioxidant capacity ($p < 0.05$) than maceration crude extract. The toxicity assay and the challenge test were conducted using *Artemia* nauplii for sonication crude extract with all experiments performed in quadruplicate. The toxicity assay showed a concentration and time-dependent toxic effect with LC_{50} values of 9.65 mg/mL for 48 hours and 21.49 mg/mL for 24 hours. The challenge test showed that *K. alvarezii* crude extract, from the sonication method, significantly decreased *Artemia* mortality against *V. parahaemolyticus* at 10^6 CFU/mL. The enhanced survival was associated with a reduction of the total microbial count of *V. parahaemolyticus*, indicating that the extract suppressed the bacterial proliferation through its antibacterial property. Overall, the findings showed that *K. alvarezii* crude extracts from the above three extraction methods, possess potential antibacterial and antioxidant properties. This evidence shows, the usage of *K. alvarezii* as a natural source of antimicrobial agent in sustainable aquaculture disease management. Further purification and dosage optimization will open a path for safer applications.

Keywords: *Vibrio parahaemolyticus*, antibacterial activity, disc diffusion method, extraction methods, cytotoxicity bioassay

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We thank the National Aquatic Resources Research and Development Agency (NARA) of Sri Lanka for providing bacterial culture samples that greatly facilitated our research.

Evaluation of Protective Effect of Neem (*Azadirachta indica*) Leaf Extract as a Phytobiotic Agent Against *Vibrio parahaemolyticus* Using *Gnotobiotic Artemia* model

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Abstract

Vibriosis is one of the major constraints to sustainable aquaculture development, causing severe economic losses due to high mortality rates in cultured aquatic organisms. Among the causative agents, *Vibrio parahaemolyticus* is recognized as a highly virulent pathogen affecting fish and shellfish production systems. The management of this disease primarily relies on antibiotics. However, their excessive and uncontrolled usage has led not only to the accumulation of antibiotic residues in aquatic environments but also to the emergence of antibiotic-resistant bacteria. Hence, the development of safe, eco-friendly and effective plant-based alternatives has become a priority for the long-term growth of the aquaculture sector. The present study evaluated the potential of Neem (*Azadirachta indica*) Leaf Extract (NLE) as a phytobiotic agent for sustainable aquaculture health management against *V. parahaemolyticus*. Neem leaves were extracted using 70% ethanol through ultrasonic extraction, yielding 7.05% crude extract. Phytochemical screening and Fourier Transform Infrared Spectroscopy (FTIR) analysis confirmed the presence of biologically active compounds, including alkaloids, flavonoids, diterpenes, phenols, and tannins, which are known to contribute to antimicrobial activity. Toxicity assessment using *Artemia salina* demonstrated low cytotoxicity of NLE, with high LC_{50} values of 2855.77 mg/L and 1432.29 mg/L after 24 hrs and 48 hrs of continuous exposure, respectively. Antibacterial activity assessed by the disc diffusion method demonstrated significant inhibition ($p < 0.05$) compared to the negative control, with inhibition zones increasing in a concentration-dependent manner. The highest mean inhibition zone (17.27 ± 2.73 mm) was observed at 200 mg/L. In the subsequent gnotobiotic challenge trial, which included a challenged control, a non-challenged control and three concentrations of NLE (50, 100 and 200 mg/L), *A. salina* nauplii were challenged with *V. parahaemolyticus* at a bacterial cell density of 10^6 cells mL^{-1}. This prophylactic application exhibited a clear dose-dependent protective effect, where the 200 mg/L treatment resulted in the highest survival of challenged *A. salina*. Plate count analysis further confirmed this effect by demonstrating a significant reduction in *V. parahaemolyticus* count. Overall, the findings highlight NLE as a promising natural antibacterial and prophylactic agent that can support sustainable aquaculture development by reducing dependency on synthetic antibiotics, enhancing disease management and minimizing environmental risks.

Keywords: *Azadirachta indica* leaf, *Vibrio parahaemolyticus*, antibacterial activity, phytobiotic, sustainable disease management

Acknowledgements

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Evaluation of Genus *Bdellovibrio* as a Potential Probiotic Against Pathogenic *Vibrio parahaemolyticus* Using *Artemia* as a model

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Abstract

Infectious diseases significantly limit aquaculture production, especially during intensive culture of shrimp post-larvae, where high mortality is often caused by gram-negative pathogens such as *Vibrio parahaemolyticus*. The use of probiotics as a preventive strategy against Vibrio infections has gained increasing attention. This study investigated the potential of members of the genus *Bdellovibrio* and like organisms (BALOs) as probiotics using a gnotobiotic *Artemia* model. BALOs were isolated from the Old Dutch Canal, Galle, and a freshwater pond in the University of Ruhuna, Sri Lanka. Isolation was carried out using *V. parahaemolyticus* as the prey organism through enrichment, filtration, and purification methods. Active BALOs were confirmed using double-layer agar and plaque assays, while predatory activity was assessed using bacterial lawn assays. BALOs were enumerated by serial dilution and overlay plating, and Vibrio counts were determined using TCBS agar. Clear, well-defined lytic plaques on double-layer agar plates confirmed effective predation. An in vivo challenge experiment was conducted using the gnotobiotic *Artemia* model with three groups: non-challenged control, challenged control, and BALOs-treated group (10^{-6} BALOs/mL), each with triplicates of 10 *Artemia* nauplii in petri dishes. The challenge test with *V. parahaemolyticus* (10^{-6} cells/mL) showed significant protective effects of BALOs against Vibrio infection. Survival percentages were significantly higher in the BALOs-treated group, reaching 80% and 77.5% at 24 and 48 hours, respectively, compared to approximately 40% survival in the challenged control. No significant difference was observed between the BALOs-treated group and the non-challenged control. Reduced Vibrio counts in treated water further confirmed the bactericidal activity of BALOs. In conclusion, BALOs effectively suppressed *V. parahaemolyticus* and improved host survival, highlighting their potential as eco-friendly biocontrol agents for sustainable disease management in aquaculture systems.

Keywords: *Bdellovibrio sp*., predation, in vivo, biocontrol, *Vibrio parahaemolyticus*

Antibacterial Potential of *Ludwigia adscendens* Against Aquatic Pathogens *Flavobacterium columnare* and *Vibrio parahaemolyticus*

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Abstract

Ludwigia adscendens, which belongs to the family Onagraceae, is an important aquatic herb widely distributed in the freshwater bodies across Sri Lanka and other tropical regions that consist highly specific phytochemical activity. To evaluate the antibacterial activity of *L. adscendens* aerial parts, extractions were done with two different extraction methods using 70% ethanol and hot water. Phytochemical screening of the ethanolic extract resulted in the isolation of the flavonoids, tannins, glycosides, alkaloids, phenols, and diterpenes, while the hot water extract isolated mainly saponins, diterpenes, phenols, and tannins in high amounts. FTIR analysis proved the presence of aromatic and stretching functional groups. The free radical scavenging potential of extracts obtained using 70% ethanolic Soxhlet extraction and hot water reflux extraction was compared. The 70% ethanolic extract showed a value of 1589.48 ± 7.54, while the hot water extract showed 1126.75 ± 4.39 (µmol Fe^{2+}/g dry weight). The flavonoid content of ethanolic and hot water extract was 52.78 ± 0.12 and 37.12 ± 0.45 (mg/QE/g), respectively. Significant antibacterial effect was shown by the ethanolic and hot water extracts against *Flavobacterium columnare* and *Vibrio parahaemolyticus* which highly affected to the aquatic organisms. The minimum inhibitory concentration of the ethanolic extract was 30 mg/mL, with a 12.66 ± 0.75 mm inhibition zone diameter against the *F. columnare*. An 11.23 ± 0.51 mm inhibition zone diameter was shown by the hot water extract against *F. columnare*. The ethanolic extract showed a minimum inhibitory concentration of 50 mg/mL against *V. parahaemolyticus*, with an inhibition zone diameter of 13.04 ± 0.51 mm. For the hot water extract, *V. parahemolyticus* showed the minimum inhibitory concentration that was 30 mg/mL with 12.15 ± 0.45 minimum inhibition zone diameter. The *L. adscendens* plant extract showed antibacterial activity compared with acriflavine, which is used in aquaculture farms. In a toxicity study using brine shrimp nauplii, the LC_{50} values of ethanolic and hot water extracts were found to be 27.67 mg/mL and 30.99 mg/mL, respectively. This study demonstrated that *L. adscendens* is a promising plant-based antibacterial agent that can be used against aquatic pathogenic bacteria.

Keywords: *Ludwigia adscendens*, acriflavine, phytochemical compounds, cytotoxicity, disc diffusion method

Evaluating the Efficiency of Nutmeg Essential Oil as an Anesthetic Agent for *Xiphophorus helleri*

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Abstract

The aquaculture and fisheries industries require effective and safe anesthetics to minimize handling-induced stress and injury during routine husbandry, transport, and research procedures. Due to regulatory concerns and prolonged withdrawal periods associated with synthetic agents such as Tricaine Methanesulfonate (MS-222), together with increasing attention to the environmental impact of synthetic chemicals, there is growing interest in naturally derived alternatives. This study evaluated the immersion anesthetic efficacy of ethanolic nutmeg essential oil (NEO), extracted from *Myristica fragrans*, in Swordtail fish, *Xiphophorus helleri*. Juveniles (2.68 ± 0.13 g, 4.76 ± 0.11 cm) were individually exposed to three NEO concentrations (3500, 4500, and 5500 µL/L) in 300 mL exposure chambers, and anesthetic response variables were evaluated separately in eight individual fish for each treatment. NEO was first dissolved in 96% ethanol and then dispersed in water to ensure solubility and homogeneity. The primary response variables were induction time to surgical anesthesia and recovery time to full equilibrium restoration. Acute physiological stress was assessed by peripheral blood glucose measured from the caudal vein. Concentration-dependent responses were analyzed using regression analysis, revealing a significant inverse relationship between NEO concentration and induction time ($p < 0.05$), while recovery times remained rapid across effective concentrations. The 3500 µL/L treatment failed to meet the accepted induction threshold of 180 s. In contrast, 5500 µL/L produced the fastest induction (74.38 ± 30.19 s), followed by 4500 µL/L (91.00 ± 18.39 s), with both treatments achieving full recovery within 78 s and 100% survival. Blood glucose levels at both concentrations were statistically comparable to fish anesthetized with clove oil (300 µL/L), included as a benchmark natural anesthetic widely used in aquaculture. Although both concentrations were effective, 4500 µL/L is recommended as the optimal anesthetic dose based on the principle of lowest effective concentration. These findings demonstrate that NEO is a safe, effective, and eco-friendly natural anesthetic for aquaculture applications.

