CAA8

THE 8TH INTERNATIONAL SYMPOSIUM ON CAGE AQUACULTURE IN ASIA

"Green and Smart development of Cage Aquaculture in Asia"

Organized by

Asian Fisheries Society (AFS) and Nha Trang University (NTU)

Co-organized by

Shanghai Ocean University (SHOU), Ocean University of China (OUC), China-ASEAN Belt and Road Joint Laboratory on Mariculture Technology

July 15 - 18, 2026 *Khanh Hoa, Vietnam*

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July 15 – 18, 2026

Khanh Hoa, Vietnam

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Australis

Scaling Tropical Marine Aquaculture

A Better Future for Sustainable White Fish Supply

SUSTAINABLE PRACTICES | PREMIUM QUALITY | GLOBAL IMPACT

Fully Intergrated Producer
Serving Global Markets

THE Better Fish

MarLumina

Ocean Solutions through Science and Technology

Working in the marine environment presents inherent challenges. These include fluctuating weather conditions, differing operating platforms, isolation from immediate assistance, and often operations across jurisdictional boundaries. Overlaid on these norms has been rapid innovation in marine technologies and the need for specialize and unique solutions. Founded in 2010, **MarLumina LLC** works with clients to develop tailored approaches and solutions for small to mid-sized projects, with the goal of providing the highest quality results and outcomes.

Areas of Support:

- Marine Aquaculture Support
- Survey and Sampling Design
- Oceanographic Dynamics, Topography for Offshore Infrastructure
- Technology Assessment/Evaluation
- Maritime Safety/Training Assessment/Evaluation
- Specialized Transportation and Logistics
- Marine Resources
- Marine Salvage
- Marine Energy Resources
- Marine Science and Conservation
- Scientific Review/Evaluation

Contact:

- **MarLumina LLC**
- Website: https://marlumina.com/
- Email: mark@marlumina.com

Current Asian Partners:

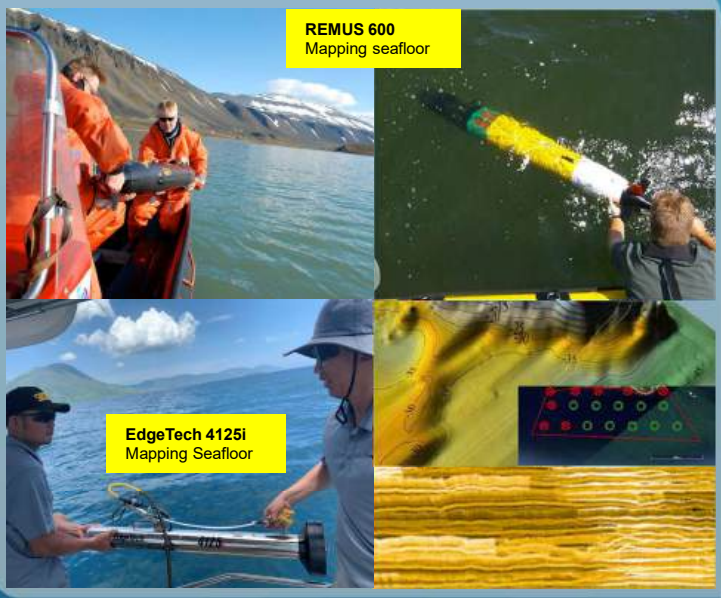
Australis Aquaculture Vietnam Ltd

Viện Hải dương học
VAST Institute of Oceanography

MARLUMINA

Ocean Solutions through Science and Technology

Topography & Aquaculture Support



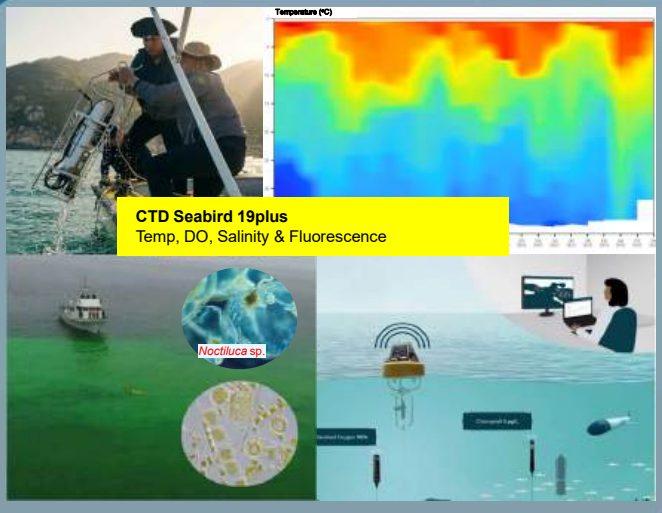
REMUS 600
Mapping seafloor

EdgeTech 4125i
Mapping Seafloor

Oceanographic Dynamics

AWAC AST 600 kHz
Wave and Current

WS-2902D Weather Station
Rainfall, Wind, Humidity & T°C



CTD Seabird 19plus
Temp, DO, Salinity & Fluorescence

Environmental Monitoring

COMET 300
Mapping seafloor, Water Quality, Videos & Photography

Offshore Conservation & Economic Support

Current Asian Partners:

Australis
Aquaculture Vietnam Ltd

Viện Hải dương học
VAST Institute of Oceanography

COMPANY & BRAND OVERVIEW

Established in 2018, Lan Song Technology is committed to IoT products and value-adding services in aquafarming, with the goal of fundamentally improving industry efficiency. Lan Song creates an intelligent aquafarming system by connecting current machinery and introducing new sensors. The system relieves farmers from inspecting their ponds several times per day with cell phone remote control. Also, with automatic fault warning, automatic feeding and water dissolved oxygen and temperature detection, the system lowers risk and improves efficiency during the whole production process. The first product, nicknamed Pond Steward, was released in 2019, and Lan Song quickly gained the largest market share in intelligent aquafarming.

PIONEERING

1 Aeration Machine Controller
China's First Aesthetic Design Patent

2 First Utility Patent
Dissolved Oxygen Content Detection Equipment

3 First practical patent
New Type of Leaf Wheel Aerator

4 China's First Full Series of
Planned IoT Control Devices for Aquaculture

- Aquaculture Online IoT Devices hold a **68%** market share in China.
- Lan Song Technology is a well-known brand and high-tech enterprise in the field of smart aquaculture in China, rapidly expanding in China through a franchise business model.
- To date,the number of online devices in the Pond Manager series has 300,000

Pond Manager Smart Aquaculture System Series

Smart Feed Tray

> Replaces manual inspection of feed in the pond
> Takes timed photos and videos
> Remotely checks remaining shrimp feed
> Observes shrimp feces, leftover feed, intestinal condition, and growth health
> Can be linked with the precision-type smart air-conveying feeder to achieve small, multiple meals and reduce the feed conversion ratio (FCR)

Pond Manager Controller

> Remote Control
> Power and device failure alarms
> Timer switch
> Multiuser Management
> Power Consumption Statistics
> Over current protection
> Low voltage protection
> Manual Operation
> Simple Operation

Modular Aerator Controller

> Customize freely: 1 master controller can support up to 8 switches
> High-Power Device Control: 15kw or 3kw
> Easy to maintain
> Equipment protection

DO Meter Cube

> Real-time monitoring of DO and temperature
> Low oxygen alert
> Easy-to-clean probe
> LED DO and temperature display
> Smartphone access to DO and Temperature data
> Can be paired with Aerator Controller to turn on aerator automatically when oxygen is low
> Extensible design that can support multiple sensors including water level, velocity, pressure and etc.

360 Smart Wind-Blown Feeder (Precision Type)

> Specialized throwing system for shrimp ponds, easy to install
> Patented curved throwing tray, large throwing area, low breakage rate
> Built-in blower for positive pressure conveying
> Built-in spiral feeder, stable and uniform conveying speed
> Supports large and small circulation, long-term slow feeding, reduces waste and lowers feed conversion ratio
> Conveying speed stable and unaffected by voltage fluctuations
> Built-in multiple protections, supports remote fault diagnosis

Multi-Nozzle Pipe Feeder

> Multiple nozzles can be deployed
> Each nozzle can be controlled individually
> Feed is not crushed
> Supports large and small circulation for long-term slow feeding
> Feeding speed is stable and precise
> One feeder can manage multiple culture ponds
> Suitable for specially shaped small ponds (e.g., small greenhouse shrimp ponds) and numerous culture ponds (e.g., round tanks, net cages, raceway tanks, factory farming)

360 Smart Wind-Blown Feeder (High-Speed Type)

> Large throwing area
> Curved composite throwing tray, low breakage rate
> Built-in blower, strong conveying capacity
> Patented anti-clogging function, more worry-free feeding
> Simple installation
> Multiple sizes of hopper available
> Supports different distance throwing trays, flexibly adaptable to various ponds

Smart Weighing Feeder

> Remote management via mobile phone, saves labor, more flexible operation
> Precise weighing, can feed by weight
> Timed feeding, small amounts and multiple meals, lowers feed conversion ratio
> Customizable feeding speed and feeding interval
> Automatic stop when feed runs out / automatic fault alarm
> Automatically records feeding data
> Vibrator for discharging
> Feeding speed stable and uniform, unaffected by voltage
> Low-speed large curved throwing tray, low breakage rate, large throwing area
> Connects to smart monitoring, real-timeview of feeding status, scoring of fish feeding performance

> Modular hopper, available in three sizes: small, medium, and large. The small hopper has a capacity of 180 liters, which can hold 50 jin of No. 8 sinking feed or 155 jin of No. 1 floating feed. For every 20 cm increase in height, the hopper volume by 124 liters (equivalent to 172 jin of sinking feed or 107 jin of floating feed).

Dissolved Oxygen Meter

> Smart online dissolved oxygen monitoring device.
> Water temperature and dissolved oxygen are monitored online 24 hours.
> Automatically calibrate DO sensor before each measurement
> Low dissolved oxygen alarm
> Automatically turn on aerator when dissolved oxygen is low
> Rapid response, stableness, high reliability and low maintenance cost.
> Suitable for both sea water and fresh water

RAS-Optimized DO Meter

> Added pressure and water level sensors
> Immediate alerts will be sent if the aerator's
> pressure is abnormal or water level is too low/high, ensuring safer aquaculture operations.

Portable DO Meter

> Handheld DO meter with LED display
> Easy operation and fast response
> Response time: T90 < 30s
> Suitable for both seawater and freshwater

Smart Water Quality Teste

> PH/Ammonia nitrogen/Nitrite and other critical aquaculture parameters
> HD display for easy reading
> Accurate measurements with automatic historical data recording
> Bluetooth connectivity for mobile pairing and online calibration
> Water target analysis algorithm based on big data can provide water management suggestions according to historical records.
> Support Dissolved Oxygen measurement with optional Fluorescence DO Probe

Smart Unmanned Feed Spreading Boat

> Equipped with a small-hopper weighing feeder
> Remote feeding management via mobile phone
> Can be remotely controlled or set with planned routes via mobile phone

4G Solar-Powered PTZ Surveillance Camera

> Full-Color Night Vision
> 4G connectivity with unlimited data
> Truly wireless: no network or power cables needed
> Motion detection and human tracking
> Solar-powered with ultra-long battery life
> Automatic monitoring, snapshot, and alert notifications
> 10x optical zoom for crisp, smooth footage

Smart Feeder Camera

> Remotely monitor fish feeding behavior
> mini- program automatically scores feed intake,
> truly enables remote feeding management

Unmanned Auto-Spraying Boat

> Route Planning via Mobile App
> Autonomous pond patrolling,Automatic water intake and shut-off
> Spraying history records accessible
> Lightweight design for easy transfer between ponds
> Time-saving and labor-saving
> Travel speed: 1.5 m/s
> Spraying rate: 8.5 L/s
> Load capacity: 70 kg
> Remote control range: 300 meters
> Spraying radius: 6–8 meters
> Configurable for spraying liquids, granules, or feed
> Up to 2 hours of full-speed operation; user-replaceable high-capacity battery

Gearless Aerator

> New national motor standards
> High efficiency motor
> Available in 1.5kW, 750W, and 370W models

Yu Dada Official Phone Number

400-886-6611

Email：caoxs@yuyuyu.com.cn

Contact information:

ZYF-20K Blower Product Manual

1. Product Overview

The ZYF-20K Blower is a high-performance, energy-efficient industrial-grade fan, engineered for industrial and commercial applications requiring stable, robust air pressure and flow. Manufactured using advanced aerodynamic principles and premium materials, this unit offers the advantages of stable operation, low noise, extended service life, and easy maintenance. It is widely used across various sectors, including sewage treatment, aquaculture, pneumatic conveying, combustion support, material drying, and environmental dust removal.

Powered by a high-power 1400W brushless DC motor, the ZYF-20K delivers powerful airflow while optimizing energy efficiency, making it an ideal air supply solution for modern industrial automation systems.

2. Product Features

- **High Efficiency & Energy Saving:** Equipped with a high-efficiency permanent magnet synchronous brushless DC motor, significantly reducing operational energy consumption and lowering usage costs.
- **Powerful Airflow & Pressure:** Delivers a maximum airflow of **260 m³/h** and a maximum pressure of **20 kPa**, meeting the demands of various operating conditions.
- **Low Noise Design:** Optimized impeller structure combined with a sound-insulated housing ensures operational noise is ≤ **70 dB(A)**, making it suitable for noise-sensitive environments.

Robust & Durable: The housing is constructed from high-strength die-cast aluminum with a powder-coated finish, offering excellent resistance to corrosion and high temperatures for harsh working conditions.

Multiple Protection Mechanisms: Built-in overload and overheat protection to ensure safe equipment operation.

Easy Maintenance: Modular design allows for the rapid removal of filters, the blower unit, and the controller for cleaning or replacement.

Flexible Installation: Compact and lightweight design with a base mounting option for easy adaptation to different environments.

3. Technical Specifications

Item	Parameter
RatedPower	1400W
RatedVoltage	Single-phase220V±10%
RatedFrequency	50Hz
RatedCurrent	Single-phase6.4A
MaximumAirflow	260 m³/h
MaximumPressure	20 kPa
NoiseLevel	≤70 dB(A)
Air Outlet Diameter	DN50
ProtectionLevel	IP54
InsulationClass	ClassF
OperatingTemperatureRange	-10℃ ~+45℃
Dimensions(L×W×H)	450×280×250 mm

4. External View

LONG SINH CO., LTD

ISO 9001 - ISO 45001 - HACCP

Specialized in manufacturing & trading

- Supplement, water treatment for aquaculture.
- Products for larva shrimp
- High quality fertilizer.
- Products for omamental fish, pet food
- Materials for livestock feed: Fish meal & Fish oil.
- Chitosan.

Long-term benefit - Sinh lợi lâu bền

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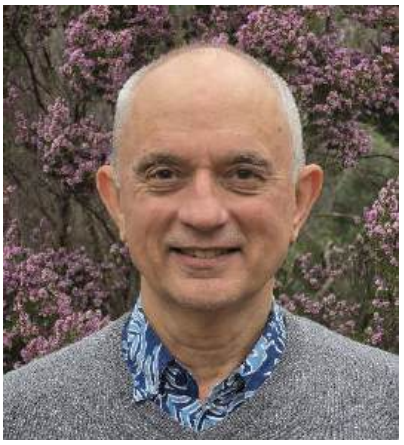
KEYNOTES



Prof. Neil Loneragan

Professor Emeritus of Fisheries and Marine Ecology,
Murdoch University
Adjunct Professor, IPB University, Indonesia
Immediate Past President Asian Fisheries Society (2025-28)
Editor-in-Chief, Journal of Asian Fisheries Science (2023-)

Dr. Loneragan is Professor Emeritus at Murdoch University with research interests covering fish and invertebrate ecology, estuarine and marine food webs, stock enhancement, ecosystem modelling and small-scale fisheries. He spent 14 years with CSIRO researching prawn/shrimp fisheries and habitats in northern Australia and through southeast Asia. At Murdoch, he has been Director of the Centre for Fisheries and Aquatic Ecosystems Research, leader of the Environmental and Conservation Sciences and has supervised PhD, Masters and Honours research candidates from Australia, Indonesia, Malaysia, the USA and China. He has delivered workshops on Fisheries Science and Management in Indonesia and in 2023. co-coordinated an FAO workshop on the status of Asian fish stocks. He has published ~200 articles in international journals, edited one book and five special symposia (Scopus H = 53; Google Scholar = 68) and is the immediate President of the Asian Fisheries Society and Editor-in-Chief of Asian Fisheries Science. Professor Loneragan holds an Adjunct Professorship at IPB University (Indonesia) and was a Visiting Professor at the Universiti Putra Malaysia.

KEYNOTES

Prof. Mai Kangsen

Ocean University of China

Dr. Mai Kangsen holds a doctorate from the National University of Ireland. He is an Academician of the Chinese Academy of Engineering and a Professor at Ocean University of China. As an expert in aquatic animal nutrition and feed, he once served as Vice President of Ocean University of China and Deputy Director of the Agricultural Division of the Chinese Academy of Engineering. Currently, he had/has also held multiple concurrent positions, including Vice Chairman of the International Committee on Fish Nutrition, Vice President of the Chinese Society of Fisheries, Vice President of the China Feed Industry Association, Vice President of the Chinese Society of Biotechnology, and Member of the Science and Technology Innovation Advisory Committee of the Ministry of Agriculture and Rural Affairs.

KEYNOTES

Prof. Liangbiao Chen

Shanghai Ocean University

Liangbiao Chen, professor, Shanghai Ocean University. Director of Research Center for Aquaculture Breeding, Shanghai Ocean University. Published more than 150 SCI indexed papers. Main research interests include: Origin and Evolution of antifreeze proteins in polar fishes; Molecular mechanisms of cold adaptation in fishes; Molecular breeding for cold/heat/disease resistant varieties in aquaculture species including Nile Tilapia and bigmouth bass. Won the First Prize of the Outstanding Scientific Research Achievements Award for Higher Education Institutions, Ministry of Education of China.

KEYNOTES

Assoc. Prof Zhang Wenbo

Department of Aquaculture at Shanghai Ocean University

Dr. Zhang Wenbo, Associate Professor at Shanghai Ocean University, holds a Ph.D. from the University of Stirling (UK). Specializing in sustainable aquaculture and policy, he serves as consultant for FAO and NACA. He led the Blue Transformation of Aquaculture in the Asia-Pacific Region white paper and currently leads national aquaculture investment plans for India, Thailand, and the Philippines. In 2026, he was selected for the UN CFS/HLPE-FSN flagship report drafting team. His research published in Nature advances global freshwater aquaculture and blue food studies.

KEYNOTES

Assoc. Prof Ching Fui Fui

Dean of the Higher Institution Centre of Excellence (HiCOE), Institut Marin Borneo (IMB), Universiti Malaysia Sabah (UMS), Malaysia

Assoc. Prof. Dr Ching Fui Fui is the Dean of the Higher Institution Centre of Excellence (HiCOE), Institut Marin Borneo (IMB), Universiti Malaysia Sabah (UMS), Malaysia. She obtained her Ph.D. in Aquaculture from Kindai University, Japan. Her research focuses on fish breeding and seed production, hatchery technology, larval biology and physiology and sustainable aquaculture. She has extensive experience in leading marine fish hatchery operations, successfully producing high-quality seed of groupers, snappers, and several other commercially important marine finfish species. She is currently leading research on the captive breeding and seed production of the endangered humphead wrasse contributing to species conservation and sustainable aquaculture development. She serves as an Adjunct Professor at universities in Japan, Indonesia, and Brunei Darussalam, and has provided scientific consultancy and technical advisory services for aquaculture development in Malaysia, Indonesia, and Japan. She is also actively involved in community knowledge transfer projects that empower coastal and rural communities and strengthen aquaculture capacity building. Through research, consultancy, and community engagement, she continues to advance seafood security, sustainable aquaculture, and the Blue Economy.

KEYNOTES

Prof. Dr Alice Joan G. Ferrer

University of the Philippines Visayas

Dr. Alice Joan G. Ferrer is Professor 12 and UP Scientist (Economics) at the University of the Philippines Visayas and currently serves as Vice Chancellor for Academic Affairs. An internationally recognized fisheries social scientist, her work spans small-scale fisheries, aquaculture, gender, governance, environmental economics, and climate resilience. A member of Asian Fisheries Society (AFS) since 2004, she has served the Society as councilor, Vice President, President, and Immediate Past President during the period October 2013 to February 2025. She is also responsible for reviving the Asian Fisheries Social Science Research Network of the AFS in 2018, serving as coordinator and later Chair (2019 to 2021). She currently serves as the Constitution Coordinator of the AFS Gender in Aquaculture and Fisheries Section (2017 to present). In the Philippines, she is the founding Executive Director of the National Consortium for Small-scale Fisheries Research and Development with 48 Higher Education Institutions as members.

KEYNOTES

Assoc. Prof Dr Hung Duc Pham

Department of Aquaculture, School of Fisheries and Life Sciences
Nha Trang University, Vietnam

Assoc. Prof. Dr Hung Duc Pham is a senior lecturer and researcher at the Institute of Aquaculture, Nha Trang University, Viet Nam. He received his Bachelor's and Master's degrees in Aquaculture from Nha Trang University and completed his Ph.D. in Environment and Agriculture at Curtin University, Australia.

His research focuses on aquaculture nutrition, aquatic animal physiology, marine fish seed production, and sustainable marine aquaculture development. Over the past several years, he has led and participated in numerous national and provincial research projects related to marine fish nutrition, broodstock management, larval rearing, climate change adaptation, and health management of high-value marine species.

Assoc. Prof. Dr. Hung Duc Pham has published many scientific papers in international journals such as *Aquaculture*, *Aquaculture Nutrition*, *Aquaculture Research*, *Aquaculture Reports*, *Regional Studies in Marine Science*, and *Journal of Fish Biology*. His recent studies have focused on nutrition and feed development for marine fish species including Barramundi (*Lates calcarifer*), giant trevally (*Caranx ignobilis*), pompano (*Trachinotus blochii*), and other commercially important marine fishes.

He is currently actively involved in research and development programs on sustainable marine cage aquaculture, offshore aquaculture technologies, fish health and immunity, and climate-resilient aquaculture systems in Viet Nam.

KEYNOTES

CAGE AQUACULTURE AS AN INTEGRAL PART OF GLOBAL SEAFOOD PRODUCTION

Emeritus Neil Loneragan

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Aquaculture production for maintaining global seafood supply is increasingly important because of the limited scope for growth in production from capture fisheries. Globally, the FAO reported aquaculture production contributed 50% of total animal seafood production in 2021 and reached 52% in 2024. Asian fisheries and aquaculture contribute an estimated 70% to global seafood production and hosts the largest fleet globally and employs 85% of the global workforce in aquaculture and fisheries, supporting millions of livelihoods. These figures assume ever greater significance when the unreported production of small-scale farmers and fishers is considered. The Indo-Pacific region is also a global centre for marine biodiversity conservation. China has led the world in aquaculture production systems, achieving 50% contribution to total animal seafood production in 1992 which has grown to 80% in 2024. The rapid growth of aquaculture in Asia is projected to continue which poses challenges for coastal planning and minimising potential impacts on marine ecosystems, fisheries and biodiversity. It also challenges the development of effective policies and management to achieve growth targets for secure, sustainable seafood supply. These challenges highlight the importance of transdisciplinary and partnership approaches to ensure that sustainable green cage culture continues to meet the growing demand for seafood. This requires us to consider the whole culture system, including the sectors and people involved, supply and value chains and the environment and policies for increasing production. Asian scientists have the capacity, innovation and perseverance to address these challenges which would be enhanced by establishing networks of practioners and developing partnerships with a range of organisations across government, universities, non-government organisations, farmers and the aquaculture industry.

