ASSESSING THE SOCIO-ECONOMIC VIABILITY OF INTEGRATED MULTI-TROPHIC AQUACULTURE (IMTA): A CASE STUDY IN TALOOT, ARGAO, SOUTH CEBU, PHILIPPINES

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Abstract. This case study conducted in Taloot, Argao, Philippines, assesses the socio-economic feasibility of implementing Integrated Multi-Trophic Aquaculture (IMTA) among small-scale fish farmers through a community-based approach. The study explores how local knowledge and perceptions influence the acceptance, adoption, and marketability of IMTA products. Using qualitative and participatory methodologies, the study reveals that positive community perceptions significantly contribute to the adoption and market acceptance of IMTA. The locality's well-structured aquaculture systems, supported by local government agencies, civic organizations, and private sector collaborations, provide a favorable environment for sustainable development. The results demonstrate a statistically significant increase in farmers' knowledge ($p = 0.014$) and confidence in sustainable practices, alongside perceived improvements in water quality and product quality, particularly in milkfish cultivation. Despite operational challenges such as predation and technical constraints, the integrated approach offers opportunities for diversification and environmental sustainability. The study suggests that social acceptance, community support, and collaborative networks are critical components in scaling IMTA practices, with implications for enhancing livelihoods and advancing responsible aquaculture in the region.
Keywords: *community perception, milkfish aquaculture, participatory action research, social acceptance*

Introduction

The global population has experienced unprecedented growth, reaching approximately 7.8 billion inhabitants according to recent estimates, with projections indicating an increase of 25% by 2050 (FAO, 2015). This demographic surge is predominantly concentrated in the least developed regions (Bongaarts, 2009), where the primary challenge lies in ensuring adequate nutritional intake, particularly sufficient protein sources (Henchion et al., 2017). As socio-demographic pressures intensify, reliance on animal-based proteins has escalated, consequently amplifying the environmental footprint associated with livestock and traditional aquaculture systems (Froehlich et al., 2018).

Aquaculture has emerged as a vital component of global food security, currently supplying about 70% of the world's aquatic animal production (Hua et al., 2019). However, the dependence on conventional aquafeeds and intensive farming practices raises sustainability concerns, notably due to increased waste generation from uneaten feed and effluents within confined culture systems (Dauda et al., 2019). To address

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these issues, the adoption of responsible and ecologically integrated aquaculture practices is imperative, aiming to balance ecological integrity with economic and social benefits.

One promising approach is Integrated Multi-Trophic Aquaculture (IMTA), which combines species from different trophic levels to create a synergistic and environmentally sustainable system (Chopin, 2013). Rooted in centuries-old Asian polyculture practices (Nissar et al., 2023), IMTA embodies a paradigm shift toward sustainable aquaculture by recapturing waste nutrients through the cultivation of complementary species. The origins of modern IMTA, can, however, be traced back to the 1970s, when the Woods Hole Oceanographic Institution pioneered “integrated waste-recycling marine polyculture systems,” laying the foundation for nutrient recycling and multispecies integration (Altamirano et al., 2022). Over subsequent decades, various adaptations and practices emerged globally, with Troell et al. (2003) reviewing the progress and challenges of IMTA, highlighting achievements such as effective nutrient removal and ease of maintenance, alongside limitations related to profitability. The 21st century has seen a shift toward open-water IMTA systems at broader scales, with regional adaptations reflecting unique geographic, climatic, and cultural contexts, such as China’s bay-scale “transitional IMTA” in Sanggou Bay and community-based practices like Japan’s “satoumi” and small-scale Southeast Asian systems (Altamirano et al., 2022). Despite its origins, IMTA’s principles are gradually gaining acceptance in western countries, although its intentional implementation remains limited within Asia.

The success of IMTA has long been challenged by social perception. Fujita et al. (2023) identified social factors, such as consumer awareness of environmental externalities coupled with societal demand for responsibly produced seafood, which can drive market acceptance and incentivize broader implementation. Several studies pointed out economic and societal benefits by enhanced resource efficiency and diversified product outputs. For example, the cultivation of extractive species such as *Holothuria scabra*, *Perna viridis*, and *Sargassum siliquosum* alongside finfish presents significant opportunities (Azcuna-Montaňo and Largo, unpubl. data). *Holothuria* spp., which can reach marketable sizes (~300 g) within seven months near mariculture farms, command high market prices ranging from US$13 to US$385 per kilogram (Dumalan et al., 2019; Purcell, 2014). Similarly, *P. viridis*, with shell lengths of 50 - 60 mm, attains harvestable biomass in six months and enjoys substantial demand in local and international markets, although its performance to assimilate fish wastes remains complex (Layugan et al., 2018; Sanz-Lazaro et al., 2017). In addition, recognizing the bio-mitigative services provided by these species economically, such as nutrient removal and carbon sequestration, can open new market pathways, including nutrient and carbon trading credits, thus facilitating scaling-up efforts (Chopin et al., 2012). The seagrass *Sargassum siliquosum*, for instance, is valued for its bioactive compounds, offers potential as a raw material for cosmetics and industrial applications, contributing to the expanding global seaweed market, which was valued at approximately US$11.48 billion in 2017 (Arguelles and Sapin, 2020).

In the Philippines, the feasibility of IMTA system is promising due to the country’s rich biodiversity, therefore more options for IMTA candidates, combined with traditional practices to attain a sustainable, community-centered aquaculture. Taking *H. scabra* as an example, the declining wild stocks of this species has high market value, and existing variedly effective culture systems (small-scale ponds, intertidal pens, and

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open-sea ranches) make this species ideal for IMTA integration (Altamirano, 2022). However, biological and environmental challenges, such as low organic matter assimilation potential, sensitivity to sediment organic content, predation risks, and environmental fluctuations must be addressed to optimize its role within IMTA systems (Zamora and Jeffs, 2011; Dumalan et al., 2019).

Aside from the IMTA challenges for a more robust science-based evidences, achieving widespread adoption requires an interdisciplinary approach that integrates research, socio-economic support, and policy frameworks that primarily benefit the local communities and the broader ecosystem. For small-scale farmers in the Philippines, socio-economic factors like lack of awareness, misconceptions rooted in traditional monoculture practices, high costs and perceived risks (Miyata et al., 2017; Chopin, 2013), were reported to have hindered its wide acceptance. Community-based approaches, exemplified by small-scale IMTA projects in Guimaras involving milkfish and indigenous knowledge, have shown potential to improve socio-economic resilience and promote sustainable livelihoods (Castel et al., 2022).