Keywords: *Myristica fragrans, Xiphophorus helleri,* anesthesia, natural anesthetics, induction and recovery

Technical Session III

Freshwater Systems and Environmental Issues

Evaluating Root Reinforcement Factors of Riparian Plants *Securinega leucopyrus* (Katupila) and *Urena lobata* (Apala)

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Abstract

The presence of riparian vegetation increases soil reinforcement and reduces riverbank erosion. Riverbank stability is largely determined by root architecture, which governs the mechanical and hydraulic properties of the soil-root interrelationship. This study focused on the architectural characteristics of the root systems of two selected shrub species: *Securinega leucopyrus* (Katupila) and *Urena lobata* (Apala) and ultimately ranked them by their soil reinforcement capacity by establishing a soil-root relationship. The study area was a natural riverbank with well developed selected shrub species (6°11'12" N, 80°48'39" E). Laboratory tests were conducted to measure root tensile strength and estimate the root density distribution with depth (Root Area Ratio). The power-law relationship between tensile strength and root diameter was estimated. Additional soil shear resistance provided by roots was theoretically calculated using the Root Area Ratio (RAR) and root tensile strength values. Results indicated significant variation in root reinforcement capabilities between the two species ($P < 0.05$), suggesting that soil type and moisture content strongly influence root effectiveness. The study's findings emphasize soil conservation strategies by highlighting the role of native vegetation in reinforcing soil stability. Both *S. leucopyrus* and *U. lobata* possess significant potential for soil stabilization. *S. leucopyrus* roots tend to provide better reinforcement in coarse, drier soils (0.09 ± 0.1 Pa), and their roots are mainly horizontally distributed (mean horizontal distribution = 30 ± 0.1 cm), whereas *U. lobata* shows higher reinforcement potential (0.095 ± 0.1 Pa) in fine, moisture-rich soils with a more vertically distributed root system (mean vertical distribution = 25 ± 0.1 cm). For both species, root tensile strength showed a consistent inverse relationship with root diameter at all sampling locations. Significant soil reinforcement is indicated by higher root tensile strength (~20 – 120 Nmm^{-2}), increased root area ratio (up to 0.0186), and improved apparent cohesion (0.3658) which significantly reduces erosion susceptibility in sensitive areas. Overall, root tensile strength, distribution, and cohesion values highlight the critical role that these plants play in preventing soil erosion.

Keywords: Root reinforcement, riparian vegetation, *Securinega leucopyrus,* soil stabilization, *Urena lobata*

Assessment of Acute Toxicity and Environmental Risk of *Garcinia gummi-gutta* Paste Processing Wastewater, using a Freshwater Fish Model (*Poecilia reticulata*)

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Abstract

Industrial processing of *Garcinia gummi-gutta* produces wastewater rich in hydroxycitric acid, phenolics, and total suspended solids, posing undocumented risks to freshwater ecosystems. The present study was designed to assess the acute toxicity and environmental risk of wastewater produced by *Garcinia gummi-gutta* products using a freshwater fish model, *Poecilia reticulata*. The experiment was conducted as a 72-hour static bioassay at six concentrations, with three replicates each (0.125-1.5 g/L; 10 fish per replicate) under controlled conditions (28.5 ± 0.6°C, pH 7.0). Seven-day acclimatised, same-size (1.80 ± 0.20 cm, 0.07 ± 0.02 g) male *Poecilia* individuals were used in the aquarium tanks filled with 4 L of dechlorinated tap water. Different levels of wastewater concentration were used to determine toxicological parameters, including lethal, sublethal, low adverse effect, and no adverse effect responses in the fish. Furthermore, considering the exposure level and reference dose, the Hazard Quotient (HQ) was calculated. Probit analysis (R^2 = 0.95) determined LC_{50} to the model fish as 0.346 g/L (lethal to 50% of fish in an experiment tank), EC_{50} as 0.371 g/L (effective concentration for 50%), and EC_{10} was 0.207 g/L. The no observed adverse effect level (NOAEL) was 0.125 g/L and the lowest observed-adverse-effect level (LOAEL) was 0.250 g/L. The risk ratio (RR) between the EC_{50} (0.371 g/L) and EC_{10} was 1.79, indicating acute risk, as the RR was greater than 1. Mortality increased dose-dependently, correlating with the pH decline (6.60 to 4.70) and conductivity rise simultaneously (79 to 98 µS/cm). Sublethal effects, such as erratic or backward swimming, were observed even at the NOAEL. It was further confirmed that the HQ was 5.65×10^{-2} mg/g/day, which was higher than the WHO accepted risk level of 1×10^{-6} for exposure to any toxicant. Further research is recommended to quantify the chemical composition of wastewater and its specific toxicity levels.

Keywords: Acute toxicity, *Garcinia gummi-gutta,* hazard quotient, probit analysis, risk ratio

Natural Coagulant Derived from Sugarcane Bagasse for Efficient Textile Dye Wastewater Treatment

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Abstract

Treatment of dye-containing wastewater has a considerable impact on industrial and environmental sustainability. Replacing the usage of chemical coagulants with natural coagulants has drawn attention because of its efficiency and environmentally friendly behavior. This study was conducted with an extracted coagulant from sugarcane bagasse to treat textile dye wastewater to investigate its colour removal efficiency. Sugarcane bagasse with pre-determined moisture and yield was subjected to a delignification process to obtain an extract of sugarcane bagasse, and followed by phytochemical screening. Textile wastewater containing the same initial colour intensity treated in a series of experimental setups with varying conditions (pH, dosage, and contact time) of the coagulant. Colour intensity of dye wastewater was measured by the light absorption at 534nm using a UV-visible spectrophotometer and colour removal efficiency was calculated as the percentage reduction in colour intensity relative to the original colour intensity. These values were then used to optimize the coagulant treatment conditions (pH, dosage, and contact time). Additionally, coagulants with optimized conditions were treated with textile wastewater and measurements were taken for pH, temperature, turbidity, electrical conductivity, total dissolved solids, salinity, dissolved oxygen level and chemical oxygen demand with treated textile wastewater. The same procedure was followed by mixing natural coagulant with alum coagulant in a 1:1 ratio for efficiency comparison. Aluminium alum was used as the positive control. Carbohydrates, flavonoids, phenolic compounds, tannin, glycoside, and saponin were found as secondary metabolites in coagulant extract. The optimum conditions were determined to be pH 2, a coagulant dosage of 0.67 mL/L, and a contact time of 18 hrs. The treatment showed high removal efficiency for total dissolved solids (86.92%) and turbidity (71.16%), color (63.99%), electrical conductivity (59.19%) and chemical oxygen demands (41.61%) whereas other parameters showed minimal changes. The optimum colour removal efficiency with different coagulant systems of sugarcane bagasse extract, aluminium-based alum sugarcane bagasse extract mixture and aluminium-based alum were 63.99%, 93.00% and 90.00%, respectively. Maximum colour removal was observed in the system contained mixture of sugarcane bagasse extract and aluminium- alum mixture indicating the usage of natural coagulant to reduce the synthetic aluminium alum in the future. These findings indicate that sugarcane bagasse extract has strong potential as an environmentally friendly coagulant and could partially replace aluminium-based alum in textile dye wastewater treatment, thereby reducing the use of synthetic chemicals while maintaining high treatment efficiency.

Keywords: Coagulation, color removal, dye wastewater, sugarcane bagasse, natural coagulant

Assessing the Role of Wetland Ecosystem Services and their Support for Sustainable Livelihood of Local Community: A Case Study in Kirala Kele Wetland, Matara

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Abstract

Wetlands are vital ecosystems offering valuable goods and services to the local community. However, there is a gap in understanding the economic contributions of the Kirala Kele Wetland (KKW), located in Matara District, Sri Lanka, to the nearby community. This understanding is important because demonstrating this economic value is necessary to drive policies that balance ecological conservation with sustainable livelihoods. Accordingly, this study assesses the direct economic role of KKW and analyzes the socioeconomic determinants affecting community dependence on wetland resources for their sustainable livelihoods. Additionally, this study aims to assess the perception of the local community on KKW's intangible ecosystem services and environmental concerns. A mixed-method research design was employed, consisting of survey of 184 households and 6 Key Informant Interviews (KII) in three Grama Niladhari divisions adjacent to KKW. This study used the market-price valuation method to estimate annual wetland-derived household economic value (WDHEV) and used statistical analyses (Mann–Whitney U tests, Spearman correlation, and multiple linear regression) to identify socioeconomic determinants of wetland resource use. Additionally, qualitative thematic analysis assessed community perceptions towards KKW. The key results show that 74.5% of households surveyed gain direct economic benefits from KKW. Among economically dependent households, the mean annual WDHEV was LKR 413,070, consisting of an average of 48.9% of their total annual household income. Further statistical analysis showed that KKW serves as a vital "safety net" for low-income households sustaining their livelihoods. The Regression analysis ($R^2 \approx 0.25$) showed that distance to the wetland and the presence of agricultural land significantly affected the WDHEV, whereas variables age, household size, education level, and involvement in wetland conservation activities had no significant effect. The qualitative thematic analysis identified the cultural, regulating, and supporting ecosystem services of KKW. At the same time, pollution, invasive species, illegal waste disposal, and governance failures were identified as leading to significant environmental degradation on KKW, which threatens the sustainability of local livelihoods. This study contributes an analysis about both the tangible and intangible benefits to local communities which urban wetlands provide, thus contributes an understanding of the importance in conserving them. The policy and practice implications are that evidence-based policies promoting community-based co-management are crucial to balance ecological preservation with community economic well-being. Further, management strategies should prioritize enforcing conservation regulations, control pollution, and promoting sustainable alternative livelihoods to reduce pressure on wetland resources.