Keywords: *fisheries and aquaculture, Asian aquaculture, fisheries-aquaculture-conservation interactions, social dimensions, partnership*

KEYNOTES

SOME REFLECTIONS ON THE SUSTAINABLE DEVELOPMENT OF CHINA'S DEEP-SEA AND FAR-SEA MARICULTURE

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Against the backdrop of continuous global population growth and a sharp increase in demand for animal protein, expanding new food production spaces has become a critical issue for the future of humanity. As a country with a large population, China faces a particularly arduous task in ensuring food supply security, given its per capita arable land resources are far below the world average. In this context, practicing the "Big Food Concept" and developing deep-sea and far-sea mariculture by tapping into the oceans—which cover 71% of the Earth's surface—are strategic measures for ensuring national food security. This paper systematically reviews China's explorations and practices in the field of deep-sea mariculture over the past two decades, noting that aquaculture equipment is developing towards larger scale, platform-based, and multi-functional systems. Innovative models such as open-sea cages and mobile aquaculture farming vessels have emerged, representing a technological leap from "catching up" to "leading" in certain areas. However, China's deep-sea mariculture industry still faces severe challenges, particularly the threats posed by typhoons and other extreme sea conditions, as well as issues such as huge initial investment, high operational costs, incomplete industrial chains, and an aging aquaculture workforce, which constrain its large-scale sustainable development. Research indicates that the key to solving these problems lies in constructing sustainable profitability models and comprehensively promoting the application of intelligent technologies. By digitalizing all elements of aquaculture, developing growth regulation models, creating operational robots, and integrating smart fishery systems, the industry can achieve precision management and unmanned operations. This is the core strategic path to significantly improve production efficiency, reduce operational risks, and shift the industry from "experience-driven" to "science-driven." Therefore, fostering deep integration of technological innovation and business model innovation is the fundamental guarantee for achieving environmentally friendly and economically viable sustainable development of China's deep-sea mariculture in the future.

Keywords: *Deep-sea and far-sea mariculture; Food security; Big Food Concept; Aquaculture equipment; Intelligentization; Sustainable development*

KEYNOTES

BRIEF INTRODUCTION TO THE PROGRESS IN TILAPIA BREEDING IN CHINA

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Several tilapia species have been introduced to China for farming, especial the strain GIFT has become the predominant farmed strain since the middle of last century. This strain is characterized by its relatively high environmental stress endurance and fast growth. Since introduced into China, the growth rate is further improved in newer strains. However, its low temperature and *Streptococcus agalactiae* vulnerability, have been greatly impacted the farming of Nile Tilapia in recent decades. This presentation will go through a brief introduction for research in the regulatory mechanisms of cold susceptibility, and the key genes we have identified that may confer cold and disease resistance, as well as sex determination. These genes provide usable markers for molecular breeding of improved farming strains.

***Key words**: Tilapia, cold resistant, disease resistant, genetic breeding, sex determination.*

KEYNOTES

AQUACULTURE TRANSFORMATION IN ASIA AND THE PACIFIC REGION

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Asia and the Pacific region dominates global aquaculture production, accounting for over 91% of world output and supplying more than 100 million tonnes of aquatic foods annually. As capture fisheries have plateaued and global demand for aquatic foods is projected to increase by 15% by 2030, sustainable aquaculture intensification and expansion represent the primary pathway to ensuring future food and nutrition security. However, the region faces persistent challenges including unsustainable intensification practices, climate change impacts, limited land and water resources, labor shortages, governance gaps, and a deficit in science and technology innovation. In response, FAO and the Network of Aquaculture Centres in Asia-Pacific (NACA) developed the *White Paper on Aquaculture Transformation in Asia and the Pacific Region*, translating the global "Blue Transformation" vision into a region-specific action framework. This paper presents a comprehensive roadmap built upon five strategic targets: (1) sustaining aquaculture production growth at a minimum 3% annual increase to exceed 103 million tonnes by 2030; (2) improving environmental and climate resilience through better resource-use efficiency, feed transformation, biodiversity conservation, and biosecurity; (3) developing efficient, inclusive, and resilient value chains that promote healthy diets and decent work; (4) strengthening governance through national policy integration, monitoring systems, and certification; and (5) enhancing multi-stakeholder partnerships to accelerate knowledge exchange and investment. The framework adopts a food systems approach that recognizes trade-offs between efficiency and equity, production and environmental protection, and global and local priorities. Central to implementation are National Innovation and Investment Plans (NIIPs), which provide countries with step-by-step guidance to assess baseline conditions, formulate strategic visions, prioritize high-impact actions, develop concrete projects, and establish monitoring and evaluation systems. By shifting from labor-intensive, business-as-usual models to technology- and innovation-driven farming, the transformation agenda seeks to build more efficient, inclusive, resilient, and sustainable aquatic food systems that benefit producers, consumers, and ecosystems across the region.

Keywords: *aquaculture transformation, Blue Transformation, sustainable intensification, National Innovation and Investment Plan (NIIP), Asia-Pacific region*

KEYNOTES

FROM HATCHERY TO HARVEST: EVERY SUCCESSFUL CAGE FARM BEGINS WITH HEALTHY SEED

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The rapid expansion of marine cage aquaculture has positioned it as one of the most important sectors for meeting Asia's growing demand for safe, nutritious, and sustainable aquatic food. However, the long-term success of cage farming depends not only on innovations during the grow-out phase, but also on the quality of fish produced at the very beginning of the production cycle. Every successful cage farm begins with healthy seed, making the hatchery the most critical starting point for sustainable and resilient cage aquaculture. The emphasis of this paper will be placed on the production of robust, disease-resistant, and high-performing seed through improved breeding strategies, precision larval nutrition, enhanced biosecurity, and innovative hatchery practices. The presentation will further examine how functional feeds, microbiome based approaches and precision health management can maximize fish performance while improving production efficiency and environmental sustainability. Recognizing the challenges posed by climate change, emerging diseases, limited coastal resources, and increasing consumer expectations, the paper will also highlight the importance of integrating science, technology, and sustainable management throughout the production chain. By strengthening the foundation of aquaculture, Asia's cage aquaculture industry can enhance productivity, profitability, resilience, and environmental stewardship while making a significant contribution to regional seafood security and the sustainable Blue Economy.

KEYNOTES

BEYOND THE CAGE: RETHINKING AQUACULTURE IN ASIA THROUGH THE LENS OF PEOPLE, POWER, AND SUSTAINABILITY

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Aquaculture has become a cornerstone of Asia's food systems, contributing significantly to food security, rural livelihoods, and economic growth. As cage aquaculture continues to expand under the Blue Economy agenda, discussions often emphasize technological innovation, production efficiency, and investment opportunities. However, the rapid transformation of aquatic spaces also raises critical questions about governance, equity, and sustainability. This keynote argues that the future of cage aquaculture depends not only on producing more fish, but on ensuring that development is socially inclusive, ecologically responsible, and institutionally sound.

Drawing on contemporary debates in common-pool resource governance, Blue Justice, and sustainable development, the keynote examines how cage aquaculture reshapes relationships between people, ecosystems, and institutions. Using evidence from the Philippine experience with mariculture parks, it illustrates how well-intentioned aquaculture initiatives can unintentionally marginalize small-scale fishers, alter access to shared waters, and create unequal distributions of benefits when governance, participation, and transparency are inadequate. These experiences underscore the importance of recognizing water as both a productive resource and a shared common.

The keynote highlights the roles of participatory governance, Marine Spatial Planning, ecosystem based management, and stewardship-oriented licensing systems in balancing aquaculture development with the rights and livelihoods of diverse resource users. Building on the principles of collective action and commons governance, it advocates for interdisciplinary collaboration, meaningful stakeholder engagement, and equitable policy frameworks that strengthen resilience while addressing climate change and competing uses of aquatic resources.

Ultimately, the keynote calls for a shift in how success is measured—from production alone to improvements in human well-being, ecosystem health, social justice, and trust. Moving beyond the cage requires governance systems that enable innovation while ensuring that prosperity, equity, and sustainability advance together across Asia's aquaculture landscapes.

KEYNOTES

MARINE CAGE AQUACULTURE IN SOUTH CENTRAL VIETNAM: CHALLENGES, OPPORTUNITIES, AND FUTURE DIRECTIONS

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Marine cage aquaculture is an important sector supporting coastal livelihoods and the marine economy in South Central Vietnam. Favorable environmental conditions have promoted the farming of high-value species such as cobia (*Rachycentron canadum*), Barramundi (*Lates calcarifer*), grouers (*Epinephelus spp.*), lobsters (*Panulirus spp.*), and marine mollusks. In recent years, culture of carangid species including pompano (*Trachinotus spp.*), golden trevally (*Gnathanodon speciosus*), and giant trevally (*Caranx ignobilis*), as well as sciaenid species such as red drum (*Sciaenops ocellatus*) and blackspotted croaker (*Protonibea diacanthus*), has also expanded rapidly in provinces such as Khanh Hoa, Phu Yen, Ninh Thuan, and Binh Dinh. However, the industry faces several challenges, including environmental pollution, disease outbreaks, dependence on trash fish, unstable seed quality, climate change impacts, and limited technological application. Increasing sea temperature, typhoons, and water quality fluctuations are further threatening farming sustainability. At the same time, opportunities for sustainable development are increasing through government support for offshore aquaculture, technological innovation, and growing seafood demand. Advanced technologies such as HDPE offshore cages, automated feeding, IoT-based monitoring, AI applications, and integrated multi-trophic aquaculture (IMTA) are creating new directions for modern marine farming. This presentation provides an overview of the current status of marine cage aquaculture in South Central Vietnam, highlights key challenges and opportunities, and discusses future strategies for sustainable and resilient development.

***Keywords**: Marine cage aquaculture; South Central Vietnam; Sustainable development; Offshore aquaculture; Aquaculture technology.*

TWO-TIER CAGE CULTURE OF ASIAN SEABASS (*Lates calcarifer*) INVOLVING FISHER COMMUNITIES IN THE COASTAL AREAS OF BANGLADESH

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An experiment was conducted to determine the possibilities of two-tier system (nursery and grow-out stage) cage culture of Asian seabass *Lates calcarifer* in the coast of Munshiganj, Satkhira and Moheshkhali Channel, Cox's Bazar, in six cages (1 for nursery and 2 for grow-out in each location) with direct participation of coastal fisher communities for 365 days. Survival, growth performance viz. weight gain (WG), specific growth rate (SGR), and feed conversion ratio (FCR) (nursery stage); along with proximate composition, gut content, intestinal histology and cost-benefit were analysed in the grow-out stage. In the nursery stage (initial weight 1.05 g), fish fed with 52% crude protein feed at 10–8% of biomass twice a day for 90 days resulted in 61.13 and 57.47% survival rate, 9.20 and 6.98 g WG, 2.53 and 2.26 %/day SGR, 1.97 and 2.85 FCR in Munshiganj and Moheshkhali, respectively. Subsequently, fish was distributed to the grow-out cages at a density of 15 fish/m^3, fed with 45–40% protein supplemented feed at 5–1% of their body weight for 275 days. Result showed significantly higher survival (90.13%), WG (1009.15 g), and lower FCR (1.71) in Munshiganj compared to Moheshkhali (Survival 85.06%, WG 815.93 g, and FCR 1.93). Gut content analysis revealed that fish predated macro-sized natural food inside the cages during the culture period. Cage-cultured fish contained significantly higher amount of protein (highest in Munshiganj 19.07%) compared to the respective wild in both locations. Histo-morphology of intestine revealed that fish intestine was in better condition than as were observed in the wild. Production was higher in Munshiganj (800–840 kg/cage) than Moheshkhali (600–650 kg/cage), thus, benefit-cost ratio was higher in Munshiganj (1.66) compared to Moheshkhali (1.37). This study explored the opportunities of marine cage farming of seabass in Bangladesh, ultimately, will help to increase mariculture production through cage farming of marine finfishes and ensure better food and nutritional security.

Keywords: *mariculture, cage culture, coastal fisher, livelihoods, two-tier aquaculture*

ADAPTATION OF WILD ASIAN SEABASS (*Lates calcarifer*) TO ARTIFICIAL DIETS IN CAGE CULTURE

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This study investigates the adaptation strategy of wild Asian seabass (*Lates calcarifer*) to artificial feed in an open floating cage aquaculture system over a period of 360 days. A total of 1800 wild seabass with an initial length of 19.91 ± 1.40 cm and a weight of 72.85 ± 21.57 g were stocked at a density of 15 fish per m^3 in 60 m^3 circular floating net cages (900 fish in each cage) and subjected to two feeding strategies. In treatment 1 (T1), fish were fed chopped tilapia (*Oreochromis niloticus*) across four feeding stages (S1, S2, S3, and S4). In treatment 2 (T2), fish were fed chopped tilapia as their primary feed in S1, subsequently, chopped tilapia and commercial feed (45% protein) at a 1:1 ratio in S2, followed by commercial feed (45% protein) in S3, and finally formulated feed (37% protein) in S4 at 5-1.2% of their body weight for 90 days in each stage. Significant changes ($p < 0.05$) were found in specific growth rate (SGR) across different feeding stages of the treatments. The overall growth performance included a survival rate of 94.33%, weight gain (WG) of 1035.85 ± 186.71 g, SGR of 0.76 ± 0.06 %/day, feed conversion ratio (FCR) of 2.75, and feed efficiency ratio (FER) of 0.36 in T1. In comparison, T2 exhibited a survival rate of 92.44%, WG of 1221.54 ± 261.78 g, SGR of 0.81± 0.10 %/day, FCR of 2.45, and FER of 0.41. Gut contents analysis revealed that fish predated natural food inside the cages in every feeding stage. Intestine morphology showed significant changes ($p < 0.05$) in different feeding stages of the treatments. Total production of seabass was 904 kg (15.07 kg/m^3) in T1 and 1050 kg (17.5 kg/m^3) in T2. The benefit-cost ratio (BCR) in both T1 and T2 was 1.7, indicating this technique is economically viable.

Keywords: *formulated feed, seabass, physiology, cage culture, coastal water*

OFFSHORE CAGE AQUACULTURE AI APPLICATION FOR PRECISION NUTRITION

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Offshore cage aquaculture is expanding quickly across the globe, with artificial intelligence (AI) increasingly integrated into its operations. Technologies such as sensors, cameras, sonar systems, and data transmission platforms are used to monitor aquaculture environments, infrastructure conditions, and fish-related parameters including behavior, biomass, and feeding activity. The collected data can be consolidated into AI-driven analytical systems, which in turn enable automated management and control of routine aquaculture practices.

Within the grow-out phase of aquaculture, feed represents approximately 60–70% of total production costs. Therefore, accurate information on fish behavior, feeding responses, and biomass estimation is critically important for achieving precise and efficient feeding strategies. Newly developed technologies now allow for the generation of real-time, continuous datasets that link fish growth performance with changing environmental conditions.

By integrating sensor-derived data-such as environmental parameters, fish growth metrics, analytical outputs, and operational adjustments-producers can optimize aquaculture practices to ensure they are both effective and appropriate. This approach introduces a transformative perspective by enabling continuous monitoring without disturbing the fish, unlike traditional fish nutrition studies. Furthermore, these datasets present valuable research opportunities, including understanding nutritional requirements at different life stages and identifying key moments of accelerated growth in relation to environmental factors.

Key words: *AI application, Fish Nutrition*

RETINEX-GUIDED JOINT SOURCE-CHANNEL CODING FOR ROBUST WIRELESS TRANSMISSION OF UNDERWATER AQUACULTURE SURVEILLANCE IMAGERY

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Reliable real-time video surveillance is fundamental to biomass estimation, behavioral monitoring, and health management in modern offshore cage aquaculture. De- spite that, underwater environments impose two com- pounding challenges: severe light attenuation that degrades image quality in densely populated scenes, and bandwidth constraints that limit robust trans- mission over noisy wireless channels. Existing Joint Source–Channel Coding (JSCC) approaches treat these as separate problems and fail to account for the physical optics of underwater degradation, resulting in poor re- construction fidelity under realistic channel conditions. We propose RetiJSCC, an end-to-end deep learning framework that jointly addresses underwater image degradation and efficient transmission. Grounded in Retinex theory, our encoder decomposes each frame into illumination and reflectance components, isolat- ing fish-specific texture from lighting artifacts prior to transmission. An adaptive Transformer-based JSCC backbone then encodes and transmits these components with bandwidth allocation that responds dynamically to real-time channel quality. At the receiver, a physics- informed decoder reconstructs high- fidelity frames by compensating for underwater light attenuation, guided by an identity loss that preserves machine-interpretable visual structure for downstream analysis.

Evaluated across a wide range of channel conditions (5to 20 dB SNR), RetiJSCC outperforms standard JSCC baselines by up to 3dB in PSNR and 0.02 in SSIM, with particularly pronounced gains in low-SNR regimes critical to offshore deployments. These results demon-strate a dependable, bandwidth-efficient pathway for automated remote monitoring, equipping aquaculture operators with consistently high-quality visual data to support stock protection and yield optimization.

Keywords: *Joint Source-Channel Coding, Wireless Video Transmission, Vision Transformers, Retinex Theory, Underwater Image Enhancement.*

LIGHTWEIGHT CONTINUAL ADAPTATION FOR UNDERWATER CAMERA-SONAR OBJECT DETECTION

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Underwater multimodal perception remains fragile under domain shift. Models trained in one site often fail in new environments because water turbidity, lighting change, background structure, acoustic interference, and temporal misalignment alter the joint distribution of camera and sonar observations. As a result, multimodal fusion that performs well in controlled settings can collapse during deployment, even when both sensing streams are still available. This paper presents a lightweight continual adaptation framework for underwater camera-sonar perception, with object detection as the target task. To prevent fusion collapse without relying on unstable parameter updates, the proposed method leverages a cross-modal self-training approach. The framework continuously evaluates the confidence of both sensing streams and uses the dominant to generate high quality pseudo-labels. These self-generated labels are then used to dynamically adjust a set of lightweight attention modules, enforcing feature alignment between the sensors without requiring ground truth target labels or full network retraining. This design allows the model to adjust its representation during deployment without full retraining or access to target labels. Experiments on paired or near- paired public camera-sonar sequences under controlled target shifts show that the proposed method improves target-domain perception, reduces degradation under corruption. These results support continual adaptation as a practical direction for robust underwater multimodal perception in changing environments.

Keywords: *Underwater, Multimodal, Adaptation, Detection, Camera-Sonar*

MECHANISM INVESTIGATION AND OPTIMIZATION DESIGN OF LIQUID DAMPING FOR LOAD REDUCTION AND MOTION SUPPRESSION IN TRUSS NET AQUACULTURE CAGE

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Liquid damping has been widely adopted in marine engineering, yet its mitigation effectiveness is inherently governed by structural geometry. In this study, a tuned liquid column damper (TLCD) is proposed to enhance the broadband motion mitigation performance of a truss net aquaculture cage under wave excitation. The concept extends the isolated tuned liquid dampers previously integrated within hollow columns by interconnecting discrete liquid compartments through pontoon channels, thereby transforming isolated liquid dampers into an interconnected liquid column damping system. A high-fidelity computational fluid dynamics (CFD) model is developed to simulate the coupled interactions among incident waves, cage dynamics, and internal liquid motion, upon which a systematic parametric sensitivity analysis of the TLCD is conducted. Results demonstrate that, compared to the isolated tuned liquid damper configuration, the proposed TLCD effectively couples the gravitational restoring moment generated by the liquid mass with the beneficial damping induced by sloshing loads, achieving superior load reduction and motion suppression by simultaneously attenuating the rotational acceleration and surge of the cage structure. Furthermore, broadband suppression of the pitch response spectrum is realized, and the robustness of the cage motion response across varying wave heading angles is substantially improved. The optimized TLCD design exhibits strong engineering practicability and offers essential design insights for enhancing the survivability and operability of offshore aquaculture systems.

Keywords: *Offshore aquaculture cage; Tuned liquid column damper; CFD; Hydrodynamic response*

AN IMMERSED BOUNDARY METHOD-BASED POROUS MEDIA MODEL FOR AQUACULTURE NETS IN WAVE

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This study couples the continuous forced immersed boundary method with the porous media model to simulate aquaculture nets. The proposed model can predict the hydrodynamics of the netting in waves. Fluid motion is computed by solving the Reynolds-averaged Navier–Stokes equations and the phase equation. During the simulation, a porous media source term is incorporated into the momentum equations, which account for the resistance exerted by the nets on the waves. Owing to the complex geometry of the net–fluid interface, the immersed boundary method is employed to represent this interface. Meanwhile, the porosity and porous media coefficients of the immersed boundary are specified through the definition of the porous media volume fraction. Compared with the original formulation, the improved porous media model alleviates the mesh refinement requirements associated with nets of complex geometry, reduces the number of iterative solves at meshes, and improves both computational efficiency and numerical accuracy. To validate the improved model, the present study tests it against published data. The validation considers the effects of net solidity, the number of net panels, net shape, wave height, and wave period on the hydrodynamic loads acting on the nets and the wave field around the nets. The results show that the relative error between the present numerical model and the published data is less than 6.5%. Under the same wave conditions and mesh number, the computational efficiency of the present model is more than 2.6 times higher than that of the existing porous media model.

Keywords: *aquacultural net, immersed boundary method, CFD, porous media model, hydrodynamics, wave field*

NUMERICAL SIMULATION OF FLOW FIELD CHARACTERISTICS IN A FLOW-DIVERTING DEEP- SEA AQUACULTURE CAGE UNDER EXTREME CURRENT CONDITIONS

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Offshore aquaculture is increasingly important for sustainable protein supply and marine economic development, yet current deep-sea cages face challenges under extreme currents, which can compromise structural safety and fish welfare. This study investigates the hydrodynamic performance of a novel deep-sea cage design incorporating an octagonal frame, double-layer netting, flow-diverting devices, and integrated harvesting compartments. A numerical simulation framework combining STAR-CCM+ with turbulence and porous media models was established and validated against physical test data. Flow field characteristics of individual components and complete cages were analyzed, revealing that the combined structural arrangement effectively reduces flow velocity, enhances vertical uniformity, and mitigates adverse impacts of extreme currents. The findings provide systematic theoretical guidance for optimizing deep-sea cage design and improving offshore aquaculture safety and efficiency.

Keywords: *Offshore aquaculture; Flow field characteristics; Flow diversion; Porous media model; Numerical simulatio*

HYDRODYNAMIC ANALYSIS OF A ROTATABLE HORIZONTAL AQUACULTURE CAGE WITH EXTERNAL FLOATS

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Biofouling and motion instability are important constraints on deep-sea aquaculture cages. This paper presents a rotatable horizontal aquaculture cage with external floats and evaluates its hydrodynamic response under a 50-year return-period extreme sea condition. The cage and float system were modeled in SolidWorks, DesignModeler and ANSYS AQWA. Hydrodynamic loads on the net structure were calculated using the Morison-equation formulation and equivalent drag coefficients. The heave, sway and roll responses of the cage with and without external passive damper floats were compared. The results show that the floats reduce the maximum underwater heave displacement from -5.332 m to -4.111 m and suppress the negative peak roll angle from -14.588° to -8.021°. The sway response is direction- dependent: the positive peak increases slightly, whereas the negative peak decreases. Overall, the external floats provide additional damping and improve the attitude stability and anti-overturning performance of the horizontal cage.