Public perceptions, knowledge, and practices significantly influence the success and sustainability of IMTA systems (Barrington et al., 2008). Ridler et al. (2007) reported an approximately 50% respondents expressing their willingness to pay a 10% premium for IMTA-produced species, reflecting a positive consumer perception of its sustainability attributes. This willingness indicates that IMTA can enhance market differentiation and offer a competitive advantage for farmers adopting integrated systems (Ridler et al., 2007). Negative perceptions, though, driven by environmental concerns such as biofouling, disease transmission, and ecological disturbances can impede industry growth and provoke conflicts (Mazur and Curtis, 2008; Froehlich et al., 2018). For instance, opposition from the tourism sector in Southern Chile (Outeiro et al., 2018) and conflicts over finfish aquaculture in Tasmania and Norway (Cullen-Knox et al., 2018; Osmundsen and Olsen, 2016) illustrate how public attitudes influence policy and industry practices.

This study evaluates local community perceptions securing the IMTA's social license to operate in Barangay Taloot, Argao, South Cebu. Specifically, it seeks to describe the current state of aquaculture in the area and to assess how community knowledge and perceptions influence the acceptance and marketability of IMTA products. Understanding these factors is essential for attaining aquaculture practices that are environmentally responsible, economically viable, and socially acceptable within the local context. Through experimental IMTA implementation with local fishers, the study demonstrates the potential for integrating other species into milkfish farming, and promotes positive market perceptions that support sustainable aquaculture development.

Conceptual framework

Since social acceptability is a critical system influencing aquaculture success, the concepts of Barrington et al. (2008) and Ridler et al. (2007) will be adopted with some modifications. *Figure 1* shows that the public's perception and the economic viability are linked components in mariculture applying IMTA technologies. The framework posits that the sustainability and success of IMTA systems depend on two primary determinants within the community: the perception of its impacts towards the environment and its contribution to safe food products, and the system's extent to which these diversified IMTA species highly acceptable in the market can generate income for the farmer.

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These determinants, perception and economic viability, operate within a dynamic feedback loop. When public perceptions are positive, it means an affirmative community support, which encourages farmers to adopt sustainable practices and invest in diversification. Conversely, successful economic outcomes reinforce positive perceptions, creating a virtuous cycle that promotes sustainable aquaculture development. Ultimately, the alignment of social acceptance and economic benefits

determines the overall success of IMTA systems, emphasizing the importance of addressing both the community perceptions and market dynamics for long-term viability.

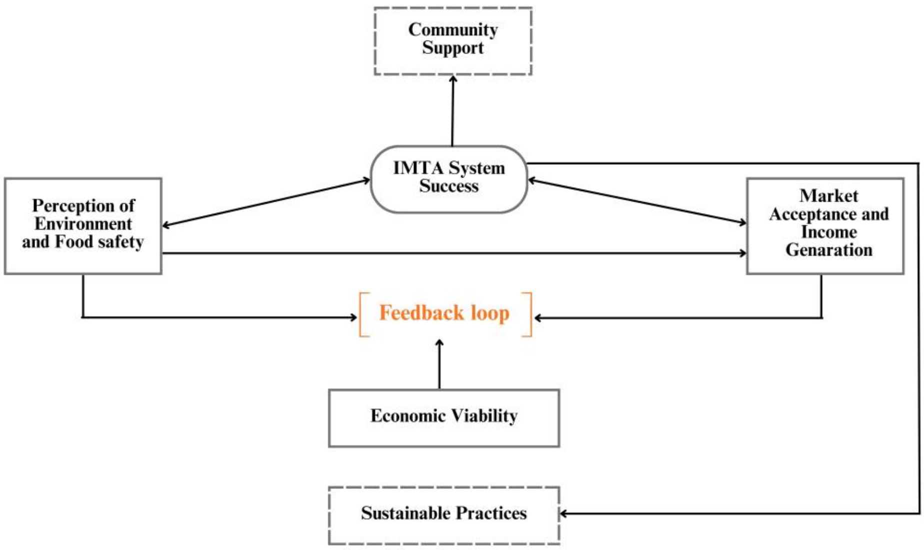

Figure 1. *A conceptual map showing that the IMTA system success is influenced by the community perceptions on environmental and food safety impacts and the economic viability as a result of market acceptance and income generation. The bidirectional arrow between these two components indicates a feedback loop where positive perceptions enhance economic viability, and economic success further improves perceptions. The outer layer, community support and sustainable practices are considered outcomes stemming from this interaction*

Methods

Background case study

Milkfish remains the second priority aquaculture commodity in the Philippines, contributing significantly to local incomes and national food security. According to 2023 Philippine Fisheries Profile (BFAR, 2024), the Philippines produced approximately 353,024.05 metric tons of milkfish, with Central Visayas, including South Cebu, accounting for a growing share of regional production. The economic value from milkfish grow-out of small-scale aquaculture in Argao provides livelihood opportunities for local fishers and entrepreneurs in the municipality. Production scale is categorized based on harvest volume, with fish cages yielding < 5 tons per harvest classified as small-scale aquaculture by the Local Government Unit (LGU).

The emergence of aquaculture set-ups in coastal zones of Argao started when there was a need to meet the growing protein demands given the decreasing catch from increased fishing pressure (PSA, 2023) and the limited capacity of their 10-km stretch of municipal waters. This led the local government unit to encourage fishers through their

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people's organization (PO) shift towards aquaculture activities. During conversations with MAO-Argao fisheries technician, as of 2023, there were less than 20 fishers engaged in aquaculture from the six out of ten coastal barangays in the municipality.