Keywords: Wetland ecosystem services, sustainable livelihoods, Kirala Kele wetland, economic valuation, wetland dependency

Formulation and Evaluation of a Skin Moisturizer Containing Chitosan Extracted from Tilapia Scales

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Abstract

Chitosan is a linear polymer that exhibits moisturizing and antimicrobial properties. The present study aims to develop a moisturizer using chitosan from Tilapia scales to enhance its moisturizing properties and to determine the optimum solvent from two different solvents (lactic acid or acetic acid) for chitosan solubility. Extracted chitosan was analyzed for yield, moisture, ash, degree of deacetylation, Fourier transform infrared (FTIR) spectroscopy, and other physicochemical parameters. 3% lactic acid was identified as the optimal solvent and acid concentration for chitosan dissolution. The chitosan yield was 10.60%. The moisture, ash, degree of deacetylation, fat binding capacity, and water binding capacity were found as 12.71 ± 1.05%, 2.66 ± 0.70%, 94 ± 3.41%, 434.97 ± 4.07% and 419.47 ± 10.14%, respectively. Chitosan FTIR analysis showed successful deacetylation at 878 cm^{-1} and numerous bands of functional groups present. Three moisturizers, F1 (moisturizer without chitosan), F2 (moisturizer with chitosan dissolved in acetic acid), and F3 (moisturizer with chitosan dissolved in lactic acid), were tested for physicochemical properties. F3 showed a significantly higher pH (5.23 ± 0.02) compared to F1 and F2. No significant differences were observed among the three formulations in moisture content (25.72 ± 0.02% – 27.15 ± 0.03%) or spreadability (3.64 ± 0.14 – 3.75 ± 0.13 cm). F1 was significantly different from F2 and F3 in viscosity (56,650 ± 697.86 – 69,045 ± 2,220.86 cP), Sun Protection Factor (SPF) (0.0010 ± 0.001 – 0.0047 ± 0.001), and adhesion (1.28 ± 0.32 – 4.09 ± 0.61). All three moisturizers were homogeneous, oil-in-water type, stable with no phase separation, and showed spherical droplets with highly visible individual droplets. Sensory evaluation indicated that consumers slightly liked all attributes across all moisturizers. Compared to the reference sample (RF), F3 showed better physicochemical properties.

Keywords: Chitosan, physicochemical properties, skin moisturizer, tilapia scales

Green Coagulant from *Dillenia retusa* Combined with Magnetite as a Hybrid Material for Colourant Wastewater Treatment

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Abstract

Present study aimed to fabricate a *Dillenia retusa* (DR) seed coagulant combined with Magnetic Nanoparticles (MNPs) magnetite as a novel hybrid coagulant for the removal of Reactive Red 195 (RR195) azo dye in textile wastewater. The effects of pH, coagulant to alum ratio (C: A), coagulant type, settling behaviour, sludge production and initial dye concentration on dye removal efficiency were investigated. MNPs were synthesized via a modified sol-gel method and hybridized using magnetic stirring. The structure of the hybrid material was analyzed by Fourier transform infrared spectroscopy (FTIR), which confirmed the presence of hydroxyl, carboxyl and amine groups in DR seed powder and Fe-O bond in magnetite, verifying successful formation of DR-MNPs. According to the results, the optimum dye removal was achieved at pH 4-5 with DR-MNPs Hybrid coagulant, with a maximum dye removal efficiency of 92% during the shortest settling time of 5.98 min. The DR Hybrid resulted 90% of dye removal, whereas it was only 78% with alum. Statistical analysis confirmed that the dye removal efficiency is significantly different ($p < 0.05$) and it varies with the coagulant type and dosage ratio. The C:A ratio at 0.25:1 worked more efficiently than 0.5:1, 1:1, 1:0.25, and 1:0.5 ratios, in the removal of RR195 in 30 mg/L solution. However, the coagulant with a 0.5:1 ratio was more effective in 20 mg/L artificial wastewater. The specific sludge production index was revealed as specific sludge production per coagulant dose (SSPc) and per treated volume (SSPv). The sludge production resulted in the DR-MNPs Hybrid producing less sludge. The light microscopic analysis confirmed denser, distinguishable and compact floc formation of DR-MNPs Hybrid, whereas for DR Hybrid, the images were more visible with larger flocs. However, microscopic images of alum appeared only as dispersed fine light pink flocs. This study further identified that the DR-MNPs coagulant is capable of floc recovery and rapid separation and confirms the suitability of the fabricated natural coagulant, DR-MNPs hybrid, as an alternative to conventional alum with promising advancements for the colourant wastewater treatment.

Keywords: *Dillenia retusa,* hybrid coagulant, Reactive Red 195, dye removal, wastewater treatment

Sunscreen Cream Ingredient Benzophenone-3 in Freshwater Systems; Toxicity Evaluation on *Poecilia reticulata* and Implications for Drinking Water Management

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Abstract

Benzophenone-3 (BP-3) is widely used as a UV filter in personal care products (PCPs) to prevent sunburn, skin damage and as a stabilizer. However, increasing concerns regarding its potential endocrine disruption, international regulatory agencies are currently re-evaluating their safety. This study investigated toxic effects of dissolved BP-3 in aquatic environments using the fish model, *Poecilia reticulata* (Guppy), under laboratory conditions. The tested commercially available sunscreen is composed of a water-soluble mixture of ingredients containing BP-3 with a labelled percentage of 6% (w/w %). Approximately 360 adult male *P. reticulata* (weight = 0.28 ± 0.09 g; length = 2.20 ± 0.19 cm) were collected from a natural habitat partially impacted by domestic wastewater effluents (pH = 7.6, 25.2± 0.1°C) and acclimatized in glass aquaria (45×25×15 cm^3) filled with de-chlorinated water (pH = 7.1, 25 ± 0.1 °C) for one week (% mortality 1.4). A concentration series of BP-3 (99.9% w/w) (molecular weight: 228.26 g/mol) (0.0 [control], 0.1, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, and 9.0 mg/L) was prepared in triplicate using ethanol (added 2 mL, for each tank including control) as a solvent in separate tanks containing 6 L of static water with 10 fish. Mortality, abnormal behavior (back swimming), water pH (7.0 ± 0.1), and temperature (25.8 ± 0.1°C) were monitored over 24 - 96 hours. BP-3 levels in dead fish and sunscreen were measured using HPLC analysis. HPLC results revealed that the sunscreen contained 7.79 % (w/w %) of BP-3, exceeding the labelled percentage. The BP-3 concentrations in the fish body in each exposed group were not significant ($p = 0.1 > 0.05$), with each group at the elevated exposure concentrations. Notably, fish from the control setup showed pre-existing BP-3 (PE_BP-3) (28.391 ± 0.001 mg/kg dry weight), indicating the exposure of collected fish in their natural habitat. Probit analysis determined LC_{50} values for 24, 48, 72, and 96 hours as 5.51, 3.70, 1.68, and 1.19 mg/L, respectively. Similarly, EC_{50} values were 4.71, 3.19, 2.32, and 1.42 mg/L, while no observed effect concentrations (NOEC) were 1.04, 0.17, 0.07, and 0.02 mg/L. The calculated risk ratios (RR) for 24-96 hours were 1.81, 4.94, 8.37, and 7.92, all of which exceeded the risk level of 1. Hazard Index (HI) values for 48-96 hours of exposure were 1.60, 2.09, and 2.66. These findings demonstrate BP-3 possess as a potential threat to aquatic organisms in freshwater at relatively low concentrations and, the level of PE_BP-3 reached environmental NOAEL at the 96 hours experimental period. This study highlights the need of establishing BP-3 values of Sri Lankan drinking and farming freshwater resources, and the development of safer UV filter alternatives in sunscreen formulations.