Keywords: *rotatable horizontal aquaculture cage; external float; hydrodynamic response; passive damping; extreme sea condition*

STUDY ON THE SETTLEMENT MOTION CHARACTERISTICS OF TRUSS-TYPE AQUACULTURE CAGE UNDER CORRELATED WAVE-CURRENT LOADS

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To investigate the attitude and safety of aquaculture cages during the settlement process, this study takes “Deep Blue 2” cage as the research object and proposes a numerical simulation method for the whole settlement process based on the structural force function of AQWA. The structural force parameters are calculated by obtaining added mass and damping data through the AQWA diffraction module and establishing a time-domain motion control equation considering variable mass characteristics based on the Cummins equation in MATLAB. In this study, numerical simulations of settlement were conducted under correlated wave-current loads (wave height 1m, current velocity 0.35 m/s), and the results were compared with those under steady water conditions. The results show that the aquaculture cage settlement presents three-stage characteristics: initial stage, rapid stage, and deceleration stage. The influence of correlated wave-current loads shows a phased transition from wave-dominated to current-dominated with increasing settlement depth. The current dominance in deep water makes the aquaculture cage depth 7.8% higher than that under steady water. The sway amplitude decreases from 0.75 m to 0.25 m, and the pitch angle is more sensitive to stage changes, rapidly attenuating to below 0.1^{o} after the rapid stage. This study provides an important reference for the engineering design and safe operation of truss-type aquaculture cage settlement control.

Keywords: *Aquaculture cage; Settlement motion; Structural force; Wave-current loads; Numerical simulation*

INTEGRATED CAGE CULTURE OF ASIAN SEABASS (*Lates calcarifer*) AND RED SEAWEED (*Kappaphycus alvarezii*) IN SIPANGKOT, SITANGKAY, TAWI-TAWI, PHILIPPINES

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Integrated multi-trophic aquaculture (IMTA) enhances nutrient utilization by combining fed and extractive species, thereby improving environmental sustainability. This study evaluated the growth performance of Asian seabass (*Lates calcarifer*) cultured in floating cages integrated with red seaweed (*Kappaphycus alvarezii*) under two stocking densities (15 and 25 fish m^{-3}) over 120 days in Sipangkot, Sitangkay, Tawi-Tawi, Philippines. Fish reared at lower stocking density exhibited significantly higher final weight (410 ± 11 g) and specific growth rate ($p < 0.05$), while seaweed biomass was significantly greater at higher stocking density (3.5 ± 0.1 kg $line^{-1}$), reflecting enhanced nutrient availability from fish-derived wastes. Water quality parameters remained within optimal ranges throughout the experiment, indicating effective nutrient assimilation by seaweed. Economic analysis revealed that 15 fish m^{-3} provided the best balance between fish growth, seaweed production, and profitability. These findings demonstrate that IMTA systems can simultaneously improve productivity and environmental performance in tropical coastal aquaculture.

Keywords: *IMTA, seabass, seaweed, stocking density, nutrient recycling, sustainable aquaculture*

PREVALENCE AND TYPES OF MORPHOLOGICAL ABNORMALITIES OF FINGERLINGS AT MARINE FISH HATCHERIES IN KHANH HOA PROVINCE, VIETNAM

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This study assessed the prevalence and types of morphological deformities in hatchery-produced juveniles of four commercially important marine finfish species, including shortfin pompano (*Trachinotus anak*), snubnose pompano (*Trachinotus blochii*), Asian seabass (*Lates calcarifer*), and golden trevally (*Gnathanodon speciosus*), produced in Khanh Hoa Province, Vietnam. Juveniles with a total length of 3–5 cm were collected from seven marine fish hatcheries. For each species, ten production batches were randomly selected during the study period. Within each batch, samples were obtained from three randomly selected rearing tanks, with 300 fish examined per tank. Morphological deformities were identified, classified, and quantified, and their prevalence was compared among species. Results showed that Asian seabass and shortfin pompano exhibited significantly higher deformity rates (7.28–10.73%) than golden trevally and snubnose pompano (2.85–3.64%). The most common abnormalities in Asian seabass and pompano were opercular deformities and vertebral malformations, whereas opercular swelling was predominantly observed in golden trevally. The findings provide baseline information on the occurrence of deformities in hatchery-produced marine fish juveniles and highlight species-specific differences in deformity prevalence. These results contribute to the development of quality control strategies for marine fish seed production and support efforts to improve hatchery management practices in Khanh Hoa Province.

Keywords: *marine finfish; produced fingerlings; skeletal deformities; morphological abnormalities; marine fish hatcheries*

INFLUENCE OF SEX RATIO ON SPAWNING AND AGGRESSIVE BEHAVIOR OF MANGROVE RED SNAPPER (*Lutjanus argentimaculatus*) BROODSTOCKS IN CAPTIVITY

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The mangrove red snapper, *Lutjanus argentimaculatus*, is an economically important marine fish species whose breeding programs still rely heavily on wild -caught broodstock, raising concerns about resource sustainability. Therefore, developing captive broodstock management using pond-reared fish is essential. This study investigated the effects of different sex ratios on spawning performance and aggressive behavior of captive mangrove red snapper broodstocks. Broodstocks reared in earthen ponds for at least 3 years (3.4–3.9 years old) were used in the experiment. Fish had a standard length of 57.2 ± 0.7–59.4 ± 1.1 cm and body weight of 3.2 ± 0.2 – 3.5 ± 0.1 kg. All broodstocks were induced with luteinizing hormone -releasing hormone analogue (LHRHa) combined with domperidone (Dom) via a single injection. Females received 60 µg LHRHa + 20 µg Dom/kg body weight, while males received 30 µg LHRHa + 10 µg Dom/kg body weight for spawning induction. The fish were stocked in circular canvas tanks (5 m diameter, 1.2 m height, and 15 -ton capacity) under controlled environmental conditions, with water temperature ranging from 27–32°C, salinity of 29–32 ppt, dissolved oxygen 4.3–6.1 mg/L, and pH 7.8–8.0. Two male-to-female sex ratios were evaluated: 2:3 and 3:2 fish per pond, with four replicates per treatment (n = 4). Broodstock behavior, including courtship, spawning activity, and aggressive interactions, was monitored daily through direct visual observation for 30 days after hormone induction. The results showed no significant differences (P>0.05) between treatments in spawning freq uency (2.0 ± 0.8–2.3 ± 0.9 times), fertilization rate (43.2 ± 20.5–43.8 ± 23.9%), or hatching rate (10.5 ± 8.3–11.7 ± 9.0%). However, aggressive behavior was more severe in the 2:3 ratio treatment, resulting in injuries and female mortality, with a loss rate of approx imately 25.0 ± 10.0%. In contrast, the 3:2 ratio treatment showed significantly lower broodstock mortality (5.0 ± 10.0%) and reduced aggressive interactions. These findings suggest that both sex ratios can support successful spawning under captive conditions; however, the 3:2 ratio appears to be more suitable for broodstock management due to lower aggression and mortality.

Keywords: *Red snapper; Marine fish breeding; Fish aggressive behavior; Broodstock management*

ASSESSMENT OF OXYGEN CONSUMPTION AND INFLUENCE OF WATER TEMPERATURE ON ROTIFER (BRACHIONUS ROTUNDIFORMIS) GROWTH EFFICIENCY USING MACHINE LEARNING

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Machine learning (ML) is increasingly pivotal in fisheries and aquaculture, including the cultivation of live feeds. For live feeds cultivation, this study employed ML techniques to evaluate and predict the growth rate (GR) of marine rotifer (Brachionus rotundiformis) by analyzing from oxygen consumption rate (RO2) and water temperature. An initial exploratory analysis applied K-means clustering to assign GR into three groups: group 1 (0.531/day GR). Subsequently, multiple predictive models were developed and benchmarked to compare accuracy: random forest (RF), decision tree (DT), and deep learning (DL). The study results from the evaluation data (n = 150) indicated that RO2 was the most influential variable governing classification outcomes, while temperature played a secondary role. Predictive performance differed among models, with RF achieving the highest accuracy (82.50%), followed by DT at 75.83% and DL at 45.00%. The RF algorithm demonstrated superior predictive performance based on RO2 and temperature variations in rotifer growth efficiency compared with DT and DL. The RF evaluation results showed that GR of rotifer depended primarily on RO2 levels, with water temperature serving as a contributing factor. Rotifer exhibited high GR when RO2 was ≤ 0.003 µL/h, while those with low growth required RO2 > 0.013 µL/h. Furthermore, at water temperatures not exceeding 28 °C, rotifer with RO2 in the 0.003–0.012 µL/h range achieved moderate to high GR. These results demonstrate the potential of ML as a practical tool for optimizing rotifer culture management.

Keywords: *Live feed cultivation; Machine learning model; Model prediction performance; Rotifer growth rate.*

EFFECTS OF REARING DENSITY ON JUVENILE MALABAR RED SNAPPER *Lutjanus malabaricus*

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The present study aimed to determine the effects of density on juvenile Malabar red snapper. Malabar red snapper (body weight of 0.16±0.01 g; total length of 1.77±0.03 cm) were randomly assigned to fifteen conical fiberglass tanks (120 L) with five rearing densities, including 0.5 (D1); 0.75 (D2); 1.0 (D3); 1.25 (D4) and 1.5 (D5) individuals/L. Each rearing density was run in triplicate tanks. The fish were fed ad libitum by hand with NRD (INVE, Thailand) pellets of 500 - 1.200 µm, contained 55,0% protein and 9,0% lipid at 7:00, 10:00, 14:00 and 17:00, for a period of 35 days. The experiment was run at indoor condition with rearing temperature of 27 – 30 ºC, salinity of 30 – 33‰, pH of 7.8 – 8.2, DO > 5.0 mg/L and TAN (total ammonia nitrogen) < 1.5 mg/L. Results from the present experiment indicated that rearing density affected growth in body weight and body length, FCR and survival rate in juvenile Malabar red snapper ($P<0.05$). The juvenile from D2 performed better growth and survival rate than those fish at either densities of D1 or D5. Meanwhile, the fish reared at D3 and D4 did not differ significantly from those fish in D2, D1 or D5 in growth and survival rate. Futher, the juvenile at D2 showed the best in FCR, followed by than those from D3, D4 and D5. The fish at D1 showed the poorest in FCR. These results indicate that a density of 0.75 -1.0 individuals/L is suitable for rearing this species.

Keywords: *Malabar red snapper, Lutjanus malabaricus, rearing density, growth, survival rate*

EFFECTS OF LIGHT INTENSITY AND SPAWNING INDUCTION METHODS ON GONADAL MATURATION, BIOCHEMICAL PROFILES, AND REPRODUCTIVE EFFICIENCY OF *PAPHIA UNDULATA*

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Optimizing broodstock conditioning and spawning induction is critical for sustainable hatchery production of the surf clam *Paphia undulata*. This study evaluated the effects of light intensity during broodstock conditioning and subsequently assessed the influence of different spawning induction methods on reproductive physiology and performance. Broodstock (shell length ≥ 44 mm) were conditioned for 21 days under low (20–300 lux), moderate (500–3,000 lux), and high (5,000–8,000 lux) light intensities. Gonadal maturation, survival, condition index, and soft tissue biochemical composition were assessed prior to spawning induction. Light intensity significantly influenced reproductive development ($p < 0.05$). Moderate light (500–3,000 lux) yielded the highest maturation rate (82.67%), promoted lipid accumulation (0.70%) and protein content (10.86% wet weight), and improved survival compared with high-light conditions. Following conditioning, broodstock were induced to spawn using thermal shock, ultraviolet irradiation, and NH4OH immersion. Spawning induction methods significantly affected reproductive outcomes. Thermal shock produced a shorter response time (98 min), higher spawning rates (78.8%), greater fecundity (454,200 eggs), and superior fertilization (76.6%) and hatching success (78.0%) compared with ultraviolet and NH_4OH treatments ($p < 0.05$). Reproductive performance was strongly associated with both the physiological status achieved during conditioning and the induction technique applied. These results demonstrate that moderate photoregulation and thermal shock induction provide an effective strategy for maximizing reproductive efficiency and improving artificial seed production of *Paphia undulata*.

Keywords: *broodstock conditioning, photoregulation, spawning induction, reproductive physiology, Paphia undulata*

SEED PRODUCTION OF MALABAR RED SNAPPER *Lutjanus malabaricus* IN KHANH HOA: HATCHERY CASE STUDIES

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Malabar red snapper is a potential species for aquaculture due to its highly valuable market, although production of the species is hampered because of a lack of seed production protocols. The present study presented results on seed production of Malabar red snapper at two hatcheries in Khanh Hoa province (Vinh Luong Hatchery – H1 and Cam Ranh Hatchery – H2) which contribute to optimize seed production protocols for the species. Broodstock fish were reared in sea-cages in the Nha Phu lagoon. The broodstocks were regularly checked for induced spawning. Matured females were injected with HGC 1,300 IU + LRHa 50 µg/kg, while a half dose was applied for the males. The fertilized eggs of the same spawned batch were transferred to the hatcheries for incubation and larvae rearing for 75 days. Larvae of 2 to 17 day post hatched (DPH) were fed with A1 DHA Selco-enriched rotifer. While, larvae from the 14 DPH onward, until 28 DPH were fed with DHA protein Selco-enriched nauplius *Artemia.* The larvae were trained to fed on artificial pellets of 300-500 µm from 25 DPH for 7 days before totally offered by pellets of 500 – 1,200 µm (NRD, INVE). Results on hatching rate at H1 and H2 were 87 and 85%, respectively. Survival rate of the 1 DPH to 2.0-2.5 cm larvae were 6.55±0.09 and 6.42±0.08%. Meanwhile, survival of larvae from 2.0-2.5 cm to juvenile > 5.0 cm were 86.61±2.48 and 83.96±2.25%. A total of 24,562 Malabar red snapper juvenile (ca 5.0 – 6.5 cm) were produced.

Keywords: *Malabar red snapper, hatchery, larvae, juvenile, survival rate*

SELECTIVE BREEDING PROXIES FOR FEED EFFICIENCY IN BARRAMUNDI *Lates calcarifer*

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Despite the potential high-value impact on productivity, feed efficiency is rarely included as a direct trait for selective breeding in aquaculture programmes due to the individual phenotyping complexity. Weight maintenance under repeated periods of feed deprivation has been identified as a high-feasibility proxy to evaluate feed efficiency and has been shown to have a high genetic correlation with FCR in species such as European seabass.

In this presentation we demonstrate levels of suitability for leveraging this proxy across multiple species including barramundi. Individuals (N=911) were evaluated for ability to maintain weight under 2 periods of 21 days of feed deprivation flanked by restricted feeding regimes of 21 days each. Weight maintenance under feed deprivation was shown to have moderate heritability (0.30) and therefore suitable for selective breeding. Individuals of the highest (N=50; mean Daily Growth Coefficient = -0.78) and lowest ability (N=50; mean DGC= -1.23) to maintain weight were then tested for feed efficiency validation. Population feed efficiency was evaluated for each low and high group across 4 periods of restricted feeding each of 21 days. The population that lost more weight during feed deprivation was consistently shown to have increased feed efficiency across the 4 feeding periods (FCR 1.20±0.27) compared to the population that lost more weight during feed deprivation (FCR 1.31±0.33). Commercial applications to implement this as a selective breeding strategy across species and in barramundi are discussed.

***Keywords**: Barramundi, genetics, feed-efficiency*

EVALUATION OF STOCKING DENSITY ON GROWTH PERFORMANCE AND SURVIVAL OF GLASS EEL (*Anguilla marmorata*) IN A CONTROLLED INDOOR REARING SYSTEM IN HO CHI MINH CITY, VIETNAM

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The giant mottled eel (*Anguilla marmorata*) represents a high-value species in Vietnam's aquaculture sector, with increasing reliance on wild-caught glass eels sourced both domestically and from regional suppliers, particularly Indonesia and the Philippines. Despite its economic importance, the nursery phase remains a critical constraint, as substantial mortality commonly occurs during the transition from glass eel to elver. This study investigated the combined effects of stocking density and rearing conditions on the survival and growth performance of *A. marmorata* cultured in indoor systems. A 90-day experiment was implemented using three stocking densities (200, 225, and 250 individuals m^{-3}), each arranged in triplicate units. Fish were provided with a commercial formulated diet (Hayan, Taiwan) throughout the trial. Key water quality variables were systematically recorded, including temperature, pH, dissolved oxygen (DO), ammonia (NH_3), and nitrite (NO_2^-). Environmental conditions remained within acceptable ranges, with mean values of 28.44 ± 1.48°C for temperature (25.2–31.1°C), pH 7.85 ± 0.18 (7.5-8.2), DO 6.18 ± 0.19 mg L^{-1} (5.9–6.5 mg L^{-1}), NH_3 0.19 ± 0.10 mg L^{-1} (0–0.5 mg L^{-1}), and NO_2^-0.05 ± 0.06 mg L^{-1} (0–0.2 mg L^{-1}). At the conclusion of the trial, mean survival reached 64.87 ± 9.97%, with values ranging from 53.18% to 77.54%, while individual weight gain averaged 1.39 ± 0.06 g $fish^{-1}$. The total length (TL) reached 11.7 ± 0.06 cm (11.8–13.7cm). Statistical analysis indicated no significant differences among stocking densities in terms of survival, growth, or feed conversion ratio (FCR) ($p > 0.05$). Nevertheless, the lowest density (200 fish m^{-3}) consistently yielded more stable performance and is therefore considered more suitable under the tested conditions. These findings underscore the dominant role of environmental stability, rather than stocking density alone, in determining the success of nursery rearing for *A. marmorata* in indoor culture systems in Ho Chi Minh City, Vietnam.

Keywords: *indoor aquaculture system, glass eel nursery, Anguilla mamorata, giant mottled eel, parameters, survival rate, stocking density*

HCP65 REGULATES IMMUNITY AND BIOMINERALIZATION IN HYRIOPSIS CUMINGII VIA THE NF-KB SIGNALING PATHWAY

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The NF-κB signaling pathway regulates immune responses, wound healing, and biomineralization. Although these processes are often studied separately, shell regeneration and pearl formation in Hyriopsis cumingii offer a model to explore their link. The role of NF-κB in biomineralization in this species remains unclear. We established shell regeneration and nucleus implantation models, inhibited Hcp65 expression, and used transcriptome analysis to study NF-κB's regulatory mechanisms in immunity and biomineralization. Transcriptome analysis showed that differentiallyexpressed genes were mainly enriched in functions related to cellular structure, binding, and catalytic activity, with significant enrichment in signal transduction, immune system, and cancer-related pathways. Hcp65 inhibition reduced the expression of immune genes (IL-17, TNF-α) and biomineralization genes (CA3, CHS1, Nacrein, pif), impaired pearl sac cell development, and disrupted calciumcrystal deposition. This study provides the first evidence that Hcp65 exerts dual regulatoryeffects on immunity and biomineralization in H. cumingii via the NF-κB signalingpathway, offering new insights into the molecular mechanisms underlying transplantation immunity in pearl mussels.

***Keywords**: Hyriopsis cumingii; NF-κB signaling pathway; Immune response; Biomineralization*

BROODSTOCK CAPTIVITY, INDUCED SPAWNING AND SEED PRODUCTION OF GOLDEN TREVALLY (*Gnathanodon speciosus*)

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Golden trevally (*Gnathanodon speciosus*) is a high-value marine fish whose seed supply remains heavily dependent on wild capture, posing a major constraint on aquaculture development. This study aimed to establish a complete artificial seed production protocol for this species in South Central Vietnam. Broodstock (n = 70; 1.61 ± 0.3 kg/fish) were maintained in sea cages and fed fresh fish supplemented with squid and shrimp twice weekly, achieving survival rates of 91.4–97.1% and a maturation rate of 75.05%. Dietary supplementation with squid and shrimp significantly improved maturation, fecundity, and egg quality compared to fresh fish alone. A single injection of 1,000 IU HCG + 40 µg LHRHa/kg female induced spawning within 31.5–39.0 hours; fecundity was 134,995 eggs/kg female; fertilization rate was 81.22%, and hatching rate was 82.3%. Eight spawning events yielded 15,870,000 eggs and 9,824,000 hatchlings. Fry-to-fingerling rearing (1.6–2.0 cm) at 10–15 larvae/L in blue- background tanks, with DHA-enriched live feed offered four times daily and weaning onto Otohime-B1 initiated at day 16 post-hatch, achieved 21.94% survival. Fingerling-to-juvenile rearing (4.9–5.4 cm) at ≤ 2 juveniles/L, salinity 25–35‰, and commercial pellets fed eight times daily yielded 76.12% survival. Three production trials produced 97,300 juveniles (4.9–5.4 cm). This is the first study in Vietnam to establish a complete technical framework for artificial seed production of golden trevally, providing a critical foundation for commercial- scale aquaculture development of this species.

Keywords: Gnathanodon speciosus*; broodstock captivity; induced spawning; larval rearing; seed production.*

EFFECTS OF FEEDING FREQUENCY ON GROWTH PERFORMANCE, SURVIVAL RATE, AND FEED CONVERSION RATIO OF JUVENILE HYBRID GROUPER (*Epinephelus lanceolatus* ♂ × *Epinephelus coioideS* ♀) REARED IN SEA CAGES

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A 60-day experiment was conducted to evaluate the effects of feeding frequency on growth performance, survival rate (SR), and feed conversion ratio (FCR) of juvenile hybrid grouper (*Epinephelus lanceolatus* ♂ × *Epinephelus coioides* ♀) reared in floating sea cages (8 m^3/cage) at Dam Bay Marine Station, Khanh Hoa Province, Vietnam. The juveniles (initial total length: 8.1 ± 0.3 cm; body weight: 12.2 ± 0.5 g) were stocked at 35 fish m^{-3} and randomly assigned to four feeding frequencies (n = 4 replicates per treatment): once (at 11:00; NT1); twice (07:00 and 17:00; NT2); three times (07:00, 11:00, and 17:00; NT3); and four times a day (07:00, 11:00, 15:00, and 17:00; NT4). The fish were offered commercial pellet feed (46–55% crude protein; supplemented with probiotics at 3 g kg^{-1} feed three days per week) at a ration of 5–7% body weight day^{-1}. Results demonstrated that feeding frequency significantly influenced growth performance, SR, and FCR of the juvenile hybrid grouper ($P < 0.05$). The fish fed three times a day (NT3) achieved the highest final body weight (48.6 ± 0.64 g), weight gain (36.4 ± 0.64 g), and specific growth rate in weight (2.30 ± 0.02 % day^{-1}), together with the highest biomass production (1.50 ± 0.03 kg m^{-3}). NT3 also showed the highest SR (88.3 ± 0.96%), the lowest FCR (1.88 ± 0.04), and the most uniform growth with the lowest coefficient of variation for body weight (CVW: 0.56 ± 0.08%). Increasing feeding frequency to four times a day (NT4) yielded no further significant improvements in growth, SR, or FCR. Meanwhile, fish fed only once a day (NT1) exhibited the lowest growth performance, the highest FCR (2.15 ± 0.03), and the poorest SR (71.6 ± 1.04%). These findings indicate that feeding three times a day is the optimal feeding frequency for juvenile hybrid grouper during the early cage-rearing phase, maximizing growth, feed utilization, and size uniformity.