Given the objectives, this study focuses only on PO-led, small scale aquaculture production in the community of Taloot (*Table 1*). From the interviews with previous operators, we learned that smaller set-ups like fish pens were established in the early 2000s, with the emergence of 13 more bamboo fish cages in 2017 (The Freeman, 2017). Sustainability challenges confront their operations, which include high inputs of commercial feeds, low production output at harvest (<30% fingerlings survival), and an experience of fish kills in the community. Later, however, to enhance production efficiency, combined initiatives were done by the Provincial Agriculture Office and LGU-Argao, and BFAR-Region 7 such as Farmer-Scientist Training Program (FishSTP) in 2017. Collaborative implementation of related programs was done to introduce mariculture to local fishers, especially members of POs to become equipped aquaculture farmers with science-based knowledge on cage fishing and seaweeds farming (PR, 2017).

Table 1. *Socio-economic background of the study area*

Characteristics	Taloot[c]
Population in 2023	4, 233 [a]
No. of households in 2023	907 [a]
Land area in 2023 (ha)	3.465 km^2 [a]
Area used for aquaculture in 2023 (ha)	~ 0.10 [b]
No. of fishers in 2023 Part-time Full-time	110 [b] 66 [b] 44 [b]
Age started fishing (range)	9-18 yo [b]
No. of aquaculture farmers in 2022-2024	~ 10 [b]
Annual aquaculture production milkfish in 2023 (kg)	2, 941.25 [b]
Average annual catch per fisher in 2023 (kg)	1, 500 -1, 800 [b]
Primary fishing ground in 2022-2024	Nearshore: Pasil, Kulasi, Mamad-on; Offshore: Ayungon, Negros Oriental and Tagbilan, Bohol [b]
Per capita fish consumption in 2023 (kg/year)	~ 34.27[c]

Information was taken from the publicly accessible data of PSA[(a)], from FGD with 2023 NAGMATA officers[(b)] and Cabral et al. (2023)[(c)]

Description of the study area

The coastline of Taloot spans approximately 1.89 km and is situated in Argao, South Cebu, Philippines (*Fig. 2*). Geographically, it is located at 9.957286, 123.612732 shares borders with neighboring barangays (communities) in the municipality, namely, Capio-an, Guiwanon, Bulasa, and Mabasa. Among the 45 municipal barangays, it ranks second in population, with about 4, 233 residents as of 2020, and an annual growth rate of 1.25% (PhilAtlas, 2020). As a coastal community, Taloot's social structure is notably represented by the fisher's organization, Nagkahiusang Mananagat sa Taloot (NAGMATA). Its members include both male fishers and mostly, female fishing vendors, reflecting the community's strong livelihood ties to the sea.

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The field surveys were conducted in Taloot, Argao, Cebu from June 2022 to May 2024. The survey involved local fisheries officials, fishers, and fish vendors who are NAGMATA members. Fish farmers (10 individuals) are members of the association who are directly engage in the operation of both the control and experimental IMTA fish cages established within the study area (*Table 2*; *Fig. 2*). These groups served as respondents to assess the increase in their knowledge regarding the Integrated Multi-Trophic Aquaculture (IMTA) system introduced in this study.

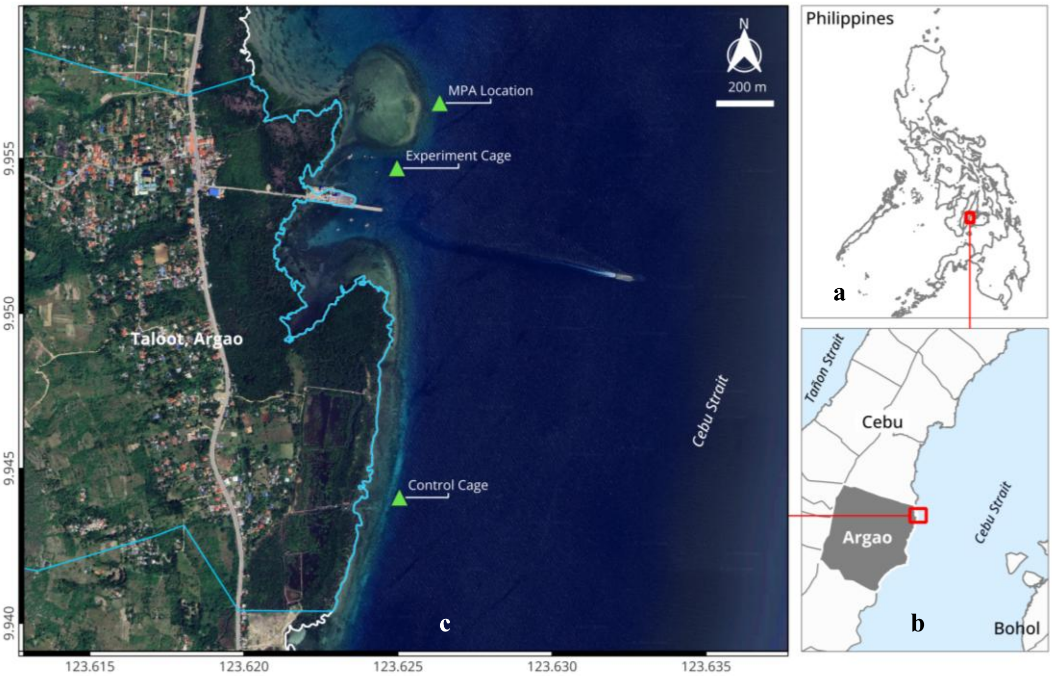

Figure 2. *Map of the study area: (a) Philippines showing Argao in the province of Cebu, and (b) location of Taloot in the municipality of Argao, and (c) the fish cages situated within the study site (mapped by Oliver Semblante)*

Survey and data gathering

The overall approach to this study was qualitative, employing purposive sampling to select participants with substantial expertise and experience in the fisheries sector (*Table 2*). The selection process was systematically designed to ensure representation, relevance, and minimization of bias. Initially, potential stakeholders were identified through consultations with the local fisheries agency, Municipal Agriculture Office (MAO)-Argao. A comprehensive list of eligible participants was then compiled based on their active involvement in fisheries-related activities. To ensure inclusivity and appropriateness, this list was cross-verified with local community leaders and key informants. Data collection involved conducting secondary data gathering of fisheries data from MAO-Argao, Key-Informant Interviews (KII) with a diverse range of community actors who are consistently engaged in coastal and fisheries activities, and Focus Group Discussions (FGD) to selected NAGMATA member involved in the IMTA technology. Communication letters were sent to local government units to secure the necessary approvals. Informed consent was also obtained from all respondents prior to their participation.