Keywords: Benzophenone-3, *Poecilia reticulata*, toxicity, risk assessment, freshwater resources

Post-Restoration Freshwater Biodiversity and Water Quality Assessment of the Thumbikulama Tank Cascade System in Sri Lanka's Dry Zone

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Abstract

Sri Lanka's dry-zone tank cascade systems represent complex socio-ecological landscapes that sustain freshwater biodiversity, regulate hydrology, and support rural livelihoods. Thumbikulama Tank, an upstream "Olagam Wewa" within the Malwathu Oya Basin, remained non-functional for nearly three decades following dam failure in 1993 and was ecologically restored in 2023 under the Healthy Landscapes Project. This study evaluates post-restoration freshwater biodiversity and physicochemical water quality within the Thumbikulama cascade system. Field surveys were conducted from March to May 2024 across five interconnected tanks representing upstream, downstream, and lateral components of the cascade. Biodiversity was assessed using visual encounter surveys and photographic documentation, while water quality parameters (pH, electrical conductivity (EC), salinity and total dissolved solids (TDS) were measured in situ using calibrated portable instruments. A total of 64 plant species were recorded, including two endemic species (*Rhinacanthus polonnaruwensis* and *Hydnocarpus venenatus*) and two near-threatened taxa, with high diversity indices, indicating a well-structured plant community. Faunal assemblages included 28 bird species, three mammal species (*Elephas maximus maximus*, *Macaca sinica*, and *Semnopithecus priam*), 10 dragonfly species including one near-threatened *(Dancing Dropwing)*, eight butterfly species, two amphibians, and three fish species, including the endemic and near-threatened *Labeo lankae*. Water quality analysis revealed spatial variability across the cascade. Upstream and restored tanks (e.g. Thumbikulama: pH 7.1–8.17; EC 904–940 µS/cm) exhibited relatively stable and slightly alkaline conditions. In contrast, downstream tanks showed elevated variability, with high EC values in Pattiya Wewa (1083 - 1692 µS/cm) indicating increased ionic loading, likely associated with agricultural runoff. Kayan Wewa recorded unusually high pH levels (9.68 - 9.82) despite lower EC values, suggesting biologically driven alkalinity, potentially linked to algal activity and early-stage eutrophication. The presence of diverse odonate assemblages and dragonfly exuviae indicates suitable aquatic habitat conditions and relatively stable ecological processes. However, due to the absence of pre-restoration baseline data, observed patterns are interpreted as indicative rather than conclusive evidence of ecological improvement. The study highlights the importance of integrated catchment management, invasive species control, and long-term ecological monitoring to ensure the sustainability of restored dry-zone tank cascade ecosystems.

Keywords: Tank cascade system, freshwater biodiversity, ecological restoration, water quality, Malwathu Oya basin

Sub-Lethal and Acute Toxic Effects of Batik Industry Wastewater on *Hydrilla verticillata*

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Abstract

Submerged freshwater macrophytes are primarily affected by textile dye effluent due to reduced light penetration in water. This study evaluated the sub-lethal and acute toxic effects of batik industry wastewater on *Hydrilla verticillata* under controlled laboratory conditions. An experiment was conducted for one week using graded concentrations of batik waste (0–225 mL added to 4 L of dechlorinated tap water, equivalent to 0 - 54.85 g/L), with one control and nine treatment groups: T1 (25 mL), T2 (50 mL), T3 (75 mL), T4 (100 mL), T5 (125 mL), T6 (150 mL), T7 (175 mL), T8 (200 mL), and T9 (225 mL). Similar-sized apical tips of *Hydrilla*, acclimatized for 37 days, were planted in experimental glass tanks. Physicochemical parameters, including temperature, pH, dissolved oxygen (DO), conductivity, and total dissolved solids (TDS), were measured daily. Morpho-anatomical responses were assessed through survival percentage, new frond formation, and microscopic cellular observations. Toxicity thresholds were calculated using Probit regression analysis to estimate lethal concentration (LC_{50}), while ecological risk was determined using effective concentrations (EC_{50}, EC_{10}), predicted environmental concentration (PEC), predicted no-effect concentration (PNEC), and relative risk (RR) indices. Results showed a clear concentration-dependent deterioration in water quality. Mortality remained low at concentrations up to 25.12 g/L and increased progressively, reaching 60% at 54.85 g/L. Treated groups showed no new frond formation, indicating significant growth suppression without immediate death. Microscopic examination revealed chloroplast clumping, pigment degradation, plasmolysis, cytoplasmic disintegration, and cell wall damage at elevated concentrations. Probit analysis estimated an extrapolated LC_{50} value of 141.25 g/L, suggesting moderate acute tolerance, while EC_{50} was approximately 43 g/L, indicating significant sub-lethal impairment at lower concentrations. The calculated relative risk value of 2.30 categorized the effluent as posing a high environmental risk. These findings suggest that *Hydrilla verticillata* exhibits tolerance to acute mortality, but it is highly sensitive to sub-lethal stress, resulting in impaired growth and cellular damage. It is recommended that waste treatment in batik industries be implemented to maintain ecological integrity and ensure sustainable industry practices.

Keywords: Batik waste, cellular damage, *Hydrilla verticillata*, probit analysis

A Novel 3D Printed MBBR Approach for Wastewater Treatment: A Comparative Study

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Abstract

The Moving Bed Biofilm Reactors (MBBR) are an advanced system which combines the advantages of both suspended and attached growth processes. This study evaluates a novel MBBR design using custom 3D printed biodegradable PLA+ carrier media, comparing its performance against conventional Kaldnes K3 carriers. The PLA+ carriers were designed in a propeller shape to rotate with the bottom aeration airflow, facilitating uniform biofilm aeration, and were fabricated using FDM 3D printing to match the specific surface area of K3 media (~560 m^2/m^3). Five bench-scale batch reactors (R1–R5) were run at the same time. R1 (no carriers, control), R2 (90 suspended K3 carriers), R3 (90 static PLA+ carriers settled on the bottom), R4 (90 K3 carriers mounted on horizontal rods to facilitate rotating), and R5 (90 PLA+ carriers mounted on horizontal rods, which also facilitate rotating). All reactors were fed hotel wastewater collected from a hotel in Tangalle. Wastewater treatment was done in a batch operation. Key parameters such as BOD, turbidity, TSS, and VSS were monitored daily, and removal efficiencies were also calculated. Statistical analysis (One-way ANOVA and Repeated measures ANOVA) assessed differences among reactors. The results show that reactors with 3D printed PLA+ carriers, especially when mounted on rotating rods, achieved significantly high efficiency in treatment, and after seven days, with significantly greater COD, BOD, Turbidity, TSS, and VSS reductions were observed than in R1, R2 and R4 ($p < 0.05$). Reactor R3 also showed higher removals than R1 and R2 with respect to the above water quality parameters. These findings prove that the rod-mounted rotating 3D printed carriers exhibited greater biofilm formation and higher activity due to reduced shear stress between carriers, higher surface roughness and improved aeration, without using motors or mechanical power. R2 and R1 showed slower pollutant removal, suggesting that conventional K3 carriers were limited by less visible biofilm development, possibly due to non-uniform aeration and biofilm detachment caused by the smooth carrier surface and shear stress between carriers. This comparative study proved the importance of 3D printed PLA+ carriers for MBBRs. The design flexibility and high roughness of 3D printed surfaces due to layer lines cause accelerated microbial growth. Also, these PLA+ carriers offer sustainability benefits because they are not prone to microplastic pollution. Overall, the comparative data suggest that integrating custom 3D printed biocarriers in MBBRs can significantly enhance pollutant removal. These findings provide a foundation for further optimization of carrier geometry and biofilm engineering in practical wastewater treatment.

Keywords: Moving bed biofilm reactors, biofilm, wastewater treatment, 3D printing, PLA+ carriers

Valorization of Water Hyacinth (*Eichhornia crassipes*) and *Gracilaria corticata* for Developing Sustainable Antibacterial Fish Packaging

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Abstract

Industrial fish preservation methods are often costly, energy-intensive and environmentally harmful due to non-biodegradable waste and pollution. Sustainable methods improve fish quality and safety, promote eco-friendly practices and support sustainable seafood production consistent with environmental and economic goals. This study evaluated the antibacterial activity, as well as the moisture and blood absorption capacity, of a sheet developed using water hyacinth (*Eichhornia crassipes*) as the cellulose source and a crude extract of *Gracilaria corticata* as the antibacterial agent. An existing soda pulping method was used to produce sheets from water hyacinth, an invasive aquatic weed. The crude extract of *G. corticata* was obtained using a combination of sonication and maceration, followed by solvent removal with a rotary evaporator. Phytochemical tests and FTIR was conducted to identify chemical substances present in the crude extract of seaweed. To prepare different treatments, the crude extract of *G. corticata* was sprayed onto the cellulose sheet at three different concentrations (T1 = no crude extract, T2 = 300 mg/mL, T3 = 500 mg/mL). Then, these treated sheets were compared with a commercial absorbent sheet for the water absorption rate, blood absorption rate, thickness and grammage. Microbial growth, assessed using the total plate count method, and pH were evaluated as indicators of storage stability in yellowfin tuna fillets wrapped with three treatment papers (T1, T2, and T3), commercial absorbent paper, and in unwrapped samples stored at 0 °C, weekly over a one-month period. The results of the phytochemical tests and FTIR showed the presence of glycosides, alkaloid, flavonoid, diterpenes and proteins in the *G. corticata* extract. When compare the properties of the sheets with a commercial absorbent sheet T1 showed the significantly highest water absorption rate (0.026 ± 0.001 g cm^{-2} min^{-1}) and the lowest grammage value (1574.94 ± 58.40 g m^{-2}). T1, T2, and T3 exhibited the same blood absorption rate (0.02 ± 0.00 g cm^{-2} min^{-1}), which was significantly lower than that of the commercial sheet. T1 and T2 showed the highest thickness values of 0.60 ± 0.03 mm and 0.53 ± 0.05 mm, respectively. The total plate count method revealed fewer colonies as the amount of seaweed increased, demonstrating the effectiveness of *G. corticata* as a natural antimicrobial agent for use in fish packaging and with increasing seaweed content, a slower rise in pH was observed, indicating a preservative effect**.** Overall, the developed water hyacinth-based absorbent sheet incorporated with *G. corticata* extract shows strong potential as an environmentally friendly substitute for conventional commercial fish packaging materials.