Keywords: *Hybrid grouper; Epinephelus lanceolatus × E. coioides; feeding frequency; growth performance; survival rate; sea cage.*

GENETIC MECHANISM OF BODY COLOR VARIATION IN COMMON CARP

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Colorations play a crucial role in the ecological adaptation and communication strategies of various organisms in the natural world. The Oujiang colour common carp, a variant of the common carp, display red, black and white colorations. We observed red is dominant to white colorations and black is dominant to no-black colorations with the Mendelian law of single-locus inheritance. Recently, we identify that the white coloration arises from cis-regulatory disruption of the *Scarb1* gene, caused by a 347 bp transposable element (TE) insertion in its promoter, whereas red coloration retain a TE-free regulatory architecture, the TE insertion abolishes binding of the key transcription factor *Sox14*, silencing *Scarb1* expression and disrupting carotenoid absorption and transport programs, leading to carotenoid-deficiency and white morph formation. For black coloration, a 232 bp deletion in promoter of *Ptprt* gene in Oujiang color common carp with no-black patches disrupts *Tfap4* binding, leading to reduced Ptprt expression and dephosphorylating Gsk3β, and then modulating downstream melanogenic signaling and enhancing MITF-dependent melanocyte proliferation in black coloration. Together, our findings define the structure variation (SV) derived cis-regulatory allele underlying coloration in common carp.

***Keywords**: Color polymorphism; structure variation; cis-regulatory rewiring; gene function*

HISTOLOGICAL TRANSFORMATION OF THE GONAD FROM SEX DIFFERENTIATION TO FEMALE-TO-MALE SEX REVERSAL IN THE ORANGE-SPOTTED GROUPER *Epinephelus coioides*

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Sex differentiation and female-to-male sex reversal in the orange-spotted grouper (*Epinephelus coioides*) are regulated by coordinated endocrine and molecular mechanisms involving the hypothalamic–pituitary–gonadal (HPG) axis, steroid hormones, and the reciprocal regulation of ovarian-associated genes (*cyp19a1a* and *foxl2*) and testicular-associated genes (*dmrt1*, *amh*, and *sox9*). These regulatory processes drive progressive gonadal remodeling from an ovary to a functional testis. This study provides a comprehensive histological characterization of gonadal development throughout the reproductive life cycle of *E. coioides*. Early gonadal differentiation was characterized by ovarian cavity formation and the coexistence of primordial male and female germ cells within the bipotential gonad, followed by ovarian development through oogonial proliferation and oocyte growth. During sex reversal, degenerating ovarian follicles were gradually replaced by proliferating spermatogenic cells, ultimately resulting in the formation of a functional testis. These findings establish a continuous histological framework linking gonadal differentiation with natural sex reversal and provide a valuable morphological basis for studies of reproductive endocrinology and broodstock management in grouper aquaculture.

Keywords*: Epinephelus coioides; gonadal histology; sex differentiation; female-to-male sex reversal; gonadal remodeling*.

MOLECULAR CHARACTERIZATION OF WNT4 AND VASA DURING GONADAL DIFFERENTIATION IN ORANGE-SPOTTED GROUPER (*Epinephelus coioides*)

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The orange-spotted grouper (*Epinephelus coioides*) is a protogynous hermaphrodite and an important marine aquaculture species in Asia. This study characterized two key genes involved in gonadal differentiation, Wnt4 and Vasa. Partial cDNA fragments of Wnt4 and Vasa containing the conserved Wnt family and DEAD-box helicase domains were successfully cloned. Amino acid sequence analysis revealed high conservation among vertebrates, with 100% identity of Wnt4 and 92% identity of Vasa to black porgy (*Acanthopagrus schlegelii*). An absolute quantitative real-time PCR platform was established for future expression analyses. Functional interpretation suggests that Wnt4 regulates ovarian somatic differentiation by promoting ovarian development and suppressing testicular pathways, whereas Vasa functions as a conserved germ-cell marker involved in germ-cell maintenance and oocyte development. These findings provide new molecular insights into ovarian differentiation and establish a foundation for future studies on reproductive regulation and sex control in protogynous groupers.

Keywords: *Wnt4; Vasa; Gonadal differentiation; Epinephelus coioides*

TEMPERATURE AS A REGULATORY DRIVER OF MICROALGAL DEMAND AND SELECTIVE FEEDING IN BLACK TIGER SHRIMP *Penaeus monodon* LARVAE UNDER VIETNAMESE HATCHERY CONDITIONS

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Temperature is a primary ecological regulator of metabolic activity and trophic dynamics in marine crustacean larvae, yet its role in mediating quantitative feed demand and qualitative microalgal selection remains poorly understood under tropical hatchery conditions. This study evaluated the combined effects of two temperature regimes 26 and 30°C and three microalgal diets including single-species diet of *Chaetoceros muelleri*, *Thalassiosira weissflogii*, and a 1:1 mixture based on cellular carbon content on survival, growth, developmental progression, feeding rate, and selective feeding behavior of Moana strain black tiger shrimp *Penaeus monodon* during Zoea stages. Microalgal demand increased ontogenetically from Zoea 1 to Zoea 3 and was significantly influenced by both temperature and algal species. At 26°C, larvae consumed *C. muelleri* from 373 $\times 10^3$ to 1,291 $\times 10^3$ cells/larva/day, increasing to 598 $\times 10^3$ to 2,016 $\times 10^3$ cells/larva/day at 30°C. In contrast, ingestion of *T. weissflogii* remained substantially lower and comparatively stable across temperatures. Despite markedly higher numerical ingestion of *C. muelleri*, consistently negative preference index values confirmed a stable selective bias toward *T. weissflogii*, independent of temperature and developmental stage. At 30°C, larvae fed *T. weissflogii* achieved the highest survival 78.0%, shortest Zoea– Mysis transition time 79.5 h, and greatest Mysis 1 length 3.84 mm. These findings demonstrate that temperature amplifies feed demand without overriding intrinsic dietary preference, providing a scientific basis for temperature-responsive nutritional strategies to enhance efficiency, sustainability in tropical shrimp hatcheries and contributing the seacage cultures development.

Keywords: *larval development, microalgal nutrition, selective feeding, temperature, Penaeus monodon*

EFFECTS OF DIETARY CHITOSAN SUPPLEMENTATION ON GROWTH PERFORMANCE, HEMATOLOGICAL PARAMETERS, AND THERMAL STRESS TOLERANCE IN JUVENILE COBIA (*Rachycentron canadum*)

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Aquaculture species are increasingly exposed to elevated water temperatures due to climate change, leading to impaired growth performance and weakened immune function. Nutritional interventions, particularly the use of dietary immunostimulants, may help mitigate the adverse effects of thermal stress. This study evaluated the effects of dietary chitosan supplementation on growth performance, feed utilization, whole-body composition, and hematological and immune responses of juvenile cobia reared under two temperature regimes: normal (30°C) and elevated (34°C). Juvenile cobia (initial weight ~10 g) were fed diets containing 0, 10, or 20 mg chitosan/kg feed for 10 weeks in a factorial experimental design (n = 3 replicates per treatment) under the two temperature conditions. Measured parameters included growth rate, feed conversion ratio (FCR), proximate body composition, organosomatic indices, and hematological and immune indicators (white and red blood cell counts, hemoglobin concentration, hematocrit, and serum lysozyme activity). Results showed that supplementation with 20 mg/kg chitosan significantly increased final body weight and specific growth rate while improving FCR, with the most pronounced effects observed at 34°C. Fish fed 20 mg/kg chitosan at 34°C achieved the highest final weight (~47.3 g) and superior FCR (1.23 compared to 2.37 in the control group). Chitosan supplementation markedly enhanced whole-body protein and lipid retention, particularly at 30°C, and partially compensated for protein and energy losses caused by exposure to 34°C. Hematological analysis revealed significant increases in red and white blood cell counts, hemoglobin concentration, hematocrit, and serum lysozyme activity in chitosan-fed fish compared to the control group, with the 20 mg/kg inclusion level providing the strongest immunostimulatory effect. Notably, even under thermal stress (34°C), cobia fed chitosan maintained immune parameters at levels comparable to fish reared at 30°C. These findings demonstrate that low-dose dietary chitosan supplementation, particularly at 20 mg/kg, significantly enhances growth performance, feed efficiency, and innate immunity in juvenile cobia, thereby mitigating the detrimental effects of elevated rearing temperature. Chitosan shows strong potential as an effective nutritional immunostimulant to improve thermal stress resilience in cobia aquaculture.

Keywords: *cobia, chitosan, thermal stress, growth performance, immunostimulant, climate change*

VITAMIN C IMPROVES GROWTH AND IMMUNITY OF RED DRUM (*Sciaenops ocellatus*) UNDER ELEVATED TEMPERATURE

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This study evaluated the combined effects of dietary vitamin C supplementation and elevated temperature on growth performance, feed utilization, biochemical composition, hematological parameters, vitamin C accumulation, and innate immune response of juvenile red drum (*Sciaenops ocellatus*). Fish (initial weight 1.2–2.1 g) were reared for 10 weeks under two temperature regimes (30°C and 34°C) and three dietary vitamin C levels (0, 200, and 400 mg/kg) in a factorial design. Results showed that both temperature and dietary vitamin C significantly affected growth and physiological performance. Fish reared at 30°C exhibited higher final body weight and better feed conversion ratio than those at 34°C. Increasing dietary vitamin C improved growth performance, with the highest final weight and lowest FCR observed at 400 mg/kg. Protein efficiency and protein retention were also enhanced with vitamin C supplementation. Whole-body protein and lipid contents increased with higher dietary vitamin C levels, particularly at 30°C. Vitamin C accumulation in liver and body tissues rose proportionally with dietary inclusion. Hematological parameters (WBC, RBC, hemoglobin, hematocrit) and lysozyme activity were significantly improved by vitamin C supplementation, with the strongest immune response observed at 400 mg/kg under 30°C. Elevated temperature (34°C) negatively affected several growth and blood parameters, indicating thermal stress. Overall, rearing juvenile red drum at 30°C with dietary supplementation of 400 mg/kg vitamin C significantly enhances growth, feed efficiency, biochemical composition, and innate immunity. These findings suggest that optimized vitamin C nutrition can mitigate thermal stress and improve aquaculture performance under climate warming conditions.

Keywords: *red drum, Sciaenops ocellatus, vitamin c supplementation, thermal stress, growth performance, hematological parameters, lysozyme activity*

EFFECTS OF COMBINED DIETARY VITAMIN C AND CHITOSAN SUPPLEMENTATION ON JUVENILE COBIA (*Rachycentron canadum*) UNDER HIGH-TEMPERATURE STRESS

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Climate change is increasing the frequency of marine heatwaves, exposing marine aquaculture species such as cobia (*Rachycentron canadum*) to elevated thermal stress. This study evaluated the effects of dietary supplementation with vitamin C and chitosan on growth performance, feed utilization, and stress resistance of juvenile cobia reared under high-temperature conditions. Juvenile fish (initial weight ~7 g) were fed for 10 weeks a basal diet (55% protein, 9% lipid) either without supplementation or supplemented with 400 mg vitamin C·kg^{-1} and 10–20 mg chitosan·kg^{-1}. Fish were reared at 30°C (normal condition) or 34°C (thermal stress), with three replicates per treatment. Elevated temperature (34°C) significantly reduced growth rate, feed efficiency, and whole-body lipid content compared with 30°C ($p < 0.01$). However, dietary vitamin C and chitosan partially mitigated these adverse effects. At 30°C, fish fed 400 mg vitamin C + 20 mg chitosan achieved the highest weight gain and best FCR (1.61 vs. 2.07 in the control group). Under thermal stress, supplemented groups maintained higher growth and feed efficiency than the non-supplemented group (FCR 1.90 vs. 2.24). Dietary supplementation also enhanced protein retention and immune responses. Red blood cell and white blood cell counts, hemoglobin concentration, and plasma lysozyme activity were significantly higher in supplemented fish ($p < 0.05$), even at 34°C. Notably, lysozyme activity in supplemented fish at 34°C was comparable to that of fish reared at 30°C, indicating improved thermal stress tolerance. No mortality was observed in any treatment. In conclusion, elevated temperature impaired growth and physiological performance of juvenile cobia, whereas combined dietary vitamin C and chitosan supplementation improved growth, feed efficiency, and innate immunity. This nutritional strategy may enhance thermal resilience of cobia under ocean warming scenarios.

Keywords: *cobia, vitamin c, chitosan, thermal stress, growth performance, immunity, climate change*

EFFECTS OF DIETARY VITAMIN C SUPPLEMENTATION ON GROWTH PERFORMANCE, IMMUNE RESPONSE, AND SKELETAL INTEGRITY OF GOLDEN POMPANO *Trachinotus blochii* JUVENILES

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Dietary vitamin C plays essential roles in growth, immunity, and skeletal development in marine fish due to their limited ability to synthesize ascorbic acid. This study evaluated the effects of dietary vitamin C on growth performance, innate immunity, hematological responses, and skeletal morphology of juvenile *Trachinotus blochii* under intensive culture conditions. Fish were fed experimental diets containing 43% fishmeal and analyzed vitamin C concentrations ranging from 7.30 to 786.30 mg/kg diet. Dietary vitamin C supplementation significantly improved growth performance, feed utilization, hematological parameters, and innate immune responses ($p < 0.05$). Fish fed diets containing approximately 99.60–186.50 mg vitamin C/kg showed higher weight gain, improved protein utilization efficiency, lower feed conversion ratio, and elevated serum protein and lysozyme activity compared with the unsupplemented control. White blood cell count, red blood cell count, hemoglobin concentration, and respiratory burst activity also increased following vitamin C supplementation, indicating enhanced physiological condition and immunocompetence. Skeletal examination revealed no vertebral, rib, or fin deformities across all dietary treatments. However, excessive dietary vitamin C levels did not provide additional improvements in several physiological and biochemical parameters. These findings indicate that dietary vitamin C levels around 100–200 mg/kg optimize growth, physiological condition, and innate immunity while maintaining normal skeletal development in juvenile *T. blochii*, providing a practical basis for micronutrient management in intensive marine aquaculture.

Keywords*: dietary vitamin C; growth performance; innate immunity; Trachinotus blochii*

COST-REDUCTION AND EFFICIENCY-IMPROVEMENT EFFECTS OF CAROTENOID COMBINATION STRATEGIES BASED ON A COMPREHENSIVE EVALUATION FRAMEWORK IN *Penaeus vannamei* AQUACULTURE

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Carotenoids play critical roles in body coloration, immune regulation, and stress resistance in Pacific white shrimp (*Penaeus vannamei*). However, under intensive aquaculture conditions, insufficient carotenoid supply often leads to quality-related problems such as dull body coloration and impaired health status. Although astaxanthin exhibits outstanding biological efficacy, its high cost limits its large-scale application. To identify alternative carotenoids with both biological benefits and cost advantages, five carotenoids, namely β-carotene, zeaxanthin, lutein, canthaxanthin, and astaxanthin, were compared based on their optimal dietary inclusion levels. An AHP-CRITIC- TOPSIS multi-criteria evaluation model was then applied to comprehensively assess their performance in terms of growth performance, health status, product quality, and economic feasibility. The results showed that the five carotenoids had similar scores for growth performance, while astaxanthin achieved the highest score for health-related indicators (0.81), and β-carotene showed the best performance in product quality (0.63). These findings indicate that different carotenoids can significantly improve the multidimensional performance of P. vannamei, although their functional priorities differ. Furthermore, response surface methodology was used to optimize the combined supplementation of three key carotenoids. Significant synergistic effects were observed among β-carotene, astaxanthin, and canthaxanthin. Validation trials further demonstrated that this carotenoid combination significantly enhanced astaxanthin accumulation and antioxidant capacity in shrimp, while reducing the supplementation cost by approximately 60% compared with astaxanthin alone. In conclusion, synergistic carotenoid combination strategies can maintain growth performance, improve body coloration and product quality, and substantially reduce additive costs, providing an efficient and economical nutritional regulation strategy for intensive *P. vannamei* aquaculture.

Key words: *carotenoids, Penaeus vannamei, AHP-CRITIC-TOPSIS comprehensive evaluation method, combination strategy*

DIETARY LEMONGRASS *Cymbopogon citratus* AQUEOUS EXTRACT ENHANCES GROWTH PERFORMANCE, FEED EFFICIENCY, AND MORPHOMETRIC DEVELOPMENT WITHOUT AFFECTING HEMATOLOGICAL HEALTH OF RED TILAPIA *Oreochromis* spp.

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This study evaluated the effects of dietary supplementation with aqueous *Cymbopogon citratus* (lemongrass) on the growth performance, feed utilization, morphometric traits, biometric indices, and hematological status of red tilapia (*Oreochromis* spp.). A 60-day feeding trial was conducted using 360 fingerlings (mean initial length = 3 cm), randomly assigned to four dietary treatments: control, 10 g/kg, 20 g/kg, and 30 g/kg lemongrass extract, each with three replicates. Fish were fed four times daily, and growth performance, morphometrics, biometric indices, and hematological parameters were systematically measured. Results showed that lemongrass supplementation significantly improved growth performance, with higher final weight, weight gain, and specific growth rates observed in all supplemented groups compared to the control ($p < 0.05$). Feed utilization was enhanced, as indicated by lower feed conversion ratios and increased biomass, particularly at 20 g/kg. Morphometric analysis revealed significant increases in total length, standard length, head length, snout length, and fin dimensions at 20 g/kg. In contrast, pelvic fin length, eye diameter, and caudal peduncle depth were unaffected. Biometric indices showed selective increases in visceral and gut weight at moderate supplementation levels, without significant changes in liver weight, relative gut length, hepatosomatic index, viscerosomatic index, or condition factor. Hematological parameters remained stable across treatments, indicating physiological safety. Correlation analyses highlighted allometric growth patterns, with somatic expansion inversely related to visceral indices and strong proportional scaling of gut structures. Overall, dietary lemongrass aqueous extract at 20 g/kg optimally enhanced growth, feed efficiency, and selective morphometric and visceral traits in red tilapia without compromising hematological health. These findings support the potential use of lemongrass as a safe and effective phytogenic feed additive in sustainable tilapia aquaculture.

Keywords: *red tilapia, lemongrass extract, growth performance, morphometric traits, phytogenic feed additive*

SUSTAINABLE HARVESTING OF *Chaetoceros* sp. USING COMMERCIAL BIO-FLOCCULANTS DERIVED FROM MARINE BY-PRODUCTS: IMPLICATIONS FOR AQUACULTURE NUTRITION

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Microalgae are a crucial nutritional source for aquatic animals, particularly during the early developmental stages in hatcheries. This study evaluated the efficacy of commercial chitosan hydrochloride salts derived from diverse marine byproducts including shrimp shells, crab shells, and squid pens as sustainable bio-flocculants for harvesting *Chaetoceros* sp. The commercial chitosans were initially characterized for their purity and functional properties prior to flocculation assays. Results indicated variations in the purity of the commercial chitosan salts depending on their raw material origins, with residual protein and ash contents ranging from <1% in the squid-derived sample (highest purity) to 1.43% and 1.56%, respectively, in the shrimp-derived sample (lowest purity). Despite these differences in purity, all samples maintained a high degree of deacetylation (>80%) and low viscosity (<50 cP). Notably, the highly pure chitosan salt derived from squid pens exhibited the best performance among the tested samples, achieving a flocculation efficiency of over 70% at a concentration of 80 ppm after 180 minutes of treatment. Although this bio-flocculation process did not yield completely clear supernatant, it successfully aggregated micro-cells into macro-flocs, serving as an excellent primary pre-concentration step. Consequently, the aggregated biomass could be easily and rapidly dewatered using simple cloth filtration to yield a dense algal paste. This two-step harvesting approach (bio-flocculation followed by cloth filtration) offers a practical, low-cost, and sustainable solution for small-scale hatcheries.

Keywords: *bio-flocculation, Chaetoceros sp., chitosan hydrochloride, algal paste, marine by- produ*

HOW DOES U.S. SOY FIT THE NEW ERA OF MARINE AQUACULTURE?

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Marine aquaculture is entering a new era characterized by rapid growth, increasing demand for high-performance feeds, and greater pressure on marine resources. Traditionally, marine fish diets relied heavily on fishmeal and other marine proteins. However, the supply of these ingredients is limited and their costs continue to rise, creating a strong need for sustainable and economically viable alternatives. As a result, the global aquafeed industry is increasingly shifting toward high-quality plant-based proteins.

Among these alternatives, U.S. soy products have emerged as a leading solution for modern marine aquaculture. Marine fish require feeds with high nutrient density, excellent digestibility, and consistent quality to support optimal growth and feed efficiency. U.S. soy offers a premium and reliable protein source with a well-balanced amino acid profile and consistent processing standards compared with many other origins. In addition, advanced soy products—such as, fermented soybean meal, soy protein concentrate and other functional soy ingredients—have been developed to address traditional challenges associated with plant proteins, including anti-nutritional factors. These innovations improve digestibility, enhance nutrient availability, and support better fish performance in high-value marine species.

Beyond nutritional performance, sustainability has become a key consideration in aquaculture feed development. U.S. soy is produced under strong sustainability frameworks and contributes to lower environmental impacts, including reduced carbon dioxide (CO_2) footprints compared with other soy origins.

Together, this nutritional, functional, and sustainability advantages position U.S. soy as an ideal ingredient for the next generation of marine aquaculture feeds, supporting both industry growth and responsible seafood production.

Keywords: *USSEC, U.S. soy, Soybean meal, Plant protein, Marine Cage Aquaculture, Marine Fish*

NEUROENDOCRINE REGULATION AND METABOLIC ADAPTATION OF GROWTH HETEROGENEITY IN JAPANESE EEL (*Anguilla japonica*): MECHANISMS AND MITIGATION STRATEGIES

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Growth-retarded eels (GREs) account for 20–30% of intensively cultured Japanese eels (*Anguilla japonica*), causing severe economic losses. Understanding the physiological mechanisms driving this extreme growth heterogeneity is essential for developing effective mitigation strategies. Our multi-omics and behavioral studies reveal that GREs undergo profound metabolic reprogramming and severe appetite suppression, characterized by downregulated orexigenic and upregulated anorexigenic genes in the brain. Furthermore, high-density social stress chronically elevates serum cortisol, severely inhibiting growth via the hypothalamic-pituitary-interrenal (HPI) axis—an effect successfully mitigated by pharmacological cortisol suppression.

To actively recover GREs, we developed targeted interventions. Dietary supplementation with 0.2% tryptophan effectively modulated the serotonergic (5-HT) system, alleviating chronic stress, enhancing hypoxia tolerance, and reducing growth disparity. Additionally, an integrated acclimation protocol combining precise temperature elevation with a specific biological diet reactivated the appetite axis, triggering substantial compensatory growth in previously stunted GREs.

Future research will explore the neurobiology of social hierarchy formation and utilize Genome-Wide Association Studies (GWAS) to identify SNPs for stress-resilient selective breeding. Ultimately, integrating targeted nutritional neuroendocrine modulation with environmental acclimation provides a robust physiological framework to actively recover GREs, enhancing the sustainability of intensive aquaculture systems.