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Face-to-face survey questionnaire

A quantitative assessment was conducted using a pre- and post-implementation questionnaire (*Table 3*) administered in Cebuano to 16 fishers and fish farmers from the NAGMATA association. The questionnaire assessed knowledge of the respondents to Integrated Multi-Trophic Aquaculture (IMTA) as a sustainable aquaculture strategy. Basic demographic data and questionnaire items were collected using multiple-choice questions.

Table 2. *Sociodemographic characteristics of the interviewees*

Groups	No. of individuals interviewed (by gender)	Age of respondents	Range of educational attainment
Government actors	5 (5 M)	23, 27, 28, 56, 60	College graduate to master's degree
Market actors	4 (1 M, 3 F)	34, 39, 45, 52	Unfinished high school to college graduate
Fishers	6 (6 M)	20, 25, 27, 28, 41, 56	Unfinished elementary to college graduate
Fish farmers	10 (8 M, 2 F)	32, 34, 36, 42, 43, 49, 51, 56, 60, 62	Unfinished elementary to high school graduate

Table 3. *Commonly caught species in the coastal area of Taloot, Argao*

Family name	Scientific name	Common name	Local name	Source	Notes
Serranidae	*Epinephelus sp.*	Grouper	Pugapo	Marine	Reef fish near MPA
Siganidae	*Siganus sp.*	Rabbitfish	Kitong/danggit	Marine	Reef fish near MPA
Lutjanidae	*Lutjanus sp.*	Emperor	Katambak	Marine	Reef fish near MPA
Acanthuridae	*Acanthurus mata*	Surgeonfish	Bagis	Marine	Reef fish near MPA
Strombidae	*Aliger sp.*	Queen/pink conch	Saang	Marine	Seagrass beds near the MPA
	Canarium labiatum	Plicate conch	Aninikad	Marine	Can be grown suspended in water column
	Lambis lambis	Spider conch	Manok-manok	Marine	Can be grown suspended in water column
Turbinidae	*Turbo sp.*	Turban snail	Lumban	Marine	Intertidal to subtidal zones with rocky substrates
Portunidae	*Scylla sp.*	Mangrove crab	Alimango	Brackish water	Within the mangrove area
Lucinidae	*Anodontia sp.*	Mangrove clam	Imbao	Brackish water	Within the mangrove area; Available daily in the community market
Octopodidae	*Amphioctopus* spp.	Small octopus	Tamala	Marine	Available daily in the community market
Holothuriidae	*Holothuria sp.*	Sea cucumber	Balat	Marine	Intertidal to subtidal zones
Aplysiidae	*Dolabella sp.*	Egg sac of sea hare	Lukot	Marine	Intertidal rocky shores

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Ostreidae	*Crassostrea sp.*	Mangrove oyster	Talaba	Brackish water	Within the mangrove area
Solieriaceae	*Eucheuma* spp.	Brown macroalgae	Bagaba	Marine	Needs boiling to be eaten
Hydrochataceae	*Enhalus acoroides*	Tape seagrass	Bungag-lusay	Marine	As food

Key-informant interviews

Stakeholder perspectives on the feasibility and potential of scaling up Integrated Multi-Trophic Aquaculture (IMTA) were gathered through nine (9) semi-structured key informant interviews (KIIs) at various stages of their engagement with IMTA implementation. Participants were purposively selected based on their leadership roles, expertise, or active involvement in the fisheries sector. The selection included leaders of fishers and women's associations, technical personnel from the Municipal Agriculture Office-Argao, local and community political officials on fisheries, bank representatives providing financial assistance to fishers, and a fish processing plant manager who serves as a major buyer of the community's milkfish produce. The interviews employed open-ended questions that explored the current status of mariculture, stakeholders' perceptions of IMTA products, and their preferred strategies for the system's development.

Focus group discussions

Participatory Action Research (PAR) was conducted with ten (10) members of the NAGMATA Association, who were engaged in the IMTA approach for the first time within their community. As a PAR study, the research design adhered to the six foundational building blocks outlined by Cornish et al. (2023): (1) building relationships, (2) establishing work practices, (3) developing a shared understanding of the issue, (4) observing, gathering, and generating relevant materials, (5) collaborative analysis, and (6) planning and implementing action.

Specific activities involved with the same group of respondents included: (1) administering pre- and post-tests to assess changes in knowledge and perceptions regarding the IMTA system, and (2) conducting group discussions centered on thematic issues and challenges related to aquaculture, as well as their perceptions of the potential impacts of integrating aquaculture with an IMTA system.

Data analyses

Quantitative data from the face-to-face survey were coded and analyzed using Excel version 2.0. Descriptive statistics such as percentages of knowledge gain were used to summarize the responses. The pre- and post-scores of the respondents were also compared using Student t-test and correlated using Pearson correlation coefficient. Key Informant Interviews (KII) were transcribed verbatim, keywords were selected, codes were assigned, and a thematic analysis was conducted following Naeem and Ozuem (2022a) methodology to identify key themes and patterns. Focus Group Discussions (FGD) transcripts were similarly transcribed and analyzed using the same approach to identify common viewpoints and differences among participants. The results of these analyses were integrated to provide a comprehensive understanding of the research questions such as, the current status of mariculture,

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stakeholders' perceptions regarding the economic and environmental implications of IMTA technology, and key challenges for large scale adoption. Additionally, field observations were systematically documented and synthesized into descriptive summaries, which categorized observed activities and contextualized findings. Photographic evidence was used to support and corroborate observational data, enhancing the validity and richness of the analysis.

Results

How is mariculture practiced in Taloot, Argao?

Based on key informant interviews and field observations, the coastal livelihood activities in the area are predominantly centered on fishing, with limited-scale aquaculture playing a supplementary role in local income (*Table 3*). The wild marine catch involves capture of wild species including finfish, reef fishes, shellfish, mud crabs, and invertebrates from key fishing sites Pasil, Kulasi, and Mamad-un. Particularly, fishing locations include sites near fish cages and marine protected area for reef fishes employing different gear types, such as hook-and-line, gillnets, and spear fishing gears. Gleaning of shells and other invertebrates (e.g., sea cucumber) for both food and livelihood alongside with the harvest of mud crabs from brackish waters are likewise practiced.