Keywords: Sonication method, packaging material, moisture and blood absorption sheet, antibacterial property, cellulose extraction

Applying Generalized Additive Models to Predict Benthic Macroinvertebrate Diversity in Relation to Water Quality: A Case Study, Mawarala Stream, Sri Lanka

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Abstract

Freshwater ecosystems harbor exceptional biodiversity, yet they remain highly sensitive to changes in physical and chemical conditions, making continuous monitoring essential for evaluating their ecological health. Benthic macroinvertebrates have been identified as suitable bio-indicators because they exhibit varying degrees of sensitivity to different environmental stressors, and they are specific to habitats. In this study we assessed the relationship between water quality physicochemical parameters and the diversity of benthic macroinvertebrates found in the Mawarala Stream located in Southern Sri Lanka. Water quality parameters that we monitored included temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), electrical conductivity, total dissolved solids (TDS), total suspended solids (TSS) and nitrates selecting four sites of the stream. A total of sixteen macroinvertebrate families belonging to nine orders were recorded. Hydropsychidae, Dermestidae, and Simuliidae were the most abundant families, whereas Aeshnidae, Paludomidae, and Corydalidae occurred in low abundances. Correlation analysis revealed a strong negative correlation between TSS and diversity ($p < 0.05$); pH, DO and temperature had weak, non-significant correlations. A multiple regression model ($R^2 = 0.27$) was insufficient to accurately explain the complex ecological patterns; therefore, a generalized additive model (GAM) was developed using TSS, DO, and pH as predictor variables, while temperature was removed due to statistical non-significance. The final GAM provided an improved fit to the observed data (adjusted $R^2 = 0.627$; deviance explained = 69.6%) and yielded a lower Akaike Information Criterion value (AIC = 70.39). The predictive capability was thought to be limited due to both the small sample size and large ecological variability. Overall, the study emphasizes how TSS, DO, and pH affect the diversity of macroinvertebrates and supports the use of GAMs in tropical freshwater bioassessment. It also highlights the need for larger datasets to improve the predictive accuracy of streams in Sri Lanka.

Keywords: Benthic macroinvertebrates, freshwater ecology, Generalized Additive Model, Shannon-Wiener index, water quality

Technical Session IV

Sustainable Fisheries

The Impact of Tourism on Fisheries in Arugam Bay, Pottuvil: A Case Study of Consumption Patterns, Market Dynamics, Seasonal Trends and Sustainability Challenges

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Abstract

Coastal tourism and fisheries are interconnected along Sri Lanka's coasts, where both depend on the same marine resources. Rapid tourism growth has increased seafood demand and loss of traditional landing infrastructure, creating a major socio-environmental sustainability challenge in Arugam Bay. This study examined the interaction between tourism and fisheries in Arugam Bay, focusing on seafood consumption patterns, market and value chain dynamics, seasonal trends, and sustainability challenges. Data were collected from 282 respondents representing five value chain partners, including fishers (51), restaurant owners (30), locals (115), tourists (83), and traders (3), through structured interviews and questionnaires. Quantitative analyses included Spearman's rank correlation and the Species Pressure Index (SPi), supported by qualitative field observations. Tourists and restaurants preferred premium options in seafood such as tuna, prawns, crabs, snappers, and groupers, while locals exhibited a more diverse consumption pattern, including lagoon fish and cultured fish. Fishers and restaurants showed strong market alignment for the premium option (53.3% and 54.08%, respectively). A strong positive Spearman's rank correlation was observed between traders/middlemen and restaurants ($\rho = 0.863$), indicating a high degree of agreement in their preference patterns. SPi identified *Thunnus albacares* (yellowfin tuna) and *Thunnus obesus* (bigeye tuna) as the most pressured species (SPi = 1.0) with high trophic levels (4.4 – 4.5) and moderate to high vulnerability (56 – 71%), indicating that tourism-driven demand is concentrated on ecologically sensitive targets. In contrast, *Amblygaster sirm* and *Sardinella gibbosa* (sardines), together with *Oreochromis mossambicus* (tilapia), exhibited low SPi values (0.05 – 0.19), reflecting lower demand pressure and comparatively greater sustainability potential than tuna species. A value chain assessment showed that 80% of seafood supplied to restaurants originated within Arugam Bay, while 20% came from external sources. Traders/middlemen dominated the pricing structure and distributed approximately 13.3% of local catches to the Pottuvil market, taking the highest profit margins in the chain. Rising fish prices during the tourist season reduce affordability for residents due to increased demand. Field findings highlight the encroachment of tourism infrastructure on traditional fishing landing sites, inadequate fishery facilities, and cultural disruptions affecting sustainable fisheries management. The findings of the present research reveal that sustainable coexistence requires protected fishing access zones, fair pricing systems, improved landing infrastructure, participatory coastal management, and consumer awareness of alternatives.

Keywords: Tourism - fisheries interaction, sustainability, value chain, Spearman's Rank Correlation, Species Pressure index (SPi)

Assessing the Impacts of Coastal Accretion and Erosion on Fisheries Yield Along Ampara, the East Coast of Sri Lanka

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Abstract

Coastal erosion and accretion, driven by natural processes and anthropogenic activities such as harbor construction, significantly alter marine habitats and fisheries productivity. This study assessed the impacts of shoreline change on fishery yields along the Ampara coast of eastern Sri Lanka from 2010 to 2024, focusing on areas influenced by the Oluvil Harbour development (2010 - 2015). Shoreline dynamics were quantified using the Digital Shoreline Analysis System (DSAS) applied to Landsat (30 m) and Sentinel-2 (10 m) imagery, with positional uncertainty < 15 m root mean square error (RMSE) relative to manual digitization. Results revealed net shoreline movement (NSM) ranging from –74.22 m to +75.07 m and end-point rates (EPR) from –9.27 to +9.37 m/yr. Key environmental parameters including chlorophyll-a (Chl-a), total suspended solids (TSS), dissolved oxygen (DO), sea surface temperature (SST), and current velocity were derived via remote sensing algorithms and the Hybrid Coordinate Ocean Model (HYCOM), then validated against in-situ measurements. Fisheries data were obtained from national databases. Simple linear regression showed that erosion alone explained approximately 40% of variance in both total catch [$R^2 = 0.404$, $F_{1,13} = 7.44$, $p = 0.020$; $\beta = 567$ (95% CI: 102 to 1032)] and catch per unit effort (CPUE) [$R^2 = 0.419$, $F_{1,13} = 7.95$, $p = 0.017$; $\beta = 0.13$ (95% CI: 0.03 to 0.23)], with accretionary zones supporting higher productivity. Significant species-specific declines were observed, particularly for skipjack tuna (*Katsuwonus pelamis*), which decreased by roughly 50% after 2019 in areas of severe erosion. In contrast, reef-associated species such as seer fish (*Scomberomorus* spp.) remained stable. Multiple regression analysis highlighted that environmental variables collectively explained ~57% of production variance after accounting for fishing effort. Spatial analysis revealed northeast accretion supporting nursery habitats, while southwest erosion exacerbated habitat fragmentation.

Keywords: Coastal erosion, shoreline accretion, remote sensing, fisheries management, Sri Lanka

Effect of Capture Method on Sensory Quality and Shelf Life of *Euthynnus affinis*

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Abstract

Sensory quality is a critical factor determining the price and the market demand of the fish. Capture methods significantly influence the sensory quality of fish by affecting the extent of quality degradation. This study investigated the effects of active (ring net) and passive (gill net) fishing gear types on quality related sensory attributes of *Euthynnus affinis*, stored at -20°C over 10 days. Fish were obtained from one-day boats of gillnets (8-hour soak time) and ring nets (short-duration soaking time). Fish samples collected from Mirissa harbour representing two distinct capture methods (5 fish for each method at one time) were evaluated by using Quality Index Method (QIM), in which evaluates fish quality by providing a cumulative numerical score based on the progressive degradation of specific sensory attributes. The analysis was conducted longitudinally at three storage intervals as Day 0 (capture day), Day 5, and Day 10 using 30 undergraduates as panellists. The entire procedure of sensory evaluation was repeated twice. The QIM scheme assessed 11 parameters, including skin appearance, stiffness, eye cornea clarity, eye form, colour of the pupil, gill colour, gill smell, gill mucus colour, viscera, blood colour, and fillet colour, with total scores ranging from 0 (best quality) to 25 (poor quality). Results demonstrated that gear type has significantly influenced the rate of quality loss. Gillnet samples exhibited consistently and significantly higher QIM scores compared to ring net samples at every time point. On the first day of storage, gillnet samples recorded a mean score of 7.14 ± 0.83, while ring net samples were significantly fresher having 3.20 ± 0.87 score. By the 10th day, gillnet samples reached a score of 21.10 ± 0.32, whereas ring net samples remained at significantly lower score of 14.88 ± 0.47. Significant differences were specifically noted in pupil coloration, gill colour, blood coloration, and fillet coloration from the first day. All attributes did not reach the maximum scores at 10th day in both gears. The higher degradation in gillnet caught fish may be attributed to weak prolonged capture stress, which accelerates anaerobic glycolysis. Simultaneously, higher soaking time may accelerate the microbial invasions and cause more physical injury for fish than those caught in ring netting. Gillnet samples showed increased blood and fillet browning, likely due to the oxidation of oxymyoglobin to meta-myoglobin fuelled by higher microbial activity. This study concludes that postharvest quality of *Euthynnus affinis* is highly sensitive to fishing gear, with those caught in ring nets having relatively improved shelf-life and greater consumer acceptability.