Keywords: *Anguilla japonica*; Growth heterogeneity; Neuroendocrine regulation; Social stress

EFFECTS OF LYCHEE (*Litchi chinensis*) SEED POWDER ON GROWTH PERFORMANCE, INNATE IMMUNITY, AND IMMUNE- ANTIOXIDANT GENE EXPRESSION IN NILE TILAPIA (*Oreochromis niloticus*) CULTURED IN A BIOFLOC SYSTEM

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This study evaluated the effects of dietary lychee Litchi chinensis seed powder (LS) on growth performance, innate immune responses, and immune-antioxidant gene expression in Nile tilapia Oreochromis niloticus cultured in a biofloc system. A total of 300 fish (14.25 ± 0.30 g) were randomly distributed into five dietary treatments containing 0, 5, 10, 20, and 40 g kg-1 LS (LS0, LS5, LS10, LS20, and LS40) with three replicate tanks per treatment and 20 fish per tank. Fish were fed the experimental diets for eight weeks. The results indicated that dietary LS supplementation did not significantly affect final weight, weight gain, specific growth rate, feed conversion ratio, or survival after four or eight weeks of feeding ($P > 0.05$). However, LS significantly enhanced innate immune responses, particularly after prolonged feeding. At week 8, skin mucus lysozyme and peroxidase activities were significantly elevated in fish fed LS10, LS20, and LS40 diets compared with the control ($P < 0.05$). Serum lysozyme and peroxidase activities were also significantly improved, with the strongest responses observed in the LS10 and LS20 groups ($P < 0.05$). In addition, dietary LS significantly modulated the expression of immunerelated genes (*IL-1*, *IL-8*, and *LBP*) and antioxidant-related genes (*GSTα, GPX*, and *GSR*) in the liver and intestine. Among the tested inclusion levels, LS10 produced the most consistent immunological and antioxidant responses. These findings suggest that lychee seed powder is not a direct growth-promoting additive but may serve as a functional feed additive to enhance health and physiological resilience in Nile tilapia reared under biofloc conditions.

Keywords: *Lychee seed powder; Nile tilapia; Biofloc; Innate immunity; Gene expression*

EFFECTS OF CHLOROGENIC ACID ON GROWTH PERFORMANCE AND MEAT QUALITY OF HYBRID TILAPIA (*Oreochromis niloticus*)

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This study investigated the effects of dietary chlorogenic acid (CA) on growth performance and meat quality in hybrid tilapia (*Oreochromis niloticus*). Fish (18.50 ± 0.03 g) were randomly assigned to five groups with three replicates each (20 fish per replicate) and fed basal diets supplemented with 0 (C), 200 (CA200), 400 (CA400), 600 (CA600), or 800 (CA800) mg/kg CAA for 56 days. Per 300-L plastic tank under natural photoperiod and ambient water temperature (28°C average). Fish were reared in aerated tap water (50% daily water exchange) and fed isonitrogenous and isolipidic diets to satiation twice daily (08:00 and 16:00). Results showed that CA600 and CA800 significantly increased final body weight, weight gain, and specific growth rate, while decreasing feed conversion ratio ($P < 0.05$). CA800 significantly increased feeding rate ($P < 0.05$). CA400 significantly reduced hepatosomatic index ($P < 0.05$). CA600 and CA800 significantly enhanced nitrogen and phosphorus retention, as well as dry matter and protein digestibility ($P < 0.05$), while reducing nitrogen and phosphorus waste outputs. Muscle crude protein and crude fat were significantly lower in the control group than in most CA-supplemented groups ($P < 0.05$). CA800 significantly increased the contents of essential, non-essential, total, and flavor amino acids in muscle ($P<0.05$). In conclusion, dietary supplementation with 600mg/kg chlorogenic acid improved growth performance and meat quality in hybrid tilapia.

Keywords: *Chlorogenic acid; Growth performance; Meat quality*

EFFECTS OF DIETARY DRIED LEMON PEEL OR FERMENTED LEMON PEEL SUPPLEMENTATION ON GROWTH, NUTRIENT DIGESTIBILITY, AND INTESTINAL HEALTH OF GROUPER (*Epinephelus lanceolatus*)

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The study was conducted to evaluate the effects of dietary supplementation with dried lemon peel and fermented lemon peel on growth performance, nutrient digestibility, and intestinal health of juvenile giant grouper (*Epinephelus lanceolatus*). A control diet was supplemented with 1% and 2% dried lemon peel (LP) or fermented lemon peel (FLP). Together with the unsupplemented control diet, total of five experimental diets were each fed to triplicate groups of grouper (initial body weight of 43.56 ± 0.12 g) in a closed recirculating aquaculture system for 8 weeks. Growth performance including weight gain, feed efficiency, protein efficiency ratio, hepatosomatic index, and apparent digestibility coefficients of dry matter, protein, and lipid were similar (p>0.05) among all groups. Intestinal interleukin-10 (IL-10) gene expression in the 1% LP group was significantly higher than that in 0% (control) groups, while IL-16 gene expression was significantly higher in the 1% LP and 2% LP groups compared with the 0% group. Histological examination of the foregut showed poor epithelial integrity and vacuolation in the mucosa of the 0% group, whereas supplementation with 1% or 2% LP or FLP improved epithelial integrity and reduced vacuolation. Principal coordinates analysis (PCoA) of intestinal microbiota indicated that the microbial communities of the 0%, 1% LP, and 2% LP groups were similar, while those of the 1% FLP and 2% FLP groups were closely clustered. Analysis of dominant intestinal bacterial species showed that *Streptococcus equines* was the predominant species in the 0% (30.6%), 1% LP (32.3%), and 2% LP (36.1%) groups. In contrast, the abundance of *S. equines* decreased to 18.9% and 13.1% in the 1% FLP and 2% FLP groups, respectively. Moreover, *Lactobacillus plantarum* became the dominant bacterial species in these two groups, accounting for 42.1% and 57.6% of the intestinal microbiota, respectively. The results of this study demonstrated that supplementation with 1% and 2% fermented lemon peel in diet can improve foregut histomorphology and intestinal health, suppress the abundance of *S. equines*, and increase the proportion of *L. plantarum* in the intestine of giant grouper.

Keywords: *lemon peel, fermented lemon peel, giant grouper, Epinephelus lanceolatus, intestinal microbiota, intestinal health.*

METABOLIC DISRUPTION AND FLESH QUALITY ALTERATION IN GRASS CARP: LONG-TERM 2-MIB EXPOSURE AND PURIFICATION RECOVERY

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2-Methylisoborneol (2-MIB) is one of the most prevalent off-flavor-causing compounds in freshwater aquaculture, responsible for significant economic losses. Although purification in clean water is widely used to remove off-flavors before harvest, little is known about the physiological and metabolic consequences of chronic 2-MIB exposure and subsequent purification. This study evaluated the effects of 45-day exposure to 2- MIB (0, 0.5, and 5 μg/L) followed by 15-day purification on growth performance, digestive function, muscle texture, and metabolomic profiles of grass carp (*Ctenopharyngodon idella*). Fish (46.46 ± 0.32 g) were randomly assigned to nine tanks (100 L water, 30 fish per tank) and fed twice daily at 3% body weight. Chronic exposure to 2-MIB significantly increased feed conversion ratio and reduced digestive enzyme activities, particularly amylase and trypsin. Exposure also altered appetite regulation, characterized by up-regulation of ghrelin and down-regulation of insra expression. Muscle hardness, chewiness, and gumminess increased significantly during exposure and recovered after purification. Several flavor-related amino acids, including glutamate, lysine, arginine, and tyrosine, were significantly altered. Metabolomic analysis revealed pronounced dose-dependent metabolic reprogramming. The 2-MIB exposure primarily suppressed nucleotide metabolism, ABC transporters, arachidonic acid metabolism, linolenic acid metabolism and vascular smooth muscle contraction. Following purification, aminoacyl-tRNA biosynthesis, lysine degradation, D-amino acid metabolism, branched-chain amino acid metabolism, ABC transporters, and mTOR signaling pathways were significantly activated, indicating enhanced protein synthesis, detoxification, and tissue repair. Chronic 2-MIB exposure induces metabolic adaptation rather than overt toxicity, and purification restores physiological and metabolic homeostasis, providing new insights for optimizing off-flavor purification strategies in aquaculture.

***Keywords**: off-flavor, digestive, purification, texture, metabonomics*

ECOLOGICAL CATALYSTS: DECIPHERING THE IMPACT OF SINGLE AND MULTI-STRAIN PROBIOTICS ON THE GUT MICROBIOTA INTERACTOME AND GROWTH PERFORMANCE OF *Litopenaeus vannamei*

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The intensification of *Litopenaeus vannamei* farming has escalated ecological challenges, necessitating sustainable alternatives to antibiotics. This study evaluates the efficacy of single-strain (*Bacillus subtilis* and *Lactobacillus acidophilus*) and multi-strain (Mix) probiotic regimes over an 84-day trial. Utilizing high-throughput 16S rRNA sequencing (V1–V9 regions) combined with LEfSe modeling and co-occurrence network analysis, we decoded the structural and functional dynamics of the shrimp gut microbiota. Results demonstrate that *Bacillus* supplementation significantly enhanced final body weight and Specific Growth Rate (SGR) by Day 74, while the multi-strain consortium optimized the Feed Conversion Ratio (FCR), indicating superior feed efficiency. Bioinformatic modeling identified 28 core biomarker OTUs, revealing that each probiotic regime triggers an independent path of selective community rearrangement rather than a simple additive effect. Notably, the *Bacillus*intervention exerted the most aggressive selective pressure, while the Mix regime maintained a profile closest to the control environment. Network analysis revealed high-centrality keystone taxa, such as *Haliangium ochraceum*, and extensive negative correlations between beneficial *Bacteroidota* and opportunistic pathogens like *Vibrio nigripulchritudo*, confirming effective competitive exclusion. Our findings conclude that probiotics function as ecological catalysts, reconfiguring the gut microbiota into unique stable equilibria. This research establishes a rigorous scientific framework for optimizing microbial management to enhance shrimp health and growth performance in sustainable intensive aquaculture.

***Keywords**: Litopenaeus vannamei, gut microbiota, probiotics, biomarkers, co-occurrence network, sustainable aquaculture.*

ENHANCING CLIMATE RESILIENCE IN COMMERCIAL GROUPER *Epinephelus* spp. AQUACULTURE: THE ROLE OF AQUAVOLTAIC FACILITIES AND SMART MONITORING SYSTEMS

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Global climate change, characterized by extreme temperatures and intense rainfall, poses unprecedented threats to aquaculture. Emerging offshore cage systems and traditional earthen ponds both face critical vulnerabilities, including heat-induced mortality and severe hypoxia.

As the sector expands into offshore cage farming, establishing a stable, climate-resilient onshore supply chain-particularly for the intermediate rearing of juveniles prior to sea transfer-is imperative for holistic industry sustainability.

This study investigates the climate adaptation potential of a commercial hybrid grouper (*Epinephelus* spp.) aquavoltaic system in southwestern Taiwan. Unlike exposed earthen ponds, this ground-mounted solar facility integrates renewable energy generation with active environmental management. The photovoltaic array provides extensive physical shading, directly minimizing solar irradiance on the water surface. Furthermore, smart water quality monitoring and real-time early-warning systems enable precise operational responses to meteorological shifts.

Field observations demonstrate that aquavoltaic shading significantly stabilizes daily water temperature variations and mitigates hypoxic risks during summer heatwaves. Beyond generating green energy and lowering carbon footprints, the system exhibits superior environmental buffering capacity. We propose that such climate-resilient land-based infrastructures serve as highly reliable intermediate nursery bases, forming a synergistic risk- diversification strategy with offshore cage aquaculture. This integrated approach ensures a stable supply of robust juveniles, fortifying the broader grouper supply chain against climate risks.

***Keywords**: Aquavoltaics, Climate Resilience, Cage Aquaculture Support, Smart Monitoring*

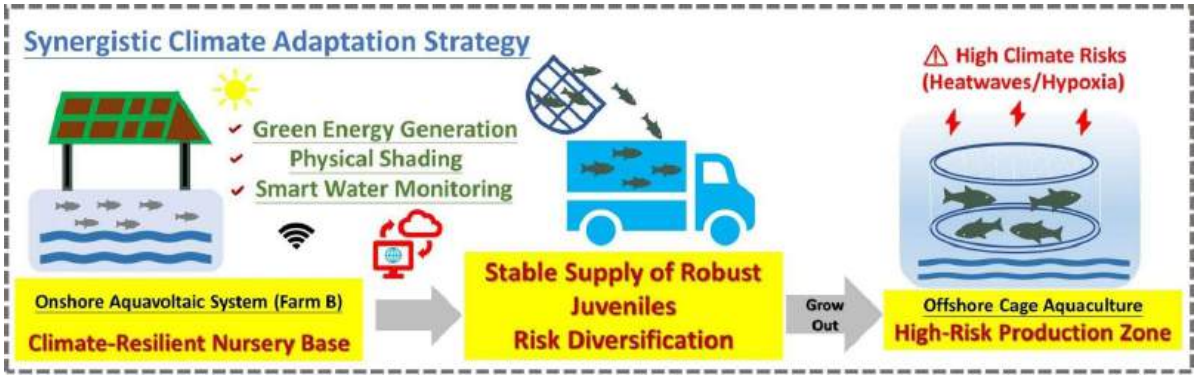

Fig. 1 Synergistic framework for climate-resilient grouper aquaculture. The diagram illustrates how land-based aquavoltaic systems (left) integrate physical shading and smart monitoring to create a buffered environment. This system serves as a highly reliable intermediate nursery base, mitigating climate risks and ensuring a stable supply of robust juveniles to support high-risk offshore cage aquaculture (right).

TECHNOLOGIES TO MITIGATE AQUACULTURE CARBON EMISSIONS AID IN CLIMATE CHANGE ADAPTATION

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Aquaculture production is rapidly expanding with the potential to contribute to sustainable diets globally. However, aquaculture sectors and production practices vary widely in their environmental performance and vulnerability to climate change impacts. Achieving climate- smart aquaculture, which considers emissions mitigation, resilience to climate change impacts, and economic and food security, requires adoption and implementation of various technologies.

Here, we review technologies used in aquaculture either to mitigate emissions or to aid climate adaptation. We focus on stages of the production process unique to aquaculture relative to other food systems. Of the 27 broad technologies we reviewed, 16 provide co-benefits to both emission mitigation and climate adaptation. For example, technologies that improve management and application of aquafeed reduce greenhouse gas emissions by limiting accumulation of organic material beneath cages and simultaneously lower vulnerability to climate change impacts by reducing reliance on external feed inputs. Only a few technologies implemented to address one challenge were associated with negative trade-offs with the other challenge, indicating that emission mitigation and climate adaptation objectives are largely aligned in aquaculture systems.

Our findings indicate an opportunity to advance climate-smart aquaculture by prioritizing adoption and implementation of co-benefiting technologies. Integrating our findings with the third pillar of climate smart aquaculture (i.e., productivity, income, and food security) is the next step toward more resilient and sustainable aquaculture.

***Keywords**: emissions mitigation, adaptation, climate-smart aquaculture*

ENHANCING OFFSHORE FISH PRODUCTION WITH ENVIRONMENTAL DATA

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Integrating high–resolution environmental data into aquaculture management is essential for optimizing the productivity and sustainability of caged fish farming. We examine how the systematic collection of diverse parameters–including water quality, oceanographic dynamics, and benthic characteristics–serves as a critical decision-support tool for modern mariculture in and around Van Phong Bay, Vietnam.

The analysis of water samples (measuring dissolved oxygen, salinity, and nutrient levels) allows for precise metabolic monitoring, ensuring optimal growth rates and early disease prevention. Simultaneously, data on currents and waves are vital for designing cages and maintaining structural integrity and efficient waste dispersion; understanding these hydrographic forces minimizes physical stress on the stock and prevents the detrimental accumulation of organic matter. Furthermore, mapping seafloor morphology and conducting sediment analysis informs cage positioning and provide insights into a site's carrying capacity and long-term environmental footprint. By correlating seafloor stability with waste deposition patterns, operators can mitigate the risk of localized hypoxia. In particular, part of results show that average temperature fluctuates at lowest at 23.8^{o}C in January and highest at 30.3^{o}C in August.

Noticeably, the temperature stratification occurs at monitoring from August to October, for instance, surface to 13m-depth layer is 29.5 ^{o}C, reduce gradually, 18.5m to 23.4 m (bottom) layer is 26.5^{o}C. Dissolve oxygen is 5.0 - 6.5 mg/L, salinity 31- 34 ppt. In terms of algae bloom, Notiluca sp. and other phytoplankton are monitored. High density of Notiluca sp. is recorded in July and December at 197 and 863 cells/L, respectively. Regarding to oceanographic dynamics, current velocity is from 0.2 m/s to 0.6 m/s, max current velocity is 0.94 m/s. Velocity at 0 m/s to 0.05 m/s is recorded at some periods.

Ultimately, the synthesis of these environmental datasets enables a transition from reactive to proactive aquaculture management. A pivotal strategy emerging from this data is the development of offshore grow areas reducing exposure to land-based nutrients/pollutants, intensive nearshore aquaculture, and harmful algal blooms. This multidimensional approach not only augments total biomass production but also ensures the economic and ecological resilience of the global aquaculture industry.

Keywords: *water quality, oceanographic dynamics, modern mariculture*

OYSTER FARMING AS A NATURE-BASED APPROACH TO CLIMATE CHANGE ADAPTATION IN THE MEKONG DELTA, VIETNAM

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This investigation assessed oyster (*Crassostrea* spp.) farming as a nature-based approach to sustainable aquaculture and climate change adaptation in the Mekong Delta, Vietnam. A structured survey was conducted between November 2024 and May 2025 with 100 oyster farmers in Ca Mau, Vinh Long, and An Giang provinces. The study analyzed socio-demographic characteristics, technical practices, economic performance, resource use, farmer perceptions, and perceived climate-related changes. The surveyed results showed that oyster farming is predominantly small- to medium-scale and relies heavily on natural inputs, including wild seed collection, natural water sources, and tidal-based water exchange. The hanging culture method was dominant (86.9%), while monoculture prevailed in Ca Mau and polyculture in An Giang. Production averaged 2.41 ± 0.61 tons/100 m²/year, with higher yields in Ca Mau. Economic analysis indicated positive profitability across provinces, with an average net profit of US$1,689.8/100 m² and a cost–benefit ratio of 2.76. Despite profitability, farmers reported declining productivity (44.1%) and income (46.2%) over the past three years, alongside increasing risks from extreme weather (69.7%) and disease outbreaks (56.5%). Farmers generally perceived oyster farming as environmentally friendly and climate-resilient. The majority of respondents agreed that oyster farming reduces waste (93.1%), adapts well to climate change (82.8%), and supports livelihood diversification (97.0%). However, prolonged hot periods (89.0%) and abnormal rainfall (81.8%) were highlighted as key climate-related challenges. Overall, oyster farming in the Mekong Delta demonstrates significant characteristics of a nature-based solution, combining low external input use, ecosystem integration, and economic viability; however, rising climate stressors may threaten long-term sustainability.

Keywords: *Oyster farming; nature-based solution; resource use; environmental sustainability*

GREENHOUSE GAS EMISSION PATTERNS AND CONTROLLING FACTORS IN TRADITIONAL TILAPIA AQUACULTURE: IMPLICATIONS FOR CARBON DYNAMICS AND ENVIRONMENTAL SUSTAINABILITY

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To reveal greenhouse gas (GHG) emission characteristics and regulatory mechanisms at the water-air interface in traditional tilapia aquaculture ponds in Guangdong, China, and to support environmental sustainability and low-carbon development in aquaculture, CO_2, CH_4, and N_2O fluxes were monitored over a 100-day culture cycle using the static opaque chamber-gas chromatography method. Key water physicochemical parameters were measured simultaneously, and correlation analysis and 100-year global warming potential (GWP) assessment were conducted. Results showed that traditional tilapia ponds serve as atmospheric GHG sources. Fluxes of CO_2, CH_4, and N_2O all increased significantly from the fry stage to the adult fish stage. Pearson correlation analysis indicated that GHG emissions were co-driven by air and water temperature, dissolved oxygen, pH, total nitrogen, and total phosphorus, with water temperature and dissolved oxygen as dominant factors. The 100-year GWPs of the three ponds reached 3.91×10^4, 3.96×10^4, and 3.61×10^4 kg CO_2-eq ha^{-1}, respectively. Additionally, pond structure significantly affected emission patterns: concrete-embankment ponds had higher CO_2 and CH_4 fluxes, while earthen ponds showed higher N_2O emissions in the adult stage. This study clarifies spatiotemporal GHG dynamics in traditional tilapia culture and identifies key regulatory factors linked to carbon balance and environmental sustainability. These results provide a scientific basis for formulating targeted GHG mitigation strategies and promoting climate-adaptive, low-carbon freshwater aquaculture in South China.

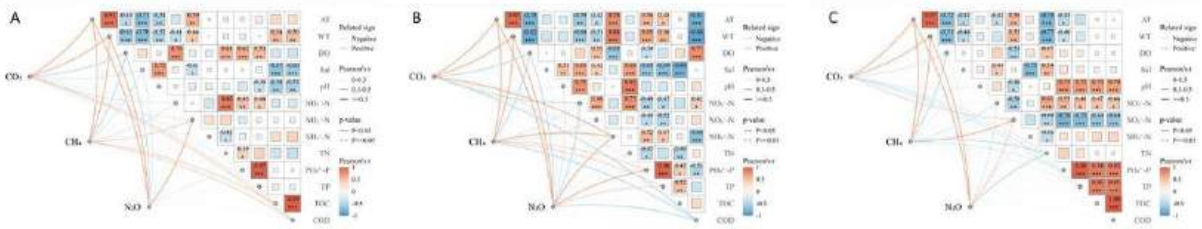

Figure. Pearson correlation analysis of CO_2, CH_4, N_2O fluxes at the air-water interface and environmental factors in Farm A-C of tilapia culture during spring and summer.

***Keywords**: Greenhouse gases; Emission fluxes; Pond aquaculture; Tilapia; Global warming potential*

UTILIZATION OF *Chaetoceros mulleri* FOR NUTRIENT REMOVAL FROM SHRIMP WASTEWATER AND ARTEMIA BIOMASS PRODUCTION

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This study aimed to (1) evaluate the growth and nitrogen (N) and phosphorus (P) removal capacity of the microalga Chaetoceros mulleri in shrimp pond wastewater, and (2) assess its use as feed for Artemia biomass production. Wastewater from intensive whiteleg shrimp ponds was analyzed and used for microalgae (filtered at 5 µm) and Artemia (filtered at 50 µm) culture experiments. In Experiment 1, C. muelleri was cultured for 5 days in 8 L containers at four initial densities (10, 20, 30, and 40 × 10^3 cells/mL), with four replicates. In Experiment 2, Artemia franciscana larvae were reared for 15 days in 5 L containers at five densities (100–500 individuals/L), with three replicates. Artemia were fed either C. muelleri grown in shrimp wastewater (Treatment 1) or in f/2 medium (control), with feeding adjusted to biomass.

Microalgal growth and nutrient removal were significantly affected by initial density ($p < 0.05$). The highest growth occurred at 30–40 × 10^3 cells/mL, with maximum removal efficiencies of 60.2% for nitrogen and 97% for phosphorus. Artemia growth and survival were highest at 100–200 individuals/L, while biomass increased with density. No significant differences in growth, survival, or biomass were observed between treatments. However, protein and lipid contents were higher in the control, whereas ash and carbohydrate contents were higher in Treatment 1 ($p < 0.05$).

These findings demonstrate that C. muelleri effectively removes nutrients from shrimp wastewater and can be used as a feed source for Artemia production.

***Keywords**: Chaetoceros mulleri, Shrimp wastewater, Nutrient removal, Artemia culture, Microalgae-based feed*

UTILIZATION OF SHRIMP FARMING WASTEWATER FOR ARTEMIA BIOMASS PRODUCTION AND NUTRIENT RECOVERY

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This study evaluated the effectiveness of using intensive shrimp farming wastewater to produce Artemia biomass. Whiteleg shrimp post-larvae were cultured for 60 days in 12 circular composite tanks (1 m³ each) at an initial density of 200 individuals per tank under two systems. In the autotrophic system, Chaetoceros mulleri and silicate were added twice weekly (30,000 cells/mL and 5 ppm). In the mixotrophic system, only silicate (5 ppm) was added. Shrimp in both systems were fed a commercial diet (40% protein) at 4–8% body weight, four times daily. Wastewater collected on day 32 was filtered (<50 µm), and some water parameters were analysed, then supplied to Artemia tanks daily.