On the other hand, aquaculture practices in the area are limited but growing. Farmers are cultivating species such as *Chanos chanos* (milkfish), *Siganus* sp. (rabbitfish) in culture pens and cages. Notably, milkfish fingerlings fed with commercial feeds are sourced out from nearby municipalities and provinces (i.e., Naga, South Cebu, Pinamungajan, South Cebu, Carmen, North Cebu, and Calape, Bohol), while, fingerlings of native species such as rabbitfish (*danggit* and *kitong*), are collected within the area and are fed with algae (*lumot*) and other natural food sources. Fishers primarily sell their catch in local markets, with prices fluctuating based on demand, storm events, and market conditions.

Information from respondents indicates that there is currently no active sea cucumber or shellfish farming in the area. Nonetheless, various sea cucumber species are harvested from the wild for food and livelihood purposes. Interviews revealed that locals harvest approximately 18 kilograms of sea cucumbers per harvest per week, selling them at prices ranging from USD 3.51 to USD 4.39 per kilogram. Market vendors then process these into ready-to-eat Filipino ceviche known as *kinilaw* by cleaning, slicing, and preparing the product daily for local consumers at about USD 0.88 per pack, which typically contains up to three live sea cucumbers.

In 2021, an experimental effort to cultivate seaweed, specifically *guso* (*Eucheuma* spp.), was initiated through a BFAR project. However, these attempts were disrupted by Super Typhoon Odette (internationally named Rai), which caused about USD 42,484,493.160 damage in tourism and properties in Central Cebu alone (Cacho, 2022) and hindered the successful establishment of seaweed cultivation in Taloot. Although respondents have no direct experience in integrating shellfish with their existing fish culture practices, it is noteworthy that co-culture of milkfish with reef fishes such as *danggit* and *kitong* has been a longstanding practice in the community.

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How is the structure of the aquaculture system in Taloot, Argao characterized?

The structure of the aquaculture system in Taloot, Argao, is characterized by a well-organized, multi-tiered community-based network that integrates various stakeholders to promote sustainable fish production and market access. Central to this system is NAGMATA, a community-level fishers' association established in compliance with the Philippine Fisheries Code of 1998, which mandates the formation of organized fishers' groups to enhance resource management and livelihood opportunities. The organization was formed through deliberate efforts by local government agencies, primarily the Municipal Agriculture Office (MAO), which responded to the expressed needs of the community by designing livelihood assistance projects (Manlosa et al., 2021). In Taloot, these projects included improving fish cage infrastructure, and linking producers to broader markets that enhances the organization's fish production capacity (*Fig. 3*).

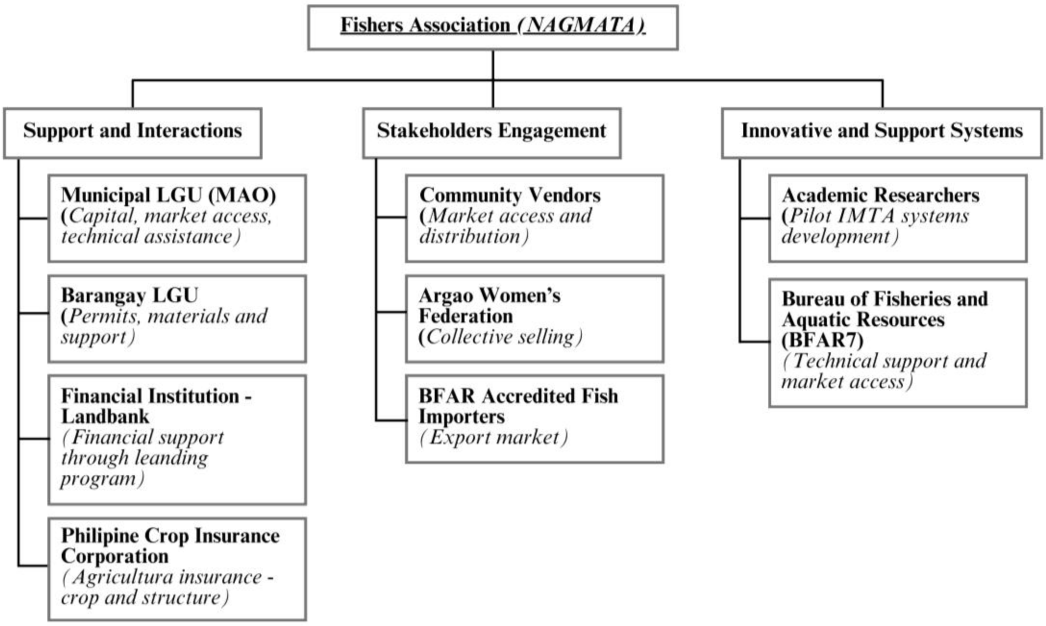

***Figure 3.** A diagram illustrating the interconnected stakeholders in the aquaculture system of Taloot, Argao. NAGMATA, the fisherfolk's association, receives support from the Municipal LGU (MAO) for capital, market access, and technical assistance, and from the Barangay LGU (BLGU) for material support. Financial support also comes from the Landbank through its lending program. NAGMATA actively engages with community vendors, the Argao-federated women's association, and BFAR-accredited fish importers, creating a mutually beneficial network for sustainable fish production and market access. An experimental Integrated Multi-Trophic Aquaculture (IMTA) system, assisted by academic researchers, represents innovative efforts to enhance sustainable aquaculture practices within the community*

The integration of NAGMATA's aquaculture products into the local market system is facilitated through its linkage with municipal vendors, notably through the federated women's association, which consolidates and sells primary products, particularly *bangus*, at controlled prices to nearby barangays, including coastal and mountainous communities. The LGU through MAO supports these activities by providing logistical assistance, such as delivery trucks and personnel, driven by the municipality's goal to ensure affordable fish supply despite limited municipal water resources. This

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arrangement ensures a steady market for the fishers' produce while maintaining price stability. Community members also serve as primary vendors, selling directly to neighbors, which enhances local economic resilience. Furthermore, NAGMATA's role extends beyond local markets to include collaboration with private entities. As an example, the organization coordinated with BFAR for access to accredited fish processing plants, which process milkfish for export markets, thereby opening international trade opportunities. Notably, the key to all these linkages and facilitation is the active role of the MAO through their fisheries technician. *"We do not have municipal ordinance particularly on aquaculture and its management as of yet. However, we want that our office is actively involved because we know this is our responsibility."* (Fisheries technician, Argao).