Keywords: *Euthynnus affinis*, capture method, Quality Index method, soaking time, sensory attributes

Stock Identification, Length-Weight Relationship, and Condition Factor Analysis of White Sardinella (*Sardinella albella*) off the Southern Coast of Sri Lanka

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Abstract

The white sardine, *Sardinella albella*, is an important pelagic fish species that lives along the southern coast of Sri Lanka and contributes significantly to the country's total marine fish production. However, studies on the stock distribution of this species are lacking. Thus, this study focused on the stock identification of *S. albella* living on the southern coast. Along with this, the length-weight relationship ($W = aL^b$) and Fulton's condition factor ($K = 100W/L^3$) were used to assess the variability in population traits and health conditions across five natural habitats along the southern coast of Sri Lanka. A total of 488 individuals of *S. albella* were collected in July from four major harbours on the southern coast of Sri Lanka. Ambalangoda, Galle, Mirissa, Dondra, and Kudawella, nearly 100 individuals from each. Seven morphometric and five meristic characters were analyzed by three methods to assess whether they are significantly divergent across the five sampling sites. Data were analyzed employing Hierarchical cluster analysis (Dendrogram), Principal Component Analysis (PCA), and Univariate statistical analysis (Kruskal-Wallis and Dunn's Post Hoc) using R Studio software version 4.4.1. Hierarchical clustering analysis for morphometric, meristic, and combined 12 characteristics suggests two primary groups. All 12 variables were positively correlated with a correlation coefficient greater than zero. PCA on standardized 12 morphometric and meristic characters data indicated that Principal Component 1(PC1) contributes to 32.14% and Principal Component 2 (PC2) contributes to 17.05% of the total morphological variance. PCA, followed by K-means clustering, separated the data into 2 stocks and one mixed stock. PCA biplot with K = 2 identified, PC1 as the principal component containing the distinguishing factors that separate the stocks. The Shapiro-Wilk test yielded p-values < 0.05 for 52 of 60 total variables across 5 sites. Kruskal-Wallis and Dunn's test further identified four stocks of *S. albella* as Ambalangoda, Galle-Mirissa, Dondra, and Kudawella. The average weight ranged from 15.24 ± 2.20 to 23.89 ± 3.81 g. The total length ranged from 11.55 ± 0.70 to 13.03 ± 0.60 cm. Length-weight relationship of the sardines collected from Ambalangoda, Galle, Mirissa, Dondra, Kudawella were $W = 0.19L^{1.79}$ ($R^2 = 0.48$), $W = 0.19L^{1.78}$ ($R^2 = 0.48$), $W = 0.04L^{2.48}$ ($R^2 = 0.66$), $W = 0.03L^{2.56}$ ($R^2 = 0.56$), $W = 0.34L^{1.57}$ ($R^2 = 0.40$), respectively. The condition factor ranged from 0.92 ± 0.12 to 1.08 ± 0.11, indicating that fish in Dondra exhibit superior physiological and biological conditions compared to other sites. Obtained morphological data can serve as a baseline for fisheries managers, biologists, and conservationists for future studies and to establish a long-term stock assessment plan along the Southern coast to conserve fisheries resources.

Keywords: White sardine, stock identification, length-weight relationship, condition factor

Present Status of Fisheries Resources and Management Practices in Parakrama Samudra, Sri Lanka

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Abstract

Reservoir fisheries, which fall under the small-scale fishery sector, play a significant role in contributing to the country's annual fish production. The Parakrama Samudra is one of the major reservoirs that makes a significant contribution to the inland fisheries industry while providing enormous livelihood opportunities for the people in Polonnaruwa, Sri Lanka. However, the status of fisheries in Parakrama Samudra has not been reported during the recent past. Therefore, the study was conducted to evaluate the present status of fisheries, the socio-economic status of fishers and management strategies adapted for the fishing activities in Parakrama Samudra. In this study, four major fish landing sites including Kalahagala, 2-Ela, Bendiwewa and Maa oya were comprehensively studied focusing on full-time and part-time fishers (n = 78) by making field visits from June to August 2025. Species composition, total catch variation by landing sites, catch per unit effort (CPUE) variation by landing sites were analyzed. As a result, 12 finfish species belonging to 07 families and 01 shellfish species belonging to Palaemonidae family were identified. The average total fish harvest of the tank was calculated as 1.83 kg $boat^{-1}day^{-1}$ and *Oreochromis niloticus, Labeo rohita and Macrobrachium rosenbergii* were the major commercial species in the fish landings. The highest total catch (40%) and highest CPUE (2.3 kg $boat^{-1}$ day^{-1}) was recorded at the 2- Ela landing site. The minimum total catch (16%) and minimum CPUE (1.4 kg $boat^{-1}$ day^{-1}) was recorded at the Kalahagala landing site. At the Bendiwewa landing site (26%) total catch and (1.6 kg $boat^{-1}$ day^{-1}) CPUE was recorded and at the Maa oya landing site (18%) total catch and (1.9 kg $boat^{-1}$ day^{-1}) CPUE was recorded. The socio-economic results revealed that fishing was the major income source for the majority of the 300 registered fishermen living in contiguous areas of the Parakrama Samudra and majority of fishermen earned more than Rs. 30,000 as their monthly income through fishing. The Socio-Economic Status (SES) index linked to fisheries in Parakrama Samudra was 0.61, indicating a medium level of socio-economic status in fisher communities. Fisheries management in the reservoir follows a co-management approach, where both government authorities and fishing communities jointly participate in decision-making. This collaborative framework aims to promote responsible resource use and the sustainable development of fisheries in Parakrama Samudra.

Keywords: Fisheries, Parakrama Samudra, Socio-Eeconomic Status (SES), catch per unit effort (CPUE)

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Assessment of Energy Efficiency Perceptions of Marine Propulsion Systems Among Small-Scale Marine Vessel Operators in Sri Lanka

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Abstract

Small-scale marine fishing vessels defined in this study as vessels typically below 15 m in length with limited onboard mechanization, play a vital role in Sri Lanka's coastal economy. However, their dependence on conventional diesel propulsion systems contributes to rising fuel costs and environmental emissions. While energy-efficient propulsion technologies offer potential improvements, their adoption largely depends on operators' perceptions and willingness to transition. This study examines the effect of awareness, perceived fuel efficiency, and cost barriers on the adoption willingness of energy-efficient propulsion systems among small-scale vessel operators. A structured questionnaire survey was conducted using a convenience sampling approach among 100 operators at selected major fishery harbours. The sample size reflects the exploratory nature of the study and practical constraints in accessing respondents. The questionnaire included demographic variables and 12 perception-based statements measured on a five-point Likert scale, covering four constructs: awareness, perceived fuel efficiency, cost barriers, and adoption willingness. Data were analyzed using descriptive statistics and mean score comparisons, while Cronbach's Alpha ($\alpha > 0.70$) confirmed internal reliability. Ethical considerations, including voluntary participation and anonymity, were ensured. Results indicate moderate awareness levels (mean range: 3.1 - 3.4) and generally positive perceptions of fuel efficiency benefits (3.5 - 3.8). However, cost barriers were high (3.8 - 4.2), negatively influencing adoption willingness (3.0 - 3.3). Operators with higher education and experience showed slightly greater openness to new technologies. The findings highlight that financial constraints remain the primary barrier despite favorable perceptions. Policymakers should prioritize targeted subsidies, financing mechanisms, and training programs to enhance adoption. Future research should expand sample size and apply advanced statistical analyses to strengthen evidence-based decision-making.

Keywords: Sustainable maritime operations, energy efficiency, marine propulsion systems, marine energy management, emission reduction

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Assessing the Agreement of Tuna and Tuna-Like Species Fishing Effort with Habitat Suitability in the Indian Ocean

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Abstract

The tuna and tuna-like species fishery is an important component of Sri Lanka's export revenue. Targeting high-probability habitats can enhance the catch per unit effort (CPUE). Habitat suitability approaches have been widely applied, using parameters such as chlorophyll-a (Chl-a) concentration, sea surface temperature (SST), sea surface height (SSH), mixed layer depth (MLD), and sea surface salinity (SSS) to forecast potential fishing zones and support fleet operations. However, investigations into the effectiveness of identifying suitable habitats in actual fishing operations are scarce in the literature. Therefore, this study aimed to examine the agreement between predicted suitable habitats and the actual locations of fishing fleets targeting tuna and tuna-like species. Habitat maps were developed using environmental parameters (SST, SSS, MLD, Chl-a, and SSH) obtained from satellite data available in the Copernicus database, along with actual fleet operation data from the Global Fishing Watch database for the period 2020 - 2024 in the Indian Ocean. Suitable habitats were mapped using the Analytical Hierarchy Process (AHP) and Multi-Criteria Decision Analysis (MCDA). Both ArcGIS and QGIS software were used in the analytical process. Fishing effort hotspot maps were generated by applying a density-based unsupervised spatial clustering algorithm (Density-Based Spatial Clustering of Applications with Noise – DBSCAN) to identify fishing effort clusters, followed by hotspot analysis (Getis-Ord Gi*). The temporal dynamics of peak fishing months revealed substantial disparities between the spatial distribution of fishing effort in the Indian Ocean and the predicted suitable habitats for tuna and tuna-like species. Based on overall compatibility percentages from 2020 to 2024, moderately suitable habitats demonstrated the highest compatibility with fishing effort hotspots (87.34 ± 2.84%) in March, while only 7.47 ± 0.36% of hotspots were located in good or very good habitats. In July, compatibility decreased significantly in good and very good habitats (13.28 ± 0.72%), while moderately suitable habitats again recorded the highest compatibility (40.58 ± 1.39%). The highest compatibility (45.99 ± 3.25%) in the good habitat category was observed in November, while 32.32 ± 1.48% of hotspots were found in moderately suitable habitats. These findings indicate a notable disparity between fishing fleet operations and habitat suitability forecasts based on environmental factors for tuna and tuna-like species in the Indian Ocean. Fishing fleets tend to operate more frequently in moderately suitable zones rather than in areas classified as good or very good habitats. Therefore, future studies should further investigate the reasons behind this mismatch between real-world fishing behavior and environmentally predicted suitable habitats in order to optimize tuna and tuna-like fisheries.