Artemia larvae (3.1 mm) were reared for 21 days in 24 plastic tanks (8 L each) at 100 individuals/L under two treatments. Treatment A used wastewater from the autotrophic system, while Treatment B used wastewater from the mixotrophic system. Samples were collected on days 7, 14, and 21 to assess Artemia growth, survival, and nitrogen content, as well as wastewater volume and nitrogen concentration. Artemia size increased over time, reaching 9.2 and 9.1 mm on day 21. Dry biomass (359 and 310.5 mg/tank) and nitrogen content (29.1 and 25.2 mg/tank) peaked on day 14 ($P < 0.05$). Survival decreased to 32.5% and 25.5% by day 21. Nitrogen recovery reached 9% in Treatment A and 7% in Treatment B.

These results indicate that Artemia can effectively convert nutrients from shrimp wastewater into valuable biomass, particularly under microalgae-enriched (autotrophic) conditions.

Keywords: *Artemia biomass, Shrimp wastewater, Nutrient recycling, Autotrophic system, Nitrogen recovery*

VITELLOGENIN RECEPTOR MEDIATES HEAT ADAPTABILITY OF OOCYTE DEVELOPMENT IN MUD CRABS AND ZEBRAFISH

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Climate-driven warming affects the reproduction of oviparous ectotherms. However, whether oviparous ectotherms possess a protection mechanism against heat stress for oocyte development, which is essential for maintaining the continuity of animal populations, is largely unknown. Under high temperatures, female mud crabs (Scylla paramamosain) typically have well-formed ovaries, while a few crabs were found to experience oocyte development failure.

To investigate the heat stress protection mechanism of oocyte development in mud crabs, we construct a chromosome-level genome of this species and identify an enhancer of the vitellogenin receptor (VtgR) that stimulates its expression under high temperatures. Lacking this enhancer due to an intronic deletion leads to low VtgR expression in abnormal crabs, resulting in abnormal vitellogenic oocyte formation in these individuals when exposed to high temperatures. Furthermore, we identify a similar heat stress protection mechanism in zebrafish. Disruption of Lrp13, a VtgR-like protein in zebrafish, results in impaired vitellogenin absorption and ovarian degeneration in zebrafish exposed to high temperatures. Our results reveal a VtgR-mediated mechanism that protects vitellogenic oocyte formation against heat stress in mud crabs and zebrafish, contributing to their heat adaptability during oocyte development.

***Keywords**: Oocyte development, heat adaptability, VtgR, mud crab, zebrafish*

DEVELOPMENT AND CHARACTERIZATION CALCIUM COMPOUNDS FROM VALORIZED MUSSEL SHELLS, CARBOXYMETHYL CELLULOSE AND BAMBOO ASH SILICA COMPOSITES FOR EFFICIENT REMOVAL OF EXCESS AMMONIA FROM AQUACULTURE WATER

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Excess nutrients and carbon dioxide pose a serious challenge to cage aquaculture by disrupting pH balance, increasing water hardness, and threatening aquatic health and productivity. In response to this, calcium compounds from valorized mussel shells, carboxymethyl cellulose and bamboo ash silica (CaX-CMC-Si, where X can be -O or -CO_3) composites were developed to remove excess CO_2 and ammonia in aquaculture water.

Scanning electron micrographs of the powders revealed generally rough surfaces, indicating the material's potential to accommodate adsorptive interactions. Energy dispersive X-ray analysis (EDX) confirmed their elemental composition, showing a notable increase in carbon, oxygen and nitrogen content after CO_2 and ammonia adsorption. X-ray diffraction patterns (XRD) identified wollastonite and calcite as the possible crystalline phases of the composites while FTIR spectra showed the confirmation of the attachment of the ammonia through the presence of N-H stretching (3000-3500 cm^{-}`) and bending peaks (~1600 cm^{-1}) and carbonates through the appearance of a new peak at 1795 $cm^{-1}$and the persistence of carbonate bands at 1450, 874, and 713 cm^{-1}, suggesting changes in functional groups of the CaX-CMC-Si adsorbent after adsorption.

Batch adsorption tests indicated that pseudo-second order model was the best fit for both adsorbates, while the Langmuir isotherm was the best fit, describing monolayer adsorption. The composites achieved 48% removal efficiency for NH_3-N within 240 minutes and 86.5% CO_2 after 180 min. Overall, the CaX-CMC-Si adsorbent demonstrated high removal efficiency and structural integrity, positioning it as an effective material for managing excess ammonia and carbon dioxide in aquaculture water systems.

***Keywords**: CaX-CMC-Si composites, carbon dioxide removal, ammonia removal*

RETENTION AND NURSERY FUNCTION OF COASTAL WATERS FOR FISH AT EARLY LIFE STAGES AND THE POTENTIAL IMPACTS OF CAGE CULTURE

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Cage aquaculture is commonly practiced in bays and nearshore waters, which also serve as essential spawning and nursery grounds for marine fishes. This study examined the reproductive and nursery functions of coastal fish communities around Hainan Island, aiming to support science-based planning for cage culture zones. Fish egg surveys were conducted in April, the peak spawning season in the South China Sea. We recorded 212 fish egg taxa and identified three major spawning hotspots around Hainan Island. We also monitored larval fish assemblages annually in a typical seagrass bed–coral reef ecosystem. In total, 213 larval fish species were identified. Larval density in seagrass beds was six times higher than in adjacent pre-reef waters, indicating strong larval retention. Larvae mainly enter seagrass beds from offshore areas during nocturnal flood tides. Investigations of juvenile fish communities in seagrass beds, sandy surf zones, and mangroves recorded 143 species, including reef- associated and pelagic fishes. Dominant commercial species included *Lutjanus russellii*, Sphyraena barracuda, and Megalops cyprinoides.

Our results show that most coastal fishes spawn offshore; larvae then drift into nearshore seagrass beds at night via flood tides for retention and development. This life-cycle pathway is vital for coastal fish stock recruitment. To protect fisheries resources, coastal cage farming should avoid critical spawning areas, preserve larval dispersal corridors, and avoid disturbing key retention and nursery habitats.

***Keywords**: Cage culture; Coastal waters; Larval retention function; Spawning and nursery grounds*

TIDAL MIGRATION OF JUVENILES IN COASTAL AREAS OF WENCHANG, HAINAN

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Coastal habitats are key nursery grounds for marine fishes, supporting juvenile settlement, growth, and recruitment to adult populations. The coastal area in Wenchang support diverse and complex habitats with a mangrove-seagrass-coral reef continuum, yet the role of flooding tides in linking these habitats remains poorly understood. This study examined juvenile fish migration during flooding tide across four nursery habitats: seagrass beds at low tide, intertidal sandflats at mid-flooding tide, and mangrove creeks and shoreline sandy beaches at high- flooding tide.

A total of 3,598 juveniles were collected, representing 81 species from 40 families, including 33 coastal-estuarineassociated and 48 reef-offshore-associated species. Juveniles were classified into early and young stages. Fish assemblages differed significantly among habitats, although several species moved across multiple habitats during flooding tide, indicating speciesspecific habitat use and tidal connectivity. Early juveniles contributed most strongly to seagrass beds, followed by sandflats and sandy beaches, and least to mangrove creeks, forming a seaward-to-shoreward evelopmental gradient. Young juveniles were generally more abundant during spring tides, except on sandflats. The assemblages of stage-specific juvenile also differed among habitats: seagrass beds mainly supported smaller reef-associated fishes, sandflats supported diverse juvenile stages of both coastal-estuarine and reef-offshore species, and mangrove creeks provided nursery habitat for small coastal-estuarine fishes and larger offshore species.

These findings suggest that Wenchang's coastal habitats function as complementary nurseries, with spring tides enhancing habitat connectivity and facilitating juvenile movement into nearshore habitats. The results highlight the need to incorporate tidal dynamics into nursery habitat conservation and fisheries management.

***Key words**: Juvenile fish; ecotypes; coastal areas; nursery; tidal phases*

ENVIRONMENTAL CONTROL OF SPATIAL–TEMPORAL DYNAMICS AND LIFE CYCLE EXPRESSION IN *Asparagopsis taxiformis* FROM CENTRAL VIETNAM

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Asparagopsis taxiformis is a high-value red macroalga with proven potential to mitigate enteric methane emissions, yet its ecology in Vietnam remains undocumented. This study resolves its spatial distribution, seasonal variability, and life cycle structuring across two contrasting coastal systems, Ly Son Archipelago (Quang Ngai Province) and Hon Chong, Nha Trang (Khanh Hoa Province).

From 2018 onwards, transects perpendicular to the shoreline were deployed along depth gradients, combined with quadrat-based biomass estimation, environmental monitoring, and morphological identification of life stages. Population structure was quantified based on the relative dominance of gametophyte and tetrasporophyte phases.

Environmental conditions diverged markedly between sites, particularly in temperature, water clarity, and dissolved nitrogen, with Ly Son consistently more favorable for growth. Biomass of both life stages was higher in Ly Son. Strong seasonal turnover was observed, with gametophytes peaking from February to May and tetrasporophytes from September to December, while phenological patterns in Hon Chong lagged by approximately two months. Clear vertical segregation was detected, with tetrasporophytes confined to 1.5–2.5 m in rocky and coral crevices, and gametophytes occupying 2.5–3.0 m on softer substrates and dead coral.

These findings demonstrate tight environmental regulation of population dynamics and life cycle expression in A. taxiformis. This study establishes the first ecological baseline for Vietnam and provides a scientific foundation for resource management and sustainable cultivation of this species in tropical marine systems.

***Keywords**: Asparagopsis taxiformis; environmental drivers; life cycle structuring; spatial–temporal dynamics; tropical marine ecosystems*

THERMAL STRESS MODULATES INTERFERON REGULATORY FACTOR 9 IN GIANT GROUPER (*Epinephelus lanceolatus*) IN THE COURSE OF ANTIVIRAL IMMUNE RESPONSE

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Interferon regulatory factor 9 (IRF9) functions as a pivotal mediator in the upregulation of antiviral gene expression during the innate immune response in groupers, with notable sensitivity to thermal variation. In this study we elucidated the regulatory influences of temperature stress on the antiviral response mechanisms of giant grouper IRF9 (ggIRF9) following nervous necrosis virus (NNV) infection. Our data demonstrated that, *in vivo*, *ggIRF9* mRNA was significantly elevated in response to LPS and poly (I:C) stimulation, as well as NNV infection. Furthermore, *in vitro* analyses revealed that *ggIRF9* overexpression significantly enhanced the promoter activity of critical antiviral genes, specifically *Mx1* and *PKR*, and inhibited NNV replication. Molecular characterization indicated that the DNA-binding domain of the ggIRF9 protein exhibited potential functional interactions with the interferon-sensitive response element of the *Mx1* promoter, thereby mediating the transcriptional regulation of *Mx1* expression. Additionally, our findings revealed the strong thermal sensitivity of *ggIRF9* expression: low temperature suppressed its expression, whereas high temperature stress induced more complex modulatory effects. Moreover, both cold and heat stress *in vitro* significantly reduced *ggIRF9* promoter activity, potentially via processes mediated by cold-induced heat shock factor 1a (HSF1a) and heat-induced HSF1b, respectively. These findings suggest that ggIRF9 serves as an essential regulator of the innate antiviral immune response and that thermal stress substantially impairs its molecular functions, consequently compromising antiviral defense in giant groupers.

***Keywords**: IRF9, NNV, giant grouper, HFS1, antiviral immunity*

DEVELOPMENT AND APPLICATION OF A MULTI-PARAMETER IN- SITU WATER QUALITY MONITORING SYSTEM FOR EARLY DETECTION OF ENVIRONMENTAL STRESS IN MARINE CAGE AQUACULTURE

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Marine cage aquaculture is among the fastest-growing food production sectors globally; however, it is highly susceptible to sudden shifts in water quality parameters that can lead to mass mortality events and substantial economic losses. To address this vulnerability, this study presents the development, field validation, and applied adaptation of a low-cost, multi-parameter, real-time in-situ water quality monitoring system. Originally designed as a Coral Bleaching Detector (CBD), the system has been repurposed for continuous surveillance of cage aquaculture environments. Specifically, it integrates sensors for temperature (surface, water column, and bottom layers), dissolved oxygen (DO), salinity, and total dissolved solids (TDS) on an ESP32-based microcontroller platform. Data are transmitted in real time via the Global System for Mobile Communications (GSM), while a complementary data-logger subsystem preserves time-series records on a memory card.

To evaluate system reliability, field trials conducted in coastal waters demonstrated functional performance across all sensor channels. Furthermore, field endurance testing in Thousand Island Waters, Jakarta Bay, indicated the tool could transmit data through its dashboard (cbd.scientica.my.id) under normal operating conditions, with a mean surface water temperature recorded at 25.8°C, water column temperature at 25.9°C and bottom temperature at 26.2°C, mean salinity of 31.1 ppm, DO at approximately 3 mg/L, and TDS at 8.2 mg/L.

Applied to the cage aquaculture context, the system enables early detection of hypoxic events, thermal stratification, and salinity intrusion–conditions that are primary drivers of fish stock losses. Additionally, integrating monitoring data with threshold-based alert algorithms and a cloud-connected dashboard platform allows farm operators to respond proactively to adverse environmental changes. Overall, the proposed system offers a scalable, affordable, and technically accessible solution for smallholder and commercial marine cage aquaculture operations in tropical regions.

Keywords: *cage aquaculture; water quality monitoring; dissolved oxygen; IoT sensors; real-time telemetry; marine aquaculture management; ESP32; thermal stratification*

GREENHOUSE GAS EMISSIONS FROM SHRIMP FARMING SYSTEMS IN THE MEKONG DELTA, VIET NAM

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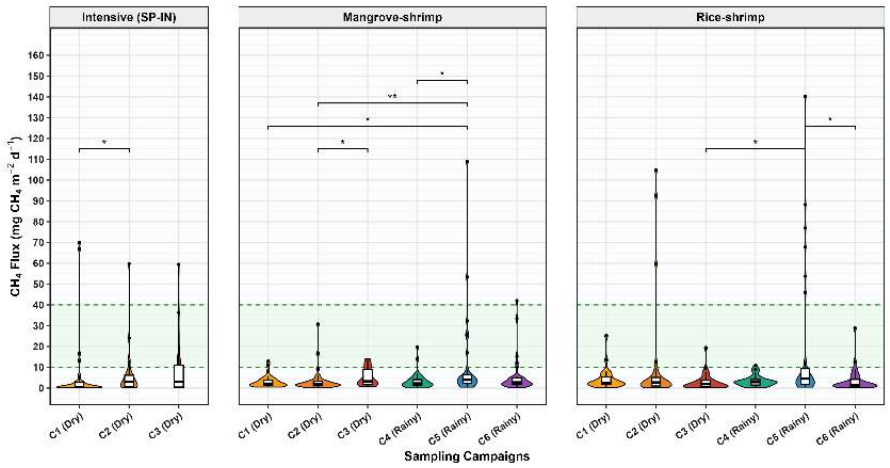
While shrimp aquaculture is a cornerstone of Viet Nam's economy, its environmental footprint, particularly greenhouse gas (GHG) emissions, remains a critical concern. This study quantified CH_4, CO_2, and N_2O fluxes across diverse shrimp cultivation models in the Mekong Delta to support the region's transition toward net-zero targets. Field sampling was conducted over six campaigns in major aquaculture provinces, including Ca Mau, Vinh Long, and An Giang, where GHG fluxes were measured via the floating chamber method at culture ponds, intake canals, and wastewater treatment zones alongside water and sediment parameter monitoring. The findings revealed substantial variations among the investigated systems, with the integrated mangrove–shrimp model demonstrating the lowest carbon footprint, generating 1.5 times fewer emissions than both intensive and rice–shrimp systems. Conversely, emission hotspots were identified within the effluent ponds and inlet canals of super-intensive operations, where gas levels surpassed those of active culture ponds by 1.3 times. Furthermore, CH_4 emissions peaked toward the end of the production cycle due to the heavy accumulation of organic matter in the bottom sediments, and a strong correlation with water degradation was observed as GHG levels nearly tripled when water conditions deteriorated from good to polluted status. These outcomes underscore that rigorous water quality management and sediment control are pivotal for emission mitigation, suggesting that promoting integrated farming models and circular economy approaches, such as Integrated Multi-Trophic Aquaculture (IMTA) and Recirculating Aquaculture Systems (RAS) is highly recommended to help the Mekong Delta achieve its climate milestones without compromising economic productivity.



LESSONS LEARNED FROM AN EVIDENCE-BASED APPROACH TO ADVANCE OFFSHORE BARRAMUNDI (*LATES CALCARIFER*) FARMING

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Barramundi (*Lates calcarifer*) is gaining global market relevance as a high-quality, climateresilient marine finfish species. However, scaling production from nearshore systems to fully offshore cage environments presents complex biological and operational challenges. Australis Aquaculture has approached this frontier with a strong commitment to evidencebased innovation. Through structured experimentation, rigorous data collection, and continuous learning, several key, quantifiable outcomes have been achieved. For example, the current parasite management strategy was developed through systematic in vitro and in vivo trials. These demonstrated that treatment with up to 150 ppm H_2O_2 is safe for the fish and rapidly eliminates monogenean parasites before further egg release, significantly improving treatment efficacy and reducing reinfection pressure. Extensive feed trials conducted under varying thermal regimes have enabled optimization of feeding strategies aligned with the species' biological growth potential. As a result, days to harvest can potentially be reduced by up to 40%, accompanied by substantial improvements in feed conversion ratios (FCR), translating into meaningful economic gains at farm level. Specific health challenges are addressed through a combination of field trials and controlled disease challenge experiments. Commercial probiotics have shown measurable benefits in gut microbiota composition and intestinal histology during critical production phases. In addition, preliminary results indicate that controlled early-life pathogen exposure may enhance immune preparedness, improving survival following sea cage transfer. Together, these results demonstrate how data-driven, evidence-based aquaculture can significantly improve productivity, resilience, and sustainability in offshore cage farming systems across Asia.

EFFECTS OF FUCOIDAN ON BACTERIAL GROWTH AND MACROPHAGE OXIDATIVE ACTIVITY IN GOLDEN POMPANO (*Trachinotus ovatus*)

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Fucoidan, a sulfated polysaccharide derived from brown seaweeds, has been widely investigated as a natural bioactive compound with potential immunomodulatory applications in aquaculture. This study evaluated the effects of fucoidan on bacterial growth and macrophage oxidative activity in golden pompano (*Trachinotus ovatus*). Fucoidan was tested at concentrations ranging from 0 to 800 µg/mL against five bacterial species, and its immunostimulatory effect was assessed by measuring Nitro Blue Tetrazolium (NBT) production in fish macrophages. Fucoidan influenced bacterial growth in a species- and concentration-dependent manner. However, the responses were not consistently inhibitory, as some bacterial species showed increased optical density at specific fucoidan concentrations. These findings indicate that the direct effect of fucoidan on bacterial growth varies among bacterial taxa and should not be interpreted as broad-spectrum antibacterial activity. In contrast, fucoidan enhanced macrophage oxidative activity, with a significant increase in NBT production observed at 50 µg/mL. The response tended to plateau at higher concentrations, particularly 400 and 800 µg/mL, suggesting a possible saturation effect. Overall, the results suggest that fucoidan has greater potential as an immunostimulatory compound than as a direct antibacterial agent in golden pompano. Its ability to enhance macrophage respiratory burst activity supports its possible application in aquaculture health management, particularly for strengthening innate immune responses and improving disease resistance in marine fish.

***Keywords**: Fucoidan; golden pompano; Trachinotus ovatus**;** macrophage; oxidative activity; NitroBlue Tetrazolium*

VIRULENCE GENE PROFILES AND PATHOLOGICAL EFFECTS OF *VIBRIO PARAHAEMOLYTICUS* ISOLATED FROM WHITELEG SHRIMP (*Litopenaeus vannamei*) POSTLARVAE

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This study characterized virulence genes and associated lesions of *Vibrio parahaemolyticus* isolates originating from postlarva of whiteleg shrimp (*Litopenaeus vannamei*) produced in commercial hatcheries in Binh Dinh and Ninh Thuan provinces, Vietnam. From 23 *Vibrio* spp. isolates obtained during 2023–2025, twelve were confirmed as *V. parahaemolyticus* based on biochemical profiling and 16S rRNA gene sequencing. All confirmed strains carried the hemolysis-related virulence genes *tlh* and *toxR*, whereas only seven strains additionally harbored the toxin genes *vhvp-1* and *vhvp-2*. Experimental infections using representative strains possessing all four virulence genes induced distinct histopathological changes in the hepatopancreas, ranging from focal epithelial necrosis to severe tissue disorganization. Challenge trials with two selected strains carrying *vhvp-1* and *vhvp-2* further demonstrated strain-specific pathological outcomes: shrimp exposed to strain VP_92 developed more extensive hepatopancreatic necrosis, while pronounced muscle opacity was only observed in shrimp infected with strain VP_DC5. These findings indicate that *V. parahaemolyticus* strains circulating in shrimp hatcheries can differ markedly in their virulence gene complements and pathological manifestations, underscoring the need to incorporate virulence-gene surveillance and strain-level characterization into health management programs for shrimp postlarva.

***Keywords**: Virulence genes, tlh, Vibrio parahaemolyticus, whiteleg shrimp, hepatopancreatic necrosis*

ANTIBIOTIC RESISTANCE AND RESISTANCE GENES IN *Vibrio* spp. ISOLATED FROM WHITELEG SHRIMP (*Litopenaeus vannamei*) POSTLARVAE IN CENTRAL VIETNAM

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Antibiotic resistance in bacterial communities associated with shrimp hatcheries is a major concern for disease control and the responsible use of antimicrobials in aquaculture. This study investigated antibiotic resistance and resistance genes in 35 *Vibrio* spp. isolates from whiteleg shrimp (*Litopenaeus vannamei*) postlarvae collected from hatcheries in Central Vietnam during 2023-2025. The Kirby-Bauer disk diffusion method and PCR were used to determine susceptibility profiles and detect resistance genes. Phenotypic analysis showed the highest resistance to streptomycin (88.6%), followed by gentamicin (25.7%) and amikacin (11.4%). In contrast, all isolates were fully susceptible to doxycycline, tetracycline, florfenicol, chloramphenicol. Six isolates exhibited multidrug-resistant (MDR) phenotypes, with simultaneous resistance to at least four antibiotics, including streptomycin, enrofloxacin, amikacin, and gentamicin (10 µg). PCR detection identified the resistance genes sul1 (17.1%), tetA (14.2%), and strA (8.5%). Three isolates carried all three genes and showed corresponding resistant phenotypes, confirming the presence of multidrug-resistant strains in the hatchery environment. These findings provide empirical evidence of antibiotic pressure in shrimp hatcheries and underscore the need for strengthened microbial monitoring, prudent antimicrobial use, and improved biosecurity to support sustainable shrimp production and reduce environmental impacts.