Financial support mechanisms underpinning this aquaculture system include contributions from the BLGU in the form of materials, as well as formal credit facilities from government bank, i.e., Landbank through their Agricultural Competitiveness Enhancement Fund (ACEF) lending program, which provides loans to fishers and associations for capital investment. Worth noting is the ACEF's mandatory enrollment in the government-owned agricultural insurance program under Philippine Crop Insurance Corporation (PCIC), which safeguards crops and structures against losses caused by natural calamities. The LGU, through its various agencies, plays a pivotal role in facilitating access to financial capital, ensuring that small-scale fishers can sustain and expand their operations. These multi-level supports, from material provision to financial loans, collectively contribute to the organizational strength of NAGMATA, enabling it to function effectively as an aquaculture producer within a supportive market and governance framework.

What lessons were learned from the development of the experimental integrated multi-trophic aquaculture (IMTA) in Taloot, Argao?

During the participatory action research-based IMTA experiment, fish farmers received training while actively participating in the implementation process. Training sessions included instruction on managing species integrated in the system, covering principles, species selection, and maintenance of long line systems with mussels and *Sargassum* sp., as well as cage systems with holothurians and milkfish. Under researcher supervision, farmers engaged in field sampling, maintenance, and monitoring activities, such as collecting water and sediment samples and measuring water quality and biomass (detailed information will be reported separately). The researches discussed the results with the farmers to enhance their understanding of system performance and environmental impacts, encouraging hands-on learning and active involvement throughout the study period.

(a) Knowledge about IMTA system

The question items (*Table 4*) to fishers and fish farmers cover foundational concepts of aquaculture systems before and after IMTA implementation. Thematic areas include environmental management, technological innovations, and specific practices within the system. Pre- and post-test results indicate a general increase in their knowledge regarding aquaculture concepts, though the extent varies across questions. Notably, the understanding of aquaculture definition improved significantly, with correct responses rising from 3 to 8 participants, reflecting a 31.25% increase. Similarly, awareness of the

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importance of water quality monitoring showed substantial improvement, increasing from 4 to 9 respondents (31.25%). Knowledge about green technologies such as multi-species cultivation also revealed a notable rise, with correct answers increasing from 7 to 11, representing a 25% increase. Understanding of IMTA systems and their benefits showed modest gains, with correct responses increasing from 6 to 8 and 6 to 8 respectively, indicating improvements of 12.5%.

However, some questions, such as the impact of extensive fish feeding and aquaculture pollution, showed minimal or no improvement, with correct response rates remaining unchanged at 11-12 for long-term effects and 3 for pollution effects. These data suggest that PAR as an approach was effective in increasing knowledge on specific aquaculture topics, particularly those related to water quality and sustainable practices, while some areas require further emphasis to achieve higher understanding.

Table 4. *Responses to questionnaire items related to knowledge of aquaculture and its environmental sustainability concepts before and after integrated multi-trophic aquaculture (IMTA) activity in Taloot, Argao, South Cebu, Philippines*

Multiple choice questions	**Pre-test (n = 16)**	**Post-test (n = 16)**	**Increased knowledge (%)**
Which among the statements best define aquaculture?	3	8	31.25
What is the long-term effect of extensive commercial fish feeding to the marine waters?	11	12	6.25
Who should primarily monitor the water quality in an aquaculture farm?	4	9	31.25
How can aquaculture sustainability be best defined?	10	11	6.25
What green technology that involves cultivating two or more species of different trophic levels with complementary ecosystem functions, where the waste of one species is utilized as food for another?	7	11	25
Among the options, which extractive species has the ability to convert inorganic nutrients to organic biomass?	6	7	6.25
Among the options, which of these are extractive species that can improve water quality by biofiltration?	5	5	0
What does an IMTA system promote?	6	8	12.5
What is a common side effect of aquaculture pollution characterized by the gradual increase of phosphorus and nitrogen levels in the water body?	3	3	0
How does sandfish farming integrate within an IMTA system?	8	10	12.5

Referring to *Table 5,* the Pearson correlation coefficient of 0.82 indicates a strong positive linear relationship between the respondents' pre-test and post-test scores, suggesting that individual's initial knowledge levels were consistently related to their later performance. T-test showed a statistically significant increase (p-value = 0.014) in scores from pre-test to post-test (*Table 5*), suggesting that the implementation of experimental IMTA had a positive effect on the measured knowledge gained by the respondents (*Table 4*). The negative t-statistic (-3.108) suggests that the mean post-test score is higher than the pre-test score, indicating improvement after the implementation.

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(b) Environmental perceptions about IMTA system

From the consolidated insights gathered through key informant interviews (KII) and focus group discussions (FGD), environmental perceptions and operational lessons are learnt from pilot implementation of an IMTA system in Taloot, Argao. The system that integrated milkfish as the primary aquaculture species, complemented by sandfish, shellfish, and *Sargassum* (seaweed) documented positive perceptions on capacity building among fish farmers, environmental benefits, and market confidence of primary product despite several operational challenges.

Table 5. *T-test: paired two sample for means*

	Pre-test	Post-test
Mean	6.67	8.44
Variance	7	9.03
Observations	9	9
Pearson correlation	0.82	
Hypothesized mean difference	0	
df	8	
t Stat	-3.108	
P (T < = t) two-tail	0.014	
t Critical two-tail	2.306	

Significance $p < 0.05$

After completing three consecutive successful milkfish grow-out cycles, fish farmers reported increased confidence and skills in managing milkfish cultivation, underscoring the educational benefits of the IMTA intervention. They expressed appreciation for the opportunities to learn water management techniques, particularly in assessing water quality parameters like salinity, temperature, dissolved oxygen, pH, and nutrient levels, which are critical for ensuring the sustainability of aquaculture activities. While the long-term impacts of water pollution due to commercial feeding remain uncertain, farmers recognized that poor water quality could lead to fish kills similar to historic events.