Keywords: Habitat models, fishing hotspots, fleet operation, spatial clustering

Effect of Natural and Synthetic Cryoprotectants on Quality and Shelf-Life of Frozen *Thunnus albacares*

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Abstract

This study was conducted to compare the effects of natural cryoprotectants (green tea and chitosan) and synthetic cryoprotectants (glycine and polyvinyl alcohol) on quality and shelf-life of yellowfin tuna. The ability of cryoprotectants to mitigate freezing-induced protein denaturation, lipid oxidation, microbial spoilage, and sensory qualities was examined over 25 days of storage time at -20 °C. Yellowfin tuna fillets were immersed in specific treatment solutions and treated in optimum concentration of each cryoprotectant (Green tea extract 0.3%, chitosan 1%, glycine 1%, polyvinyl alcohol 1%) and one with untreated control sample for preservation of natural food products. Throughout the twenty-five days of storage period, key quality parameters, including drip loss, total volatile base nitrogen (TVB-N), Trimethylamine (TMA), peroxide value (PV), carotenoid content, pH, and microbial load, were measured using standard methods at day 1, day 10 and day 25 after storage. Statistical analysis done using one way ANOVA. By the end of twenty-five days of frozen storage time, green tea extract and chitosan treatment showed significantly best preservation compared to those that were treated with synthetic agents or left untreated. Green tea extract (1.66 ± 0.84%) and chitosan (2.77 ± 2.59%) recorded the lowest drip loss values, demonstrating significantly better preservation of myofibrillar protein structure and moisture retention compared to synthetic treatments. Regarding biochemical stability, green tea extract maintained the lowest TVB-N level (30.80 ± 1.85 mg/100 g), indicating high resistance to spoilage, while chitosan showed the highest antimicrobial activity, recording the lowest colony formation (CFU) value (4.55 ± 0.18 log CFU/g), effectively suppressing microbial growth than synthetic cryoprotectant agents. In oxidative quality, both green tea extract (1.58 ± 0.01 meq O_2/kg) and chitosan (1.61 ± 0.02 meq O_2/kg) maintain low peroxide values. In contrast, glycine and polyvinyl alcohol were inadequate to suppress the chemical and microbiological changes in yellowfin tuna muscle as effectively as the natural agents. The application of 0.3% green tea extract and 1% chitosan is strongly recommended as a practical, effective, sustainable, and ''clean label'' technology to improve the quality and value of Yellowfin tuna for the Sri Lankan export industry.

Keywords: Cryoprotectants, natural, synthetic, *Thunnus albacares*, quality, shelf life

Antibacterial Activity, Phytochemical Profiling and FTIR Characteristics of *Elaeocarpus serratus* (Ceylon Olive) Leaf Extracts: Influence of Leaf Ontogeny

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Abstract

Plant-based antimicrobials have been proven to be a promising treatment option with several advantages, including fewer side effects and highly diverse pharmacological activities due to antioxidants and antibacterial agents. *Elaeocarpus serratus* L. (Ceylon olive) is a pharmacologically significant plant known for its diverse array of bioactive constituents and associated therapeutic properties. However, comparative evaluation of influence of leaf ontogeny on those bioactive properties remains limited. Thus, this study evaluates the extraction yield, phytochemical composition, Fourier Transform Infrared (FTIR) characteristics, total flavonoid content (TFC), and antibacterial activity of leaf extracts, focusing on the influence of leaf ontogeny on their bioactive potential. Dried green and dried red leaves of *E. serratus* were extracted using 70% ethanol via sonication. Extraction yield varied significantly with leaf ontogeny. A higher percentage yield was obtained from dried red leaves (10.31%), compared to dried green leaves (6.68%). Qualitative analysis confirmed the presence of primary metabolites (carbohydrates and proteins) and diverse secondary metabolites, including alkaloids, glycosides, saponins, terpenoids, phenols, tannins, flavonoids, quinones, and phytosterols across both extracts. FTIR analysis revealed characteristic functional groups corresponding to hydroxyl (O–H), carbonyl (C=O), aromatic (C=C), methylene (C–H), and ether (C–O) stretching vibrations, supporting the presence of phenolic and flavonoid compounds. TFC, determined using quercetin as the standard, ranged from 256.2 ± 0.8 mg QE/g DW to 267.4 ± 0.2 mg QE/g DW. Dried red leaf extracts exhibited significantly higher flavonoid content than dried green leaves ($p < 0.05$). Antibacterial activity was evaluated against *Staphylococcus aureus*, *Escherichia coli*, and *Vibrio parahaemolyticus* at concentrations of 100, 300, and 500 mg/mL (n = 3), with using tetracycline as the positive control. Both extracts demonstrated concentration-dependent inhibitory activity. The highest inhibition zones were observed at 500 mg/mL, particularly for dried green leaves, against *E. coli* (15.06 ± 0.20 mm) and dried red leaves against *V. parahaemolyticus* (17.18 ± 0.28 mm). Red leaves extract consistently exhibited greater antibacterial activity than the green leaves. Although positive control showed superior inhibition (9.62 ± 0.03) overall, all tested concentrations (100, 300, and 500 mg/mL) of both extracts demonstrated comparable activity against *S. aureus*. In conclusion, the leaf ontogeny significantly influenced phytochemical yield, flavonoid content, and antibacterial efficacy. Hydroethanolic extracts of dried leaves, particularly red leaves, exhibited enhanced bioactivity and antioxidant potential, underscoring the critical influence of leaf ontogeny while highlighting their considerable promise as natural antibacterial and Phyto therapeutic agents for future pharmaceutical, nutraceutical, and sustainable bioproduct development. Further studies are recommended to isolate and characterize the bioactive constituents responsible for these effects.

Keywords: Antibacterial activity, antioxidant activity, Ceylon olive, phytochemical screening, metabolites

Formulation and Quality Evaluation of Lime-Flavored Seaweed Jelly from *Gracilaria verrucosa*

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Abstract

Gracilaria verrucosa is gaining attention as a natural ingredient for nutritionally enhanced food products due to its rich content of polysaccharides, proteins, minerals, and bioactive compounds. This study aimed to develop lime-flavored jelly using different ratios of agar extracted from *G. verrucosa*. Jelly formulations were prepared using varying ratios of seaweed extract (SE) and lime juice (LJ) along with other standard ingredients and the treatments were T1 (0% SE: 50% LJ), T2 (12.5% SE: 37.5% LJ), T3 (25% SE: 25% LJ), and T4 (37.5% SE: 12.5% LJ). The gel properties of *G. verrucosa* agar were yield (32.73 ± 0.30%), pH (6.19 ± 0.02), melting temperature (85 ± 1.00 °C), and gelling temperature (32.67 ± 1.53 °C). The jelly samples were evaluated for physicochemical properties. T4 showed a significantly higher pH (3.00 ± 0.01) than T1 and T2. Titratable acidity (0.67 ± 0.03% to 2.03 ± 0.05%) and viscosity (137.95 ± 4.47 cp to 5327.9 ± 4.64 cp) differed significantly among treatments, with T4 exhibiting the highest melting temperature (75 ± 0.58 °C). Proximate composition varied significantly among treatments: moisture (45.14 ± 0.22% to 50.33 ± 0.16%), ash (0.23 ± 0.05% to 0.70 ± 0.03%), protein (3.56% to 4.04%), lipid (1.05 ± 0.03% to 1.26 ± 0.03%), carbohydrate (45.54 ± 0.16% to 50.03 ± 0.25%), and energy (200.32 ± 0.43 to 220.26 ± 0.87 kcal/100 g). As seaweed concentration increased, pH, viscosity, ash, lipid, carbohydrate, and energy values increased, while titratable acidity and moisture decreased. Sensory evaluation using a five-point hedonic scale indicated that T4 was the most preferred formulation. When compared with a commercial jelly product, T4 showed higher titratable acidity, viscosity, melting temperature, ash, lipid, protein, carbohydrate, and energy values, while pH and moisture content were lower. Overall, the formulation with a seaweed-to-lime juice ratio of 37.5%:12.5% (T4) was identified as the optimal jelly formulation.