***Keywords**: Vibrio spp., antibiotic resistance, resistance genes, postlarvae, Litopenaeus vannamei*

LONGITUDINAL DYNAMICS OF RESISTOME AND PATHOBIOME IN FARMERS, LIVESTOCK AND ENVIRONMENT IN AQUACULTURE FLOATING FARMS

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Aquaculture is one of the most fast-expanding sector of animal agriculture. Similarly to inland livestock farming, cage aquaculture farming may exposes workers to occupational hazards that directly affect the health of half a billion individuals and may play a critical role in the dissemination of antimicrobial resistance. To address this issue, we carried out an 18-month longitudinal survey (covering both the dry and rainy seasons) examining the faecal and skin microbiota of aquaculture farmers within the Nha Trang Bay, Vietnam. To examine the connectivity between compartments, we compared the microbiota of farmers with those of fish livestocks and water samples using a combination of phenotypic and genomic approaches. Results from amplicon sequence variants (ASVs) analysis revealed the most dominant potential pathogenic bacteria (PPB) lineages belonging to the *Prevotella* and *Vibrio* genera, and along with *Bacteroides, Acinetobacter, Klebsiella*, these genera showed a potential circulation between the three compartments. On the other hand, metagenomic analysis detected a total of 1216 ARGs from 26 classes with more than 20% of ARGs shared between the compartments, also indicating an active circulation of ARGs. The relative abundance of shared resistome also reflected the main classes of antibiotic used on cage farms with a dominance of ARGs related to tetracycline, beta-lactams, macrolide-lincosamide-streptogramin, and multidrug resistance, which together accounted for 86.5% and 16.9% of the shared and total ARGs, respectively. In agreement, high phenotypic resistance to beta-lactams (penicillins, cephalosporins, monobactams) were observed. Overall, our study demonstrates the interconnectedness of farmers, livestock and environment pathobiomes and resitomes. Our results also indicate that cage aquaculture farming may play a critical role in the dissemination of antimicrobial resistance, with potential consequences on human and livestock health.

PATHOGENICITY OF *VIBRIO HARVEYI* ASSOCIATED WITH SCALE LOSS AND MUSCLE NECROSIS IN CAGE-CULTURED RED DRUM (*Sciaenops ocellatus*) IN VIETNAM

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This study investigated the pathogenic role of *Vibrio* spp. recovered from cage-cultured red drum (*Sciaenops ocellatus* Linnaeus, 1766) exhibiting scale loss, muscle necrosis, and mortality in Khanh Hoa province, Vietnam, in 2023. Bacteriological examination of skin ulcers and internal organs from diseased fish revealed homogeneous colonies of Gram-negative, short rod-shaped bacteria on multiple selective media commonly used for marine *Vibrio*. All seven isolates displayed similar cultural and morphological characteristics, suggesting infection by a single bacterial species. Biochemical profiling with API 20E, combined with PCR amplification and sequencing of the *toxR* gene, consistently identified the isolates as *Vibrio harveyi*. Experimental infections were conducted by intraperitoneal injection of bacterial suspensions into healthy red drum with an average body weight of approximately 35 g. Challenged fish rapidly developed clinical signs resembling those observed in the field, including extensive scale shedding, fin erosion, muscle necrosis, and internal hemorrhages. Mortality began 24 h post-challenge and continued for up to 7 days, with a calculated LD50 of 1.5×10^5 CFU per fish, indicating a high pathogenic potential. *V. harveyi* was successfully re-isolated from experimentally infected fish, thus fulfilling Koch's postulates and confirming this species as the etiological agent of the outbreak. To our knowledge, this is the first documented case of *V. harveyi*–associated disease in cage-cultured red drum in Vietnam and highlights the urgent need for targeted health management and improved biosecurity strategies in marine finfish aquaculture.

***Keywords**: Vibrio spp., red drum (Sciaenops ocellatus), Vibrio harveyi, LD50, Vietnam*

RAPID DETECTION OF CYHV-2 USING A ONE-POT RAA-CRISPR/CAS12A ASSAY COMBINED WITH FE-IRON FLOCCULATION

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Cyprinid herpesvirus 2 (CyHV-2) is a highly pathogenic virus that causes severe economic losses in goldfish and crucian carp aquaculture. Current diagnostic methods rely on specialized equipment and invasive tissue sampling, limiting their on-site application. This study aimed to establish a rapid, visual, one-tube, and equipment-light detection method for CyHV-2 by integrating recombinase-aided amplification (RAA), CRISPR/Cas12a, and Fe-iron flocculation technology. The conserved *ORF71* gene was selected as the target. A 15% sucrose phase separation system was used to achieve one-pot RAA-CRISPR/Cas12a detection in a single closed tube. Fe-iron flocculation was applied for non-invasive waterborne virus concentration, combined with Chelex-100 for rapid nucleic acid extraction. The entire assay was completed within 60 min at 37 ℃, and results were directly visible under blue or UV light. Sensitivity testing showed a detection limit of 10 copies per reaction, which is higher than that of conventional PCR. No cross-reactivity was observed with CyHV-3, GCRV-I/II, SVCV, or *Aeromonas hydrophila*, confirming high specificity. In tests of 24 clinical and environmental samples including aquaculture water, crucian carp tissues, and cell culture supernatants, the assay achieved a positive detection rate of 91.67%, superior to the standard PCR method (87.5%). This method enables non-destructive, field-adaptable monitoring of CyHV-2 in aquaculture environments. It provides a reliable tool for early warning, disease surveillance, and sustainable control of CyHV-2 infection.

Keywords: *CyHV-2; RAA-CRISPR/Cas12a; one-pot assay; Fe-iron flocculation; rapid detection*

SINGLE-CELL ANALYSIS IDENTIFIES LYMPHOCYTES AS THE MAJOR TARGETS AND SOURCE OF MEGALOCYTIC CELLS DURING ISKNV INFECTION IN *Siniperca chuatsi*

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Infectious spleen and kidney necrosis virus (ISKNV) is a major pathogen in mandarin fish aquaculture, yet its major target cells and the origin of the characteristic megalocytic lesions remain unclear. Here, we combined single-cell RNA sequencing with histological, cytometric, and functional assays to define splenic infection during acute ISKNV challenge in mandarin fish. Profiling 82,842 splenic cells from mock and infected fish identified B lymphocytes, T lymphocytes, and a distinct CFL2+ infection- associated population as the major ISKNV-positive compartments. Viral transcript mapping and in situ colocalization confirmed that viral signals were concentrated in IgM+, CD3+, and CFL2+ cells, whereas myeloid and other splenic populations were not major targets. Trajectory analysis linked B- and T-cell states to the CFL2+ endpoint, and both tissue histology and ex vivo lymphocyte infection supported a continuum from typical lymphocytes to enlarged basophilic cells, indicating a lymphocyte origin of megalocytic pathology. At the tissue level, ISKNV induced broad inflammatory and antiviral responses; however, virus-positive target cells displayed attenuated cGAS- STING-ISG activity relative to bystander cells. In parallel, infected cells showed increased oxidative phosphorylation, TCA cycle, translation, and proteostasis programs. Among induced host factors, HSP90aa1 supported efficient infection, because pharmacological inhibition or knockdown reduced viral readouts. Together, these findings define the major cellular targets of ISKNV, clarify the origin of megalocytic cells, and provide a candidate host-directed target for future anti-ISKNV intervention.

ISOLATION, GENOMIC CHARACTERIZATION, AND CONTROL STRATEGIES FOR SCALE DROP DISEASE VIRUS: DEVELOPMENT OF VACCINES AND DIAGNOSTIC ANTIBODIES

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Scale drop disease virus (SDDV), a novel member of the genus *Megalocytivirus* (species *Megalocytivirus lates1*), poses a major threat to marine aquaculture in Asia, particularly affecting Asian seabass (*Lates calcarifer*) and yellowfin seabream (*Acanthopagrus latus*). Here, we report the isolation and characterization of an SDDV strain, ZH-06/20, from diseased yellowfin seabream in South China. The virions exhibited typical icosahedral morphology with a diameter of ~140 nm. Complete genome sequencing revealed a 131,893 bp double-stranded DNA genome encoding 143 predicted proteins. Experimental infection caused 100% mortality in yellowfin seabream, accompanied by severe ascites but without scale drop lesions. To develop control strategies, we evaluated vaccine efficacy. A formalin-inactivated SDDV vaccine conferred >97% protection in mandarin fish and >90% protection in field trials with yellowfin seabream. Furthermore, a bivalent inactivated vaccine containing ISKNV-I and SDDV provided robust cross-protection in Asian seabass against multiple megalocytivirus subtypes, achieving relative percent survival above 85%. For diagnostics, ten monoclonal antibodies (mAbs) targeting the SDDV major capsid protein were generated. All mAbs specifically recognized SDDV without cross-reactivity to other fish viruses. Selected mAbs bound intact virions and detected viral antigens in naturally infected tissues. Together, these findings advance understanding of SDDV biology and pathogenesis and establish effective vaccines and diagnostic reagents to mitigate the impact of this emerging pathogen in aquaculture.

Keywords: *Scale drop disease virus; Vaccine development; Aquaculture disease diagnostics*

MANDARIN FISH TANKYRASE 1-LIKE PROTEIN REGULATES THE Wnt/β-CATENIN PATHWAY AND FACILITATES THE INFECTIOUS SPLEEN AND KIDNEY NECROSIS VIRUS REPLICATION

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Tankyrase (TNKS), a poly (ADP-ribose) polymerase (PARP) protein, mediates the PARylation of substrates, ultimately guiding them towards proteasome-dependent degradation or altering their localization. Recent studies suggest that TNKS may play a crucial role in both innate immunity and viral infection, yet its function in teleost fish remains unexplored. This study aimed to investigate the roles of mandarin fish (*Siniperca chuatsi*) TNKS1-like (scTNKS1-like) in the Wnt/β-catenin signaling pathway and its impact on infectious spleen and kidney necrosis virus (ISKNV) infection. Bioinformation analysis results showed that scTNKS1-like contained ANK, SAM, and PARP domains, with its sequence highly conserved across different species. Expression pattern analysis showed that scTNKS1-like mRNA was ubiquitously distributed in all tissues and was significantly upregulated in response to immune stimuli and ISKNV infection. Dual-luciferase reporter assays indicated that scTNKS1- like could evoke and positively regulate the Wnt/β-catenin signaling pathway. Protein degradation assays and co–immunoprecipitation experiment further showed that scTNKS1-like interacted with and regulated axis inhibitory protein 1 to activate the Wnt/β-catenin signaling pathway. Moreover, it was found that scβ-catenin activated the Wnt/β-catenin signaling pathway, which in turn enhanced ISKNV replication. Furthermore, scTNKS1-like was observed to significantly upregulate ISKNV replication. These findings demonstrated the role of scTNKS1-like in teleost fish and contribute to our understanding of its function in virus infection.

Keywords: *TNKS1; Wnt; ISKNV; Signaling pathway; Mandarin fish*

TRANSCRIPTOMIC INSIGHTS INTO GROUPER NEURO-REGENERATION AND THE SUSCEPTIBILITY OF NERVOUS NECROSIS VIRUS

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Teleost fish possess a remarkable regenerative capacity in their central nervous system, yet they also face lethal threats from nervous necrosis virus (NNV) in aquaculture, making them ideal model organisms for studying both neural repair and immune responses. This study comprehensively investigates the intrinsic mechanisms of fish nerve regeneration and the transcriptomic responses of brain tissue to NNV infection.

Regarding nerve regeneration, Growth-Associated Protein 43 (GAP-43) plays a crucial coordinating and supporting role in the repair process. Studies indicate that during the regeneration period following optic nerve transection, GAP-43 mRNA and protein exhibit a significant biphasic upregulation. This upregulation not only promotes axonal growth and structural plasticity but also serves as a vital biochemical marker for monitoring the entire cycle of fish optic nerve regeneration.

In terms of the nervous system's antiviral response, we conducted a next-generation sequencing (NGS) transcriptome analysis on the brain tissue of grouper infected with NNV. The results reveals the intrinsic molecular mechanisms of the teleost brain when coping with nerve injury and viral invasion. These genomic data not only provide essential targets for the prevention, control, and vaccine development against aquaculture diseases like VNN, but also offer cross- species scientific insights into potential therapeutic strategies for neurodegenerative diseases.

***Keywords**: Neuro-Regeneration, Growth-Associated Protein 43 (GAP-43), nervous necrosis virus (NNV), Disease Susceptibility*

ARTIFICIAL INTELLIGENCE IN CAGE AQUACULTURE: CURRENT APPLICATIONS, CHALLENGES AND FUTURE PROSPECTS

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The rapid expansion of cage aquaculture from nearshore to offshore and deep-sea environments has brought unprecedented challenges in water quality management, feeding efficiency, disease detection, biomass estimation, and structural safety. Artificial intelligence (AI) is emerging as a transformative solution. Integrating the internet of things (IoT) sensors and AI-based predictive analytics can enable continuous, real-time monitoring and early intervention to prevent adverse conditions, the hybrid deep learning models (e.g., CNN-LSTM, PCA-LSTM, TD-LSTM) achieve an effective forecast for the water temperature, pH, salinity, dissolved oxygen, turbidity, chlorophyll and ammonia with a higher R^2. AI-driven smart feeding systems use multilayer perceptron neural networks to classify fish behaviors, achieve a perfect accuracy for real-time feeding adjustments and reduce feed waste by 15–40%. In fish disease detection and classification, AI combined the multiple models in ensemble or hybrid architectures has proven effective in enhancing detection and classification of diseases. For example, the attention mechanisms in deep learning models allow networks to focus on disease-specific features. Regarding structural integrity, AI-based models can predict mooring forces and cage motion under irregular waves with $R^2>0.94$. However, challenges remain: high initial investment, lack of standardized datasets, limited model generalization across species and environments, and technical barriers for small-scale farmers. Future directions include integrating AI with the Internet of Things (AIoT) for autonomous monitoring, deploying edge computing for real-time decisions in remote farms, developing digital twins for predictive management, and using lightweight deep learning on mobile platforms. With strong policy support and falling sensor costs, AI-enabled cage aquaculture will significantly enhance sustainability, productivity, and resilience, securing a smart “blue food” future.

Keywords: *Artificial intelligence; cage aquaculture; deep learning; smart feeding; disease detection; mooring force prediction*

CURRENT STATUS AND DEVELOPMENT TRENDS OF CHINA'S SMALL-SHED SHRIMP FARMING INDUSTRY

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Small-shed farming is the dominant intensive aquaculture model for *Penaeus vannamei* in China, and the industry has achieved a pattern of large-scale development. Currently, the total number of small sheds in China exceeds 450,000, mainly concentrated in coastal provinces such as Jiangsu, Guangdong, and Guangxi. Leveraging the advantages of multiple cropping per year, facility-based environmental control, and high and stable yields, the annual output of this farming model accounts for over 30% of the total domestic white shrimp production. It has become a core force ensuring the supply of the shrimp market and drives the coordinated development of upstream and downstream industrial chains. At the current stage, the industry faces numerous bottlenecks. Frequent outbreaks of diseases such as *Enterocytozoon hepatopenaei* (EHP) and Vibrio have led to high farming risks. Rising feed and labor costs, together with market price fluctuations, are squeezing profit margins from both sides. Increasing environmental pressure from the treatment of aquaculture tailwater and the drawbacks of extensive development are becoming increasingly evident. In the future, the industry will accelerate its transformation and upgrading, moving toward facility-based, intelligent, and green development. The adoption of new-type shed upgrades, intelligent water quality monitoring, and precision feeding technologies will become widespread. Centralized, park-style intensive operations will gradually replace scattered farming practices. Comprehensive ecological disease control and standardized tailwater treatment models will be fully promoted, facilitating a high-quality development transition from scale expansion to efficiency improvement, quality enhancement, and green sustainability.

Keywords: *Small-shed Farming; Penaeus vannamei; Industry Status; Trend*

EVALUATION OF THE EFFECTS OF STAR ANISE (*Illicium verum*) AQUEOUS EXTRACT AGAINST CYPRINID HERPESVIRUS 2

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Cyprinid herpesvirus 2 (CyHV-2) is a causative factor of herpesviral hematopoietic necrosis (HVHN) in *Carassius* species, resulting in high susceptibility and mortality with significant epidemiological value. As far, there is no effective targeting control strategy. Herein, to further explore the compounds derived in natural plants with potential antiviral effects, we focused on star anise (*Illicium verum*) with numerous active ingredients. We established a standardized water extraction process for star anise, and it exhibited the effects against CyHV-2 both in vivo and in vitro. Then we further found that quercetin as one of the major components of star anise inhibits CyHV-2 replication in vitro and in vivo, which its underlying mechanism potentially relates to inhibiting AKT phosphorylation. Additionally, we examined another 14 main compounds in star anise, among them, 9 components exhibited antiviral activity in vitro. These findings indicated that star anise, especially quercetin has potential anti-CyHV-2 effects. Since aquaculture water serves as a vector for aquatic viral diseases and the release of chemical compounds lead to pollution of the aquatic environment, we propose star anise derived in natural dietary as a promising candidate for development into a novel drug against CyHV-2 infection (Figure 1).

Keywords: *Cyprinid herpesvirus 2; Star anise aqueous extract; Quercetin; AKT*

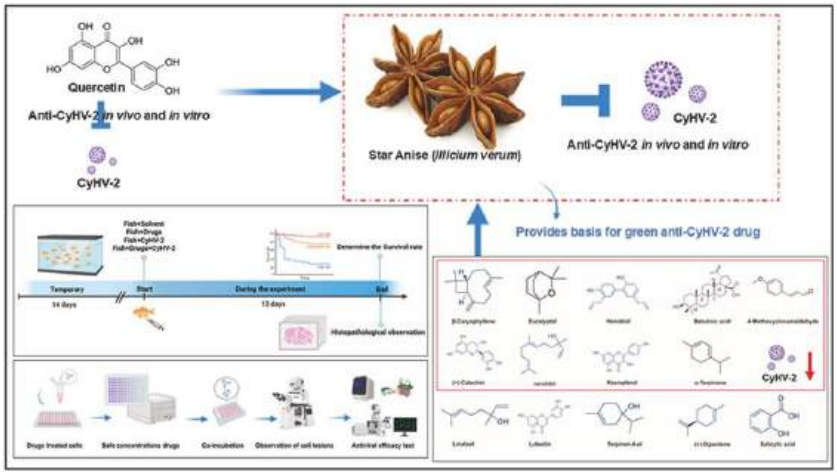

Figure 1. Graph of star anise aqueous extract and its major active ingredients against CyHV-2 infection.

ALTERNATIVES TO ANTIMICROBIALS IN AQUACULTURE

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This paper examines alternatives to antimicrobials (ATAs) in aquaculture through a policy and systems lens, focusing primarily on Southeast Asia. It argues that the principal challenge is no longer the absence of technical solutions alone, but the failure of regulatory, market, and delivery systems to support adoption at scale. The paper reviews the evidence on antimicrobial resistance (AMR) in aquaculture, highlighting its implications for food safety, trade, environmental integrity, and human health within a One Health framework. It assesses established and emerging alternatives, including vaccines, immunostimulants, probiotics, phytobiotics, improved biosecurity, bacteriophages, quorum-quenching approaches, antimicrobial peptides, nanovaccinology, and selective breeding for disease resistance.

Across these options, many promising tools remain trapped in research, pilot, or niche commercial settings. Three interlocking barriers explain this adoption gap: (1) fragmented and outdated regulatory frameworks, (2) weak market incentives and high farmer risk, and (3) limited extension, knowledge brokering, and trust at farm level. Drawing on regional policy reviews and case vignettes from innovation projects, the paper identifies five priority actions: (1) integrate aquaculture into national AMR strategies; (2) modernize and clarify regulatory pathways for aquatic biologics and other alternatives; (3) strengthen regional harmonization; (4) invest in field validation, risk-sharing, and last-mile delivery; and (5) support regional knowledge platforms such as NACA-AquaHub. The paper proposes a forward-looking roadmap for scaling antimicrobial alternatives in aquaculture for the region and concludes that reducing antimicrobial dependence will require a shift toward coordinated systems that make alternatives accessible, affordable, credible, and scalable.

AN ANALYSIS OF CARBON EMISSION FROM TOURSM ACTIVITIES IN KARIMUNJAWA, INDONESIA

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The demand for marine recreation in Karimunjawa is significantly increasing from time to time They are going for snorkeling, diving and boating. In the study area, the tourism industry is growing very fast, especially for accommodation, marine recreation activities, and also for café & restaurant with its amusement. This study aims to analyze on carbon emissions from tourism industry with special reference to waste and energy used by hotel operations; and marine recreation, particularly for snorkeling activities.

Data were collected from the selected respondents using purposive sampling for hotel/ homestay management, and boat tourist operators. The key-persons from the stakeholders of ABGC (Academician- Business-Government-Community) were also been interviewed. This study employed quantitative- and qualitative approach, then mixed methods were used to analyze the data accordingly.

The results indicated that the bigger hotel tends to produce a higher carbon emissions. This is because more energy used were consumed for air cooler, water heating, lighting, and running the services. While the smaller scaler accommodation operators, they shared for lower emissions. The marine recreation activities with bigger boat size will consume more in diesel fuel and this will contribute higher in carbon emissions. This study suggests that we indeed need to set up a mitigation strategies to manage tourism activities sustainable in Karimunjawa.

Keywords: *carbon, emissions, management, tourism, sustainable, Karimunjawa*

THE RESILIENCE OF MIGRANT FISHER'S WIVES IN SECURING THE FAMILY ECONOMY AND CHILDREN'S EDUCATION (A CASE STUDY IN BATANG REGENCY, INDONESIA)

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This research addressed the challenges faced by migratory fisher's wives who experience socio-economic pressures. The significant of this study could assist local governments in formulating strategic policies to improve fisher's household welfare and at the sametime to conserve the coastal resources.

A multi-year research were using a mixed-methods and participatory observation. The qualitative approach with in-depth analysis was used to formulate the stakeholders strategy in securing fishers family crisis. The collected data from the fields and photovoices from observation were used to do the suitable problem-solvings. Participatory observation had have enriched the analysis on the fisher's wives' daily activities and their role in surviving the family livelihoods. Recommendations from stakeholders will be used to formulate policies to improve fisher's family welfare and the sustainability of fishery resources in Batang Regency, Indonesia.

***Keywords**: Resilience, Wive, Migrant, Fishers, Family, Welfare, Batang, Indonesia*

MARINE FISH WELFARE IN VIETNAM: POMPANO AQUACULTURE AS A CASE STUDY

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As global marine aquaculture adopts higher ethical standards, fish welfare remains a poorly understood and understudied field in Vietnam. While the industry expands and export potential grows, current operational protocols still lack alignment with standardized welfare guidelines. Addressing this gap requires a comprehensive survey of stakeholder welfare perceptions to bridge the divide between those working directly with fish and the actual biological requirements of the species.

Using pompano farming in Nha Trang as a case study, this research evaluates welfare perceptions and practices across hatcheries, grow-out farms, and transport operations, focusing specifically on optimum stocking densities, health management, environmental control, and operational handling.

Hatcheries demonstrated strong adherence to density limits and the strict application of proactive health management. Conversely, transport operations presented the greatest risk; high stocking densities were identified as primary stressors, compromising water quality and oxygen levels. Grow-out operations, relying on natural water, faced physiological risks from environmental fluctuations and inconsistent chemical use. Regarding grading, although acute handling stress is generally cautioned against by experts, in practice, the procedure is regarded as vital "training" to acclimate fish for future transport and grow-out. Overall, while the concept of fish welfare is entirely new to stakeholders, the majority-particularly those in hatcheries-consciously apply practices that meet welfare standards. However, a knowledge gap persists among transporters, who prioritize immediate survival over long-term physiological condition.