Additionally, fish farmers observed a positive effect of the IMTA system on water quality, particularly noting reduced water turbidity within fish cages. Participants linked the integrated species to better water conditions, citing less turbid water and hypothesizing that the IMTA system may contribute to water filtration and nutrient uptake, although these claims require further scientific validation. Such perceptions align with the theoretical benefits of IMTA in enhancing water quality through biological filtration and nutrient absorption. *"I believe that the water quality in the aquaculture farm is better compared to cultivation cycles without species integration. However, our confidence remains in the combined support provided by MAO and the researchers, especially now that milkfish survival rates across all three cycles have reached 100%."* (Fish farmer in Taloot).

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(c) Consumers perception on IMTA-related products

Interactions with community vendors and trader revealed increased confidence in the primary product, milkfish, attributed to the IMTA system. Buyers (end consumers) noted that milkfish from the IMTA setup exhibited desirable meat qualities, such as sweetness upon cooking and the absence of undesirable mud-like odors. *"I appreciate that research is incorporated in the milkfish culture. I am confident in convincing the leader of barangay (community) women's organization to pre-order for the milkfish harvest. The size is right. The fish' meat is sweet. It does not have a muddy smell."* (Leader of the women's association in Argao). An exporter also commented on the physical health of the fish, observing that the milkfish did not display yellowish coloration, indicating good health and potentially better market acceptance. *"I personally recommend your product to our CEO because it is a research-based product. The physical appearance is of export quality. Upon endorsement to our facility, the skin color did not turn yellow, which is our usual experience for years with our purchases from other suppliers in the region. At your harvest period, most of the time, we still have stocks. But I make sure, we can avail even half a ton from your harvest because of the product quality."* (Manager of a fish processing plant in Cebu).

What are the opportunities and challenges associated with integrating IMTA into milkfish grow-out culture?

The opportunities and challenges associated with integrating IMTA into milkfish (*Chanos chanos*) grow-out culture is multifaceted. Findings from this study emphasized the pivotal role of social perceptions, experiential learning, and community support systems (*Fig. 4*). Primarily, the findings indicate that knowledge and perception significantly influence social acceptance of IMTA systems. Effective public information campaigns highlighting IMTA as an environmentally friendly "green" technology help promote broader acceptance by mitigating concerns related to the potential negative environmental consequences of aquaculture. This social acceptance manifests in increased market confidence among buyers regarding the quality of aquaculture products and enhances vendors' willingness to promote IMTA-related products, ultimately translating into higher sales for fish farmers. Experiential activities, such as hands-on IMTA demonstrations, substantially boosted farmers' confidence in adopting integrated systems. Through active environmental monitoring and reflection on past challenges, such as fish kills caused by poor practices, fish farmers now recognized the value of scientific approaches in improving aquaculture success. This experiential learning created a tangible link between scientific knowledge and practical application, reinforcing positive perceptions and encouraging continued engagement with IMTA. *"We feel excited engaging in this IMTA project because, firstly, we hope to augment our income without going to deep-sea fishing almost every day. Most challenges that we encounter during the IMTA set-up and implementation are technical. Culturing different species at one time was challenging looking back. Although the experimental project did not yield enough diversified product, we learn a lot. Through this set-up, we understood the importance of healthy environment to aquaculture. We learn the necessity of good communication for a functional organization. With our experience, I think we are more capable to manage integrated species within and near the fish cage if given a chance again."* (Fish farmer in Taloot).

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In addition, community-based multi-level support emerged as a critical factor for the success of small-scale aquaculture initiatives. Organized fisher's associations like NAGMATA, supported by government entities (i.e., BLGU, MAO, BFAR, Landbank), civic organizations, academic institution, and private sector collaborators such as fish processors, formed robust networks. These collaborations increased the organization's confidence and capacity to sustain each cultivation cycle, demonstrating the importance of collective effort in overcoming operational challenges.

Although the pilot IMTA experiment did not generate immediate economic revenue, it provided valuable insights into potential opportunities and challenges associated with cultivating integrated species such as sandfish, shellfish, and *Sargassum*. Farmers observed that current sandfish cultivation methods, particularly suspending improvised cages, are ineffective mainly due to predation by swimming crabs. Conversely, substrate-based methods showed promising survival rates, suggesting a viable alternative for future cultivation. Market data revealed that sandfish and sea cucumbers are regularly sold at approximately P50 (USD 0.87) per cup, indicating potential economic benefits if cultivation methods are optimized. In terms of shellfish, growth and survival rates demonstrated sustainable harvest potential, contingent upon regular maintenance, preferably every two days, to ensure optimal development. This practice could lead to consistent economic returns. *Sargassum* cultivation was deemed straightforward and manageable, with farmers expressing optimism about expanding this activity if market opportunities are available, providing an additional income stream post-harvest. Notably, insights from a female member of NAGMATA mentioned the capacity of women to assist with maintenance activities, suggesting that gender-inclusive approaches could strengthen operational efficiency and economic sustainability. *"Fishers are not used to cultivating first before harvesting marine products. They will go out fishing for hours and come home with fish ready for the family's food or income. Observing the IMTA set-up in our coastal seas, I know, women, like myself can definitely assist in the culture maintenance."* (Female member of NAGMATA in Taloot).

Figure 4. *Some activities undertaken by the stakeholders during IMTA implementation: (A) start of milkfish grow-out culture in a cycle, (B) experimental set-up integrating green mussels (black gallons) and Sargassum (white floaters) in long lines, (C) adjusting green mussel set-up, (D-E) PO members monitoring water parameter and during Sargassum cleaning. (Source: A-Edward Viňan, B to E-author)*

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Discussion

Coastal resource dependence and vulnerabilities

The study reveals that the community in Taloot relies heavily on wild captures of reef fishes, edible macroalgae, shellfish, gastropods, and species of crabs that mostly thrive in marine waters, with some also in brackish waters. Their dependence on wild-caught species from natural resources for food and livelihood highlights a traditional livelihood system that may expose the community to vulnerabilities associated with resource depletion (FAO, 2011). Recent studies emphasize that overharvesting of reef fishes and invertebrates can lead to significant declines in local biodiversity, threatening both ecological stability and community resilience (Pratchett et al., 2014). Their reliance on wild-caught species for food and income underscores the importance of implementing sustainable management practices and alternative livelihood options such as Integrated Multi-Trophic Aquaculture (IMTA) present promising avenue for diversifying income sources while reducing pressure on wild populations (Loayza-Aguilar et al., 2023; Chopin et al., 2010).