Keywords: *Gracilaria verrucosa*, seaweed jelly, proximate composition, physical properties, sensory evaluation

Investigation of Microplastic Contamination in Traditional Dried Fish Processing Method: A Case Study in Dondra, Matara District

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Abstract

Plastic particles smaller than 5 mm, known as Microplastics (MPs), are an emerging concern in aquatic environments and food safety. *Sardinella gibbosa* (Salaya) is a marine omnivorous filter feeder commonly used in dried fish production. This study was designed to investigate variation in and potential sources of MP contamination during traditional salt-dried fish processing in Dondra, Sri Lanka, and the levels of MP contamination in commercially available dried fish from the local market. Dried fish samples were collected from three vendors, with three fish from each vendor. Fresh 20 *Sardinella gibbosa* were collected from Dondra Harbor on two separate occasions (Sample 1 and Sample 2). Portions were processed under traditional salt-drying conditions at a drying facility. To investigate the level of MP contamination, samples of raw fish were used at the intermediate (3 days) and final (5 days) stages of drying. Whole fish samples were digested using 69 % nitric acid and filtered through 10µm filter papers. Salt and water used for dried fish processing were also collected for MPs analysis. MPs were identified using a photomicroscope, confirmed by Nile red staining, and polymer types were identified by Fourier Transformed Infrared (FTIR) analysis. Since most MPs found were small, FTIR analysis was conducted only on representative particles selected from combined samples. MPs abundance increased across processing stages, from raw fish to final dried fish, 1.59 ± 0.14 MPs/g of raw fish to 4.60 ± 0.81 MPs/g of raw fish in Sample 1, and from 3.01 ± 0.26 MPs/g of raw fish to 7.50 ± 0.37 MPs/g of raw fish in Sample 2, while Market dry fish contained fewer MPs (4.53 ± 1.62 MPs/g of dried fish). The comparatively lower MP abundance observed in market-dried fish may be due to particle loss during transport, environmental exposure, and shredding. Microplastics were found in various forms, including fibers, fragments, pellets, foams, and films, and were found in colors such as black, red, blue, orange, green, purple, and yellow. Analysis of MP counts and relative percentages showed that purple, transparent fibers, and black and orange-colored fragments were most frequently observed in all fish samples, both salt and freshwater. Film counts were found in all samples, and were transparent. Most samples have only transparent pellets. But in sample 2, intermediate and final stages, and in water, other colors were also present alongside the transparent color. Foams were found only in water and market-dried fish. MPs were categorized into three size classes: small (< 0.5 mm), medium (0.5 – 1 mm), and large (1–5 mm), with smaller particles being the most abundant. FTIR analysis confirmed the presence of different polymers, including SEBS (Styrene-Ethylene-Butylene-Styrene), PE -vernetzt (Cross-linked-polyethylene), TPO (Thermoplastic Olefin), PP (Polypropylene), and Luwax AL3 (Polyethylene wax). The study highlights the potential for microplastic contamination during traditional dried fish processing.

Keywords: Microplastics, *Sardinella gibbosa*, dried fish, salt drying

Attributes Influencing the Consumer Decision-Making Process in Purchasing Yellowfin Tuna (*Thunnus albacares*) at Local Fish Markets in Galle District, Sri Lanka

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Abstract

The fishing industry plays a vital role in fulfilling human protein requirements while contributing significantly to national economic development. Among the diverse range of fish species available in global markets, Yellowfin tuna (*Thunnus albacares*) has achieved considerable popularity among consumers worldwide. Understanding consumer behavior in the marketplace is therefore essential for both traders and the efficient functioning of markets. This study investigates the key attributes influencing consumer decision-making process when purchasing yellowfin tuna (*Thunnus albacares*) at the Galle local fish markets in Southern Sri Lanka. A structured questionnaire survey was administered to 238 consumers over one month (December 2024 to January 2025) using convenience sampling (randomly selected) during peak market hours. The study examined consumer preferences regarding organoleptic properties, purchasing behaviors, and socio-economic factors affecting purchase quantities. Multiple regression analysis revealed that amount of willing to pay emerged as the strongest positive predictor ($p < 0.001$), followed by frequency of purchase ($p = 0.004$) and cleanliness of the market environment ($p = 0.007$), while larger fish size ($p = 0.002$), higher income of consumer ($p = 0.024$), and quality/ freshness of fish ($p = 0.049$) reduce bulk purchases of yellowfin tuna (*Thunnus albacares*). The results demonstrate that socio-economic factors, market environment conditions, and consumer behavioral patterns significantly influence purchasing decisions in local fish markets. These findings provide valuable insights for improving market efficiency, developing targeted marketing strategies, and informing policy decisions to enhance local seafood value chains in Sri Lanka's fisheries sector.

Keywords: Consumer, yellowfin tuna (*Thunnus albacares*), local fish market, purchase decisions, Sri Lanka

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The Present Status of Multiday Boats Operated from Beruwala Fisheries Harbour, Sri Lanka (2018 – 2022)

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Abstract

The livelihood of coastal communities of Sri Lanka vitally depends on the coastal and offshore resources. Specially, the increasing demand and overexploitation of coastal resources have driven the expansion of offshore fisheries, supported by advanced gear and craft technology in multiday boats. Beruwala fisheries harbor (BFH) is one of the country's principal multi-day boats (MDB) landing center, contributing substantially to national marine fish production. This study aimed to assess the catch dynamics and fishery status of MDBs operating from BFH over a five-year period from 2018 to 2022. A descriptive analytical approach was applied while using secondary logbook data, supported by focused group discussions and structured interviews with 240 active fishers. Catch composition, dominant species groups, and monthly variations in catch per unit effort (CPUE) were analyzed using Microsoft Excel and SPSS. BFH emerged as a major contributor to Sri Lanka's offshore marine landing, accounting for a substantial portion of 11-16% of total offshore fisheries during the study period of 2018-2022. The annual catch landing analysis revealed a pronounced inter-annual variation, with a peak catch in 2020 of 16,000 tons. This surge coincides with the COVID-19 pandemic, which likely correlates with the, reduced illegal fishing by foreign vessels due to travel restrictions and reduced fishing pressure. The catch composition was dominated by *Decapterus russelli* (Indian scad) at 35.31% and *Katsuwonus pelamis* (Skipjack tuna) at 35.23%, accounting for a combined 70% of the total landings. The evaluation of taxonomic composition by family highlighted the dominance of Scombridae and Carangidae followed by lower contributions from families represented by common Dolphin fish, billfishes and several other minor pelagic species, highlighting the high-value species target-oriented nature of the industry. Moreover, the longline was reported to be the widely used fishing gear by the MDB fishers. For longline fisheries, the CPUE per boat (40 ft in length) exhibited a strong seasonal variation, peaking in June at 550.84 kg/ boat/ day, and reaching a minimum in May at 56.48 kg/ boat/ day, illustrating the dependency of landings on the seasonal availability of fish resources. The overall study depicts the highly dynamic nature of the MDB fishery at BFH, emphasizing the facts that the industry is heavily reliant on pelagic resources.

Keywords: Beruwala fisheries harbour, catch composition, catch per unit effort, multiday boats, offshore fishery

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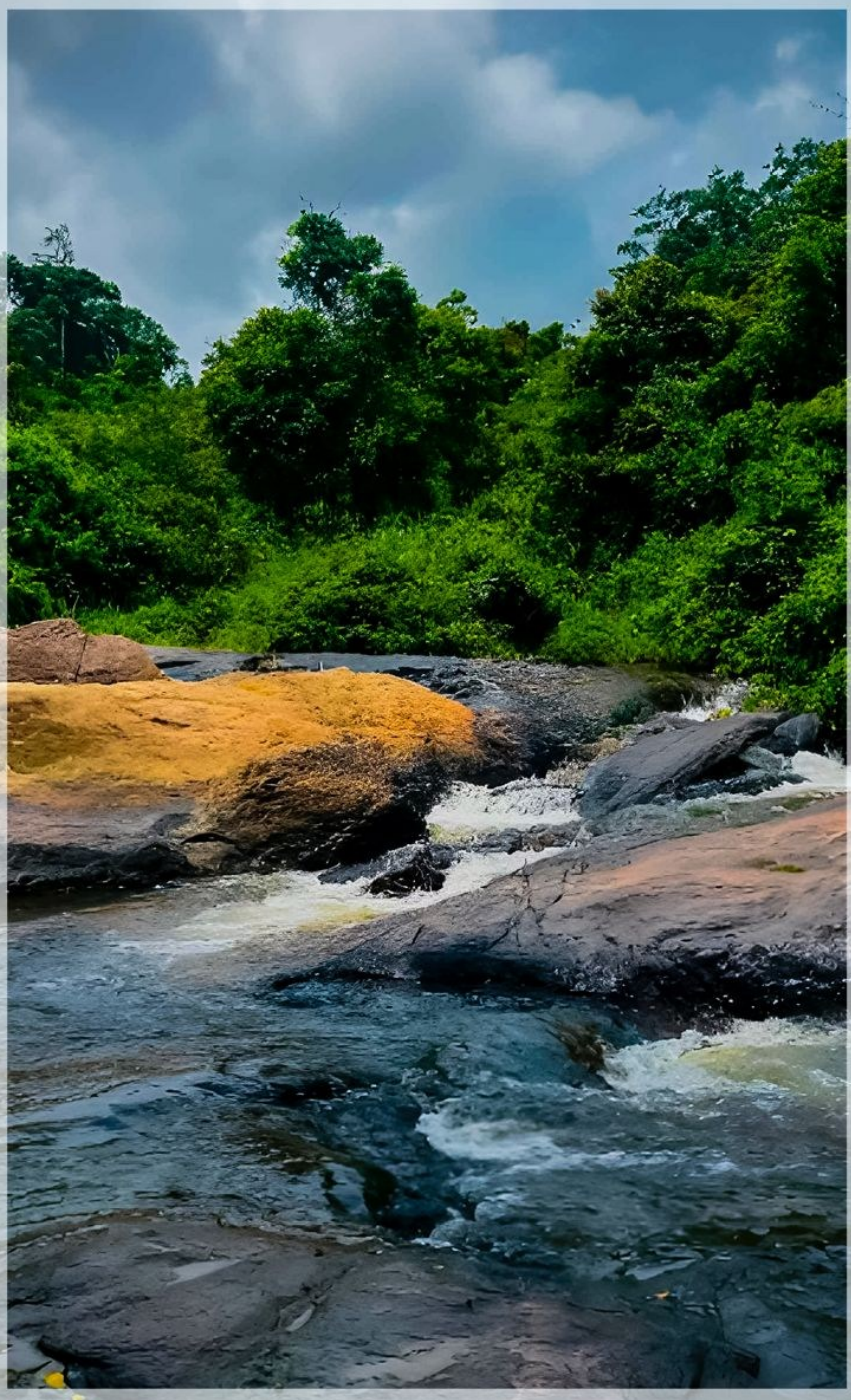

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