To unlock export potential, the industry must transition from intuitive management to evidence-based frameworks that quantify stress responses, providing a baseline for standardized welfare protocols in Vietnamese marine aquaculture.

Keywords: *pompano, marine farmed fish, welfare perception, survey*

FEASIBILITY OF ASIAN SEABASS IN FRESHWATER AQUACULTURE: A STUDY ON SALINITY ADAPTATION AND FEEDING EFFICACY

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The present study exploring the feasibility of integrating Asian seabass (*Lates calcarifer*) into freshwater systems. The fry having average body weight (± SD) of 0.45 ± 0.21 g, were reared in saline conditions (10 ppt) for 90 days and then transition them to freshwater (10 – 7 – 4 – 0 ppt) in 30 days. Furthermore, a feeding (commercial feed, trash fish, and live fish) trial was conducted with freshwater adapted fingerlings to assess their growth and health under controlled feeding conditions. The growth of fry peaking at around 6 g with a 60% survivability by the end of the rearing in saline condition. Fish weight gradually increased as salinity levels declined (10 – 7 – 4 – 0 ppt), reached 8 g with an 82% survivability at 0 ppt salinity. The hemoglobin level increased and blood glucose decreased continually as salinity decreased. A progressive rise in chloride cells was recorded as salinity decreased from 10 ppt to 0 ppt. In feeding trial in freshwater condition, maximum weight gain and specific growth rate were observed in the fish fed with live fish followed by commercial feed, and trash fish. Zero mortality was observed in live feed treatment whereas maximum mortality (20%) found in trash fish feed treatment. The hemoglobin and blood glucose level showed no distinct changes in irrespective of any feed. However, fish fed with live feed resulted in the highest number of goblet cells per villus in the intestine. Overall, these findings suggested that Asian seabass could be a suitable species in freshwater aquaculture.

Keywords: *aquaculture, salinity, vetki, hematology, histopathology*

TOWARDS SUSTAINABLE FRESHWATER PEARL AQUACULTURE: SPATIOTEMPORAL DYNAMICS ASSESSMENT OF CARRYING CAPACITY AND FARM-FITTING ZONING FOR *Hyriopsis cumingii* IN QIANHE LAKE

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Filter-feeding organisms play an important role in improving lake water quality, yet research has largely focused on filter-feeding fish, while lake-scale assessments of freshwater mussels remain limited. Accurate estimation of aquaculture carrying capacity is essential for sustainable resource management, but systematic evaluation methods for freshwater shellfish are still lacking. This study developed a dynamic framework integrating remote sensing inversion and ecological modeling to quantify the spatiotemporal carrying capacity of *Hyriopsis cumingii* in Qianhe Lake. Using four Sentinel-2 images and field observations, chlorophyll-a concentration was inverted with multiple algorithms, among which the random forest model achieved the best performance (R^2 = 0.423, RMSE = 6.163). Chlorophyll-a ranged from 3.88 to 36.28 μg/L and showed pronounced monthly and spatial variability, with the highest values in July, followed by November, April, and August, and a consistent upstream-dominant distribution. Filtration rates increased markedly with mussel age, with adults (three-year-old) showing the highest rates, particularly in July, whereas juveniles exhibited stronger monthly fluctuations. Integrating phytoplankton dynamics and filtration rates revealed strong spatiotemporal heterogeneity in carrying capacity, peaking in November and reaching minima in April and August. Adults consistently supported the highest biomass per unit volume. Spatially, downstream areas exhibited the greatest theoretical capacity, while upstream zones were least suitable, especially for juveniles. These results indicate that carrying capacity in Qianhe Lake is jointly regulated by phytoplankton availability, hydrodynamic conditions, and mussel size structure, highlighting the need for dynamic and spatially differentiated aquaculture management. This framework provides a practical tool for evaluating ecological aquaculture potential in freshwater lakes.

Keywords: *Hyriopsis cumingii; Chlorophyll a; Remote sensing retrieval; Ecological model; Carrying Capacity.*

A BIBLIOMETRIC ANALYSIS OF GENDERED HEALTH KNOWLEDGE ON PLASTICS USE IN CAGE AQUACULTURE: ASEAN RESEARCH LANDSCAPE, 2001-2025

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Gender roles in cage aquaculture differ markedly with men dominating farming and harvesting, while women are more involved in processing and marketing. These gender division of labor shapes how plastics are used and managed in aquaculture systems. Although plastics offer convenience and affordability, its continued use in the sector contributes to microplastic ingestion in marine life, fishnet entanglement, reduced fish catch, and health risks --- all of which affect men and women differently.

Using bibliometric analysis of 97,751 PubMed articles published from 2001 to 2025, this study maps the ASEAN research landscape on gendered health knowledge related to plastics use in cage aquaculture. The analysis shows the number of publications, trends, authorship, author collaborations, top journals, and ASEAN-affiliated publications. Five key findings emerge: (1) only 3,282 articles focus on plastics in aquaculture; (2) there is a rising trend in publications but those which include gender mainstreaming is minimal; (3) Singapore, Malaysia, and Thailand lead regional publications, while Cambodia, Laos, Myanmar, and Timor-Leste have the least; (4) China and UK dominate international research collaborations particularly with Singapore and Malaysia; and (5) top three journals are Science of the Total Environment, and Marine Pollution Bulletin, both by Elsevier, and Environmental Science and Pollution Research Journal, by Springer.

To address the research gaps, the study recommends integrating gender approaches and the use of gender-responsive analytical tools into health knowledge on plastics use in cage aquaculture research in the ASEAN. Hence, provide evidence that will inform gender-inclusive policymaking, sustainable aquaculture program development and governance.

***Keywords**: gendered health knowledge, ASEAN research trends, plastics use, cage aquaculture*

MANAGEMENT IMPLICATIONS OF THE SOCIO-ECONOMIC DYNAMICS AND FISHING PRACTICES AMONG SMALL-SCALE FISHERS IN LAKE DANAO NATURAL PARK, PHILIPPINES

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Fishing is a critical livelihood strategy for communities within Lake Danao Natural Park (LDNP), a protected area in Ormoc City, Leyte, Philippines. Despite its importance, limited attention has been given to the socio-economic conditions, gender roles, and governance dimensions which shape small-scale fisheries and their transition toward more sustainable livelihoods.

This study addresses this gap by examining the socio-economic profile and fishing practices of 4 female and 17 male fishers in the lake in July 2022 through a semi-structured interview. Results revealed that fishing is predominantly practiced by tenured migrant households with limited asset ownership, who primarily rely on non-motorized boats and low-capital fishing gear such as handlines, gillnets, long lines, scoop nets, and spearguns. Fishing activities are characterized by low productivity and limited time investment, reflecting both declining participation and constrained livelihood opportunities. Women's participation remains limited, suggesting the need for more inclusive livelihood strategies. The findings highlight structural livelihood vulnerabilities and underscore the importance of integrating socio-economic considerations into governance frameworks for protected areas. Cage aquaculture within LDNP is prohibited, reflecting conservation priorities and regulatory constraints associated with its protected status. In this context, the study emphasizes the need for governance approaches that balance biodiversity conservation with livelihood security by supporting alternative, sustainable, and compliant aquatic and non-aquatic livelihood options. Strengthening community-based management, inclusive participation, and policy support mechanisms is essential to enhance resilience, ensure equitable benefit-sharing, and promote the sustainable utilization of aquatic resources in Lake Danao and similar inland systems.

Keywords: *Fishing gear and practices, freshwater fisheries, protected areas management, lake*

EMPOWERMENT THROUGH MONITORING: CASES OF WOMEN AQUACULTURISTS IN THAILAND AND CAMBODIA

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Aquaculture is often considered to be a man's job, mainly because it often requires going into the water body. However, it is also noted that women work on aquaculture in various ways, including feeding. However, because aquaculture is considered a man's job, women are less confident in discussing aquaculture compared to men. Our project has tried to change this norm by engaging women in aquaculture – not through physical work, but through their observation and knowledge. The gender monitoring schema has been designed to engage women and sharpen their observations, making them field scientists on the way, through regular visits and conversations. As gender relations and women's empowerment often change slowly, regular visits are intended to capture the process. The normal monitoring can miss many small signs of change in gender relations and women's empowerment. Our monitoring schema attempted to overcome this shortcoming by focusing on the process.

The presentation will show how the changes unfolded over time and the importance of capturing small changes. The process of change can also capture how relationships between women and their family members evolve, and how women's engagement in aquaculture influences their husbands' behavior. Since regular visits foster the small changes in how women see themselves, they lead to deeper changes in household relations, and we have found ripple effects that involve their husbands in women's aquaculture work, rather than the other way round. The qualitative data are from rice-fish production in Thailand and Cambodia, conducted in 2025/26, with 25 women farmers in Thailand and 23 in Cambodia.

Keywords: *Gender, Rice-Fish Culture, Monitoring, Thailand, Cambodia*

CURRENT AQUATIC ANIMAL WELFARE RESEARCH AND PRACTICE DEVELOPMENT IN CHINA

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Over the past two decades, aquatic animal welfare science has progressed significantly in Western countries, facilitating the development of evidence-based frameworks to guide welfare practices. More recently, this area has garnered increasing attention within both academic and industry spheres in China. As the world's largest producer of seafood, China occupies an important position in the global discourse on aquatic animal welfare. Its vast production scale, ecological and species diversity, and substantial influence in international seafood markets collectively underscore its potential to shape the development of welfare standards and practices worldwide. This paper reviews recent research and industry developments related to aquatic animal welfare in China. It discusses its key challenges and opportunities across major stages of the production and supply chain. By highlighting current progress, it tries to identify remaining gaps and outlines potential directions for future research and implementation of aquatic animal welfare in China.

China entered the field of fish welfare research relatively late but has expanded its efforts rapidly in recent years. Fish welfare research in China has been characterized by a strong technological and engineering orientation, with particular emphasis on recirculating aquaculture systems (RAS), precision aquaculture, and artificial intelligence–based behavioural monitoring. Research has also addressed issues such as stocking density and spatial requirements, environmental stressors, green and healthy aquaculture technologies, and, more recently, welfare considerations in capture fisheries. From a scientific perspective, the principal challenges include a lack of baseline welfare data across China's highly diverse farmed fish species and production systems. From the perspective of producers and markets, key barriers include low levels of farmer and public awareness, limited consumer willingness to pay welfare premiums, and the near absence of dedicated welfare legislation and industry standards. At the same time, these challenges present important opportunities. Priority areas include addressing knowledge gaps on welfare data, expanding welfare-compatible RAS production systems, strengthening understanding of the relationship between welfare and product quality, enhancing collaboration between academia, industry, and international partners, and establishing regulatory and standards frameworks.

By providing an overview of ongoing fish welfare developments in China, this paper aims to contribute to broader discussions on advancing aquatic animal welfare research and practice in Asia and globally.

Keywords: *Aquatic animal welfare; Seafood industry; Sustainability; Innovation; China*

GENDER-RESPONSIVE MONITORING SCHEMA - ITS RELEVANCE TO AQUACULTURE

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Aquaculture, despite being known as male dominated, employs many women in various roles. However, women's knowledge and expertise continue to be ignored, not only in the process of innovation and technological development, but also in basic processes such as data collection, intervention and policy development. Although there is awareness of women's heavy involvement in various aquaculture systems, such as cage aquaculture, and more extensive and sustainable aquaculture, there is no systematic monitoring schema to capture this information. In addition, women's involvement does not only impact the aquaculture production systems they are involved in, but also transforms the women themselves as they learn and become more skilled, resulting in shifts in gender relations and dynamics within households, workplaces, and communities. The change process is crucial to document, since empowerment is a transformational process. However, a review of current monitoring, evaluation and learning (MEL) systems used in aquaculture are not adequate to capture these changes. This paper presents a gender monitoring schema for aquaculture that focuses on three agentic processes (awareness, images of change, and agency) and two environmental processes (attitudes towards nature-based solutions practices and climate change) to allow the monitoring, evaluation and learning of women's meaningful participation, and capture the process of change towards gender equality in the context of sustainable aquaculture. The schema was developed after a series of literature reviews and deliberation by a group of gender in aquaculture experts. To ensure the process of change is captured with the involvement of women farmers throughout the process, pilot studies were conducted in nature-based solutions in aquaculture systems such as rice-fish culture in Cambodia and Thailand, and seaweed farming in the Philippines. Monitoring visits encouraged the women farmers to make their own observations, express their own thoughts, ideas and opinions, and to ask questions. The first phase of piloting the monitoring schema has been completed with results related to the agentic and environmental processes showing that women involved in the pilot studies have become more observant of their own capacities and their transformation, realizing their potential to learn, lead and teach others. The monitoring schema aims to produce stories of change that describe women's experiences over time, which may include changes observed, why the change matters, contributing factors and evidences or examples.

***Keywords**: Gender monitoring, Women's empowerment, Sustainable aquaculture, Transformative processes*

GENDER PROCESS MONITORING IN NATURE-BASED CLIMATE SOLUTIONS IN AQUACULTURE: A CASE STUDY OF WOMEN SEAWEED FARMERS IN THE PHILIPPINES

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Women actively participate in aquaculture activities, particularly small-scale aquaculture. However, their contributions are occasionally overlooked and undervalued. At the same time, research has shown that women are empowered by their involvement in aquaculture, but the patterns are not consistent. This is pilot research that employed the Gender Monitoring Schema (Kusakabe et al. 2025) to detect and document modest changes in gender relations and gender transformation in the lives of 35 female seaweed growers in the municipality of San Dionisio, Iloilo, Philippines. Following the gender analysis, which serves as a baseline for the research, a research monitor spends 11 months with these women, beginning in September 2025 and finishing in July 2026.

The presentation contains the results for the first six months of visits (September 2025– February 2026) with two rounds of each of the schema's five domains, including climate change, attitude, awareness, agency, and image of change. The findings demonstrate that quick but frequent visits and chats with the women can inspire them to be more aware of their circumstances, more confident in themselves, and more generous in providing information about their seaweed farming and changes in their lives. The study investigated how these changes occurred, who witnessed them, and how these changes in female seaweed producers affected those around them. These findings shed light on how gender transformational programs should be designed, as well as how extension work can be modified to generate more effective and long-term results.

***Keywords**: Gender Monitoring Schema, gender analysis, monitoring, San Dionisio*

ASSESSING AQUACULTURE TRANSFORMATION INITIATIVES IN CHINA

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China is the world's largest aquaculture producer and remains central to global aquatic food security, contributing 56% of global aquaculture production in 2023 and supplying more than 80% of China's aquatic foods. However, the sector has entered a new transformation stage as production growth slows, China's global share declines, farming area and labour availability contract, and environmental pressures intensify. This paper assesses aquaculture transformation initiatives in China by reviewing policy shifts, development constraints, and innovation, investment and partnership initiatives aligned with regional aquaculture transformation goals. Since the 2010s, China's "ecological civilization" philosophy has redirected aquaculture policy from production expansion towards green development, environmental protection, food safety, and high- quality growth. Major initiatives include green and healthy aquaculture "five actions", spatial zoning of aquaculture areas, pond standardization, wastewater treatment, reduced medicine use, replacement of trash fish with formulated feed, aquatic germplasm improvement, healthy and ecological demonstration zones, mechanization, digital monitoring, offshore aquaculture, saline-alkali land aquaculture, and value-chain upgrading. The initiatives show strong policy commitment and growing technological capacity, with most innovations already in growth or expansion stages. The assessment indicates that China's transformation is increasingly production-oriented but also contributes to environmental resilience, improved governance, and food security. Further progress will require stronger inclusive value chains, broader partnerships, adaptive management, and better integration of ecological, economic, and livelihood outcomes.

Keywords: *Aquaculture transformation; Green aquaculture; Ecological civilization; Innovation and investment*

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) EXPENDITURES AMONG AQUACULTURE PRODUCERS IN THE PHILIPPINES: WHAT OUR NATIONAL SURVEYS TELL US

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For over a decade now, aquaculture has dominated the Philippine fishery industry in terms of production, economic value, and exports. In the last 15 years, aquaculture has experienced rapid expansion, overtaking commercial and small-scale fisheries. It has become the leading producer of fish in the country, with output reaching 51% in 2017 and even rising further to 55.3% in 2024.

The Aquaculture sub-sector will benefit tremendously from information and communication technology (ICT), but the generally low technology uptake among fish farmers can be a deterrent to the sub-sector's sustainable growth.

Currently, studies on ICT in Philippine aquaculture are few, resulting in a dearth of critical information for appropriate interventions and policies. This research helps close this gap by providing information on ICT in aquaculture. More specifically, the study examines ICT expenditure among aquaculture farmers in the Philippines using the Family Income and Expenditure and Labor Force Surveys. It aims to estimate the average household expenditure on ICT among aquaculture households, describe ICT expenditure patterns, and determine the factors affecting ICT expenditure. Descriptive statistics and regression analysis were used to analyze the data.

On average, aquaculture households spend 44-73 US dollars, or 3.5% of their income, on ICT. Non-poor households spend twice as much on ICT as poor households. These are largely on ICT services, mobile load, and the internet. Regression results showed that ICT expenditure is determined by household income, education, and family size. These findings show important insights into crafting appropriate interventions on ICT usage in aquaculture, addressing issues such as the digital divide between poor and non-poor households.

***Keywords**: Aquaculture, ICT spending*

BRIDGING THE GENDER GAP IN AQUACULTURE: CONSTRAINTS AND OPPORTUNITIES FROM RICE–FISH FARMING IN THAILAND

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This study examines gender-based constraints and opportunities in the development of rice–fish farming systems among small -scale farmers in Thailand. Rice–fish systems contribute to household food security, generate supplementary income, optimize land use, and reduce chemical inputs through ecological interactions, promoting sustainable agriculture. This study was conducted in Kosum Phisai and Phayakkhaphum Phisai districts, Maha Sarakha m Province, northeastern Thailand, involving 30 farmers. A qualitative approach was employed using semi - structured interviews and comparative analysis to assess how gender influences access to resources, knowledge, and participation, particularly in areas with differing irrigation conditions. In addition, a pilot implementation supported women farmers to actively engage in rice –fish farming, enabling observation of their roles, capacities, and constraints under real farming conditions. The study also frames rice–fish farming as a nature-based solution for climate change adaptation.

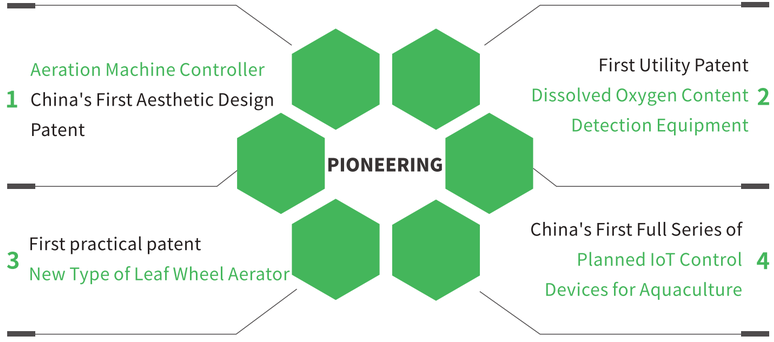
The study findings show that women play significant roles in production and community activities but face constraints, including limited access to education, technical training, m odern technologies, and extension services. These challenges are exacerbated by age -related barriers, particularly among older women, as well as limited ability to articulate needs within formal support systems. Access to water resources, especially irriga tion, is a key factor influencing system effectiveness and sustainability, with differences in resource availability shaping aquaculture outcomes.

The study highlights opportunities to bridge the gender gap through targeted capacity building, gender-responsive extension services, and improved access to water and resources. Strengthening women's participation is essential for enhancing climate resilience, food security, and sustainable rural development.

***Keywords**: gender, aquaculture, rice–fish farming, climate change, Thailand*

COMPANY & BRAND OVERVIEW

Established in 2018, Lan Song Technology is committed to IoT products and value-adding services in aquafarming, with the goal of fundamentally improving industry efficiency. Lan Song creates an intelligent aquafarming system by connecting current machinery and introducing new sensors. The system relieves farmers from inspecting their ponds several times per day with cell phone remote control. Also, with automatic fault warning, automatic feeding and water dissolved oxygen and temperature detection, the system lowers risk and improves efficiency during the whole production process. The first product, nicknamed Pond Steward, was released in 2019, and Lan Song quickly gained the largest market share in intelligent aquafarming.



- Aquaculture Online IoT Devices hold a **68%** market share in China.
- Lan Song Technology is a well-known brand and high-tech enterprise in the field of smart aquaculture in China, rapidly expanding in China through a franchise business model.
- To date,the number of online devices in the Pond Manager series has 300,000

Lan Song Technology Drives Innovation in China's Aquaculture

DEVELOPMENT PROCESS

Fish Dada, using its franchise system, has built an efficient and reliable B2B platform for aquaculture supplies to connect with farmers in China, with over 10, 000 offline franchised stores nationwide.

Established the China Fresh Aquatic Products Supply Chain B2B platform - Yu Dada App, which addresses the issue of information asymmetry in the buying and selling of aquatic products, facilitates transactions, and provides transaction guarantees, making it so that there are no hard-to-sell fish.

Developed and produced Pond Manager

Pond University is an educational platform for aquaculture, providing online high-quality courses to guide farmers in improving their breeding skills and promoting the healthy development of the aquaculture industry, with the goal of making it so that there are no difficult-to-raise fish in the world. It has been learned by 150 million people.

Established Shanghai Liansong Technology Co., Ltd., which is committed to intelligent and digital services for aquaculture, and was the first in country to use internet and IoT technology to create the intelligent farming system, Pond Manager.

Developed and produced the new type of aerator

Develop new oxygenation machine

Developed and produced the Fluorescence Dissolved Oxygen Analyzer and the Intelligent Water Quality Meter.

Developed and produced the Smart Wind-Powered Feeder and the Combined Controller; Tang Butler series online devices exceed 210, 000 units.

Droduction of intelligent feeding machine, solar energy intelligent monitoring

2008 2015 2016 2018 2019 2020 2021 2022 2023 2024 2026

FOUNDER&PARTNER

The founding team includes hardware experts, IoT experts, distribution management experts, and an experienced CFO.

JOY
Fish Dada Founder

- 无锡渔愉鱼科技有限公司创始人
- 上海览宋科技有限公司联合创始人
- 上海海洋大学/新加坡国立大学
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- 览宋科技创始人
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- 中国科技大学电子工程专业硕士
- 曾任职于英特尔、Marvell、ARM等国际知名半导体企业，担任架构设计和技术咨询
- 2014年组建腾讯智能设备创新中心
- 2016年创立小米生态链企业摩象科技并任CEO
- 2017年创立AR企业徕尼科技并任CEO
- 京东众创学院、混沌独角兽创业营、中欧教育营

Neo
Partner & Pond Manager Founder

Lan Song Technology Drives Innovation in China's Aquaculture

Advantage One

We have a team that is rich in experience and highly skilled, capable of continuously driving technological innovation.

Advantage Two

We possess core technology developed in-house, with full intellectual property ri

Advantage Three

Our products and services have been extensively tested in practice, demonstratin

Our company offers the most advanced IoT product solutions, providing comprehensive intelligent services for fish farming enterprises, including:

Environmental Monitoring: Real-time monitoring of water quality, temperature, dissolved oxygen, and other environmental parameters to promptly detect anomalies and take appropriate actions.

Aquaculture Management: Providing data analysis and decision support for aquaculture to help enterprises enhance their management standards.

Fish Population Management: Monitoring the growth of fish populations in real-time and conducting precise feeding and management based on the status of the fish populations.

Pond Manager Smart Aquaculture System Series