Development and potential of IMTA systems

Development of IMTA systems in Taloot aligns with global trends toward sustainable fisheries and aquaculture, supporting food security and economic resilience. These systems promote livelihoods diversification, ecological sustainability, and community participation in resource management (Loayza-Aguilar et al., 2023; Ayo-Aderele and Okomoda, 2024). This technology also offers capacity building and knowledge transfer, empowering local communities to adopt innovative practices (Cortes et al., 2025). The identification of species, *kitong* and *danggit* presents immediate opportunities for developing IMTA systems in Taloot. These species not only have high market value but also have demonstrated successful integration into aquaculture systems elsewhere, providing valuable experiential knowledge that can be leveraged to expand aquaculture activities locally (Lee et al., 2022; Syah et al., 2020). The integration of macroalgae like *Sargassum* can enhance nutrient recycling and water quality within aquaculture setups, aligning with the principles of sustainable and environmentally friendly practices (Zhang et al., 2025; Desrochers et al., 2022). Similarly, the cultivation of bivalves and gastropods can serve as a sustainable livelihood alternative, reducing the community's dependence on wild stocks (Ogello et al., 2024).

This study also emphasizes how bridging and linking social capital significantly contribute to the promotion of small-scale aquaculture livelihoods led by people's organizations (POs) (Manlosa et al., 2021). These forms of social capital facilitate access to essential resources such as physical assets, market opportunities, and financial services, enabling the development of well-structured aquaculture systems (Bourdieu, 1986; Pretty and Ward, 2001). Since aquaculture is a high-capital activity, access to financial services, including government loans with integrated crop and cage insurance, is vital. These financial mechanisms increase confidence among small-scale producers and mitigate risks, encouraging adoption of innovative practices like IMTA (Knowler et al., 2020). While these social capital mechanisms support the IMTA adoption, they alone are insufficient to resolve issues like water pollution from intensive aquaculture practices. Nonetheless, IMTA systems tend to foster acceptance and positively influence perceptions among fish farmers and consumers, especially when coupled with research efforts aimed at environmental mitigation. This aligns with findings that highlight the importance of social capital in successful IMTA adoption and

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environmental management (Hossain et al., 2022; Ren et al., 2022; Yu et al., 2017). Therefore, bridging and linking social capital are vital components for the successful implementation and sustainability of IMTA systems.

Knowledge, capacity building, and environmental monitoring

The increased knowledge among fishers regarding aquaculture and the IMTA system following its implementation can enhance the community's capacity to adopt and sustain green aquaculture practices. In terms of livelihoods, high product acceptance driven by improved understanding of the aquaculture process can boosts confidence among small-scale producers, particularly those organized under POs. This aligns with emerging research indicating that different social capital configurations, such as bridging and linking, facilitates social processes like IMTA adaptation and supporting the transition toward green aquaculture (Slijper et al., 2022). Training provided to fish farmers during the experimental IMTA served as a form of empowerment for small-scale producers, enabling them to address persistent water pollution issues by conducting water quality assessments measuring such as turbidity, dissolved oxygen, ammonia, nitrate, and phosphate levels that can generate evidence and reveal pollution trends in coastal areas. These data can make the impacts of polluters more visible, thereby motivating regulatory actions and community-driven interventions. In the Philippines, along with the Department of Environment and Natural Resources (DENR), the Bureau of Fisheries and Aquatic Resources (BFAR) is likewise mandated to mitigate water pollution from intensive aquaculture (FAO, 2025); however, significant positive changes have yet to be realized. If outcomes such as increased market acceptance, patronage, or diversified income streams for fish farmers are achieved, local aquaculture producers could become vital sources of water quality information, supplementing the efforts of BFAR and promoting sustainable management practices.

Market perceptions, scaling up and gender inclusivity

A positive perception of research-based products enhances social capital within market systems, as it fosters consumer confidence and can lead to increased sales. Recent studies have demonstrated that consumer perceptions are closely linked to product quality assurance and trust, especially in aquaculture products where tangible proof of quality is essential (Lu et al., 2024; Cantillo et al., 2023). During the experimental period, the quality of IMTA products supported the development of positive buyer perceptions, indicating that the system has the potential to address pressing issues such as fishing pressures, food security, and environmental sustainability. The collaborative efforts among various institutions involved in aquatic production suggest that IMTA can be scaled up effectively, leveraging existing partnerships for broader adoption (Guerrero and Cremades, 2012). Moving forward, the focus should be on refining the technology to maximize yields and income for fish farmers, ensuring that the benefits are both sustainable and economically viable (MacDonald et al., 2024; Loayza-Aguilar et al., 2023).

Lastly, the IMTA system promotes a gender-balanced approach to the socio-economic components of aquaculture communities. By recognizing and utilizing the roles of women in the entire IMTA process, communities can enhance social inclusivity and resilience. Empowering women by realizing their capacities and contributions not only promotes equitable participation but also strengthens community resilience and

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economic stability (Sertyesilisik, 2023). This approach aligns with the FAO's strategy, which actively advocates for the equal participation of women in agricultural and aquaculture development, emphasizing that gender equality is essential for sustainable development (FAO, 2025; Chikwe et al., 2024).

Conclusion

The community-driven aquaculture system in Taloot exemplifies a collaborative, multi stakeholder approach that leverages local organizational strength and strategic partnerships to promote sustainable fish production. Stakeholders perceive the IMTA system as beneficial to water quality, product quality, and their knowledge of sustainable aquaculture practices. While some technical challenges, particularly in species-specific cultivation methods, maintenance schedules, and market development persist, the positive perceptions and the community's adaptive experiences and support systems provide a foundation for further IMTA development. To ensure long-term success, continued research to scientifically validate perceived water quality improvements and to refine integrated species cultivation techniques are recommended. Likewise, capacity building, and policy support are essential to realize IMTA's full ecological and economic benefits to aquaculture industry in the region.

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