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The prospects of integrated multi-trophic aquaculture farming in Calape, Bohol for island diversification amidst of global changes (IsDA-GC)

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Abstract

In integrated multi-trophic aquaculture (IMTA), the by-products, such as waste from one aquatic species, serve as inputs like fertilizers and food for others, fostering island diversification amidst global changes. This approach reimagines and re-channels traditional diversification practices. The aim of this study is to document activities contributing to island diversification in the face of global changes, focusing on the following indices: fisherfolk profiles, potentials, and in-situ monitoring and resource management. We employed a mixed-methods research design to analyze both qualitative and quantitative data. Results have shown from the profile of the respondents majority (58.82%) falling between 35 and 50 years of age. The fact that all respondents were men (100%) and most focused on aquaculture meant that for potentials, most concentrated on nutrient recycling and habitat enhancement, while for estimated production *in situ*, most distinguished and shared both bangus and seaweeds, particularly the eucheuma, whose estimated income ranged from 93-100,000.00 and 200-275,000.00, respectively, with the flow of the marketing channels. The study also highlights the island's vulnerability to rapid changes that threaten sustainable ecosystem development. The results suggest that while the island ecosystems are susceptible to the pressures of a growing population, they play a critical role in ecological restoration and conservation.

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Introduction

The increasing demand for fish around the globe is driving the globalization of aquaculture practices. The conventional monoculture systems have been linked to nutrient contamination, habitat loss, and decreased biodiversity as well as other environmental problems. In order to build a sustainable and balanced (Aslesen, 2009) ecosystem, IMTA offers a viable alternative by mixing species from different trophic levels, such as fish, shellfish, and seaweeds is encouraged as combining feed and extractive aquaculture that also aims to produce food production methods that increase the farm's economic output while providing bio-mitigative advantages to the ecology.

This approach requires a fundamental shift (FAO/ICLARM/IRR, 2021) in how we define an 'aquaculture farm' and understand its role within an ecosystem. The economic value of the environmental and societal benefits provided by extractive species should be acknowledged and factored into the overall evaluation of these IMTA components. Additionally, seaweeds and invertebrates produced in IMTA systems should be considered for nutrient and carbon trading credits.

Aquaculture organic waste (Dauda *et al.*, 2019) has always been associated with limited benthic repercussions; nevertheless, there have also been cases where the utilization of infrastructure as substrates and mild nutrient enrichment have resulted in higher biodiversity and wild species abundance. The dual nature of nutrients-essential in small amounts but potentially polluting in excess-must be understood and managed in order to develop effective food production systems. This allows nutrients to be recaptured in moderation while maintaining concentrations that support robust and healthy ecosystems.

Indicators such as species diversity, colonization rates, abundance, growth, and ecosystem functions related to nutrient partitioning and recycling, species interactions, and disease control could serve as valuable metrics for assessing the performance and robustness of these systems.

Among all forms of integrated aquaculture, rice-fish farming is likely one of the oldest, reflecting a co-evolution of agriculture and aquaculture that has primarily taken place in Asia and has more recently expanded to other regions (Halwart and Gupta, 2004). In this system, rice fields provide the environment and habitat for fish and other aquatic animals, while the fish contribute to nutrient cycling by feeding on invertebrates and other organic matter produced in these flooded fields. Rice-fish farming often reduces the need for chemical pest control, thereby helping to preserve biodiversity. Additionally, this practice supports the use of native fish species.

In contrast to its widespread use in terrestrial systems, integrated aquaculture has been less frequently reported in marine environments. However, in recent years, the concept of integrated aquaculture has gained attention as a potential strategy to mitigate the excess nutrients and organic matter produced by intensive aquaculture activities. This has led to the development of integrated multi-trophic aquaculture (IMTA), where "multi-trophic" refers to the intentional inclusion of species from different trophic levels or nutritional roles within the same system (Chopin and Robinson, 2004). This approach is distinct from traditional polyculture, which may simply involve co-culturing different fish species at the same trophic level.

Furthermore, IMTA (Barrington *et al.*, 2009) has been defined through pilot studies in marine habitats that involve the combined cultivation of fed species, typically fish, with extractive species such as bivalves and/or macroalgae. This practice can increase the production capacity of a given site, especially when conventional methods face limitations.

Consumers and other stakeholders in the coastal zone are demanding more sustainable practices due to the expanding global use of coastal regions and the fast growth of mariculture. This presents an opportunity

for integrated mariculture. However, the inclination for specialized systems centered on single species has resulted from the rapid development of global markets, increasing the prevalence of intense monoculture marine farming.

Integrated aquaculture practices in marine and coastal environments are not well known or fully understood, and their potential to improve the sustainability of the aquaculture sector from an ecosystem perspective has not been fully explored, despite this trend. This presents a significant challenge.

Understanding how islands, with their distinct ecosystems and cultures, adapt to and mitigate the effects of global environmental, economic, and social shifts is a critical topic that involves developing this technical document, which aims to provide comprehensive information on current practices and the potential for integrated aquaculture in brackish and marine ecosystems towards island diversification in the midst of global changes.

This study aims to describe and document the activities connected with integrated multi-trophic aquaculture (IMTA) in mariculture in Calape, Bohol. Specifically, it aims to assess the profile of the mariculture operators, issues and resources, and in-situ as a strategy for island diversification amidst global changes.

Materials and methods

This study used the mixed method research design that includes both qualitative and quantitative research designs. Specifically, this study used the explanatory sequential design (QUAN qual).

In this design, the research first begins with a quantitative research phase and explores the data of the selected participants. Then, data was analyzed, and the information was used to build a second phase, which is the qualitative phase (Creswell, 2015). The research aims to characterize the activities conducted in integrated multitrophic aquaculture and this study was conducted in the island barangays of Calape, Bohol, specifically in Pangangan and the mariculture operators in Calape, Bohol.

Two types of data collection methods were used in this study. The first method was quantitative, involving surveys and questionnaires. The objective was to gather data profile, issues and resources, and in-situ monitoring and resource management. Semi-structured questionnaires anchored from SEAFDEC-AQD, 2022 was used for preliminary assessment. Purposive sampling was employed, focusing on fishermen as the primary subjects. The initial survey questionnaires were distributed (Ariji, 2013) and enhanced through a face-to-face interview. Data were analyze using the descriptive statistics and for qualitative it is arranged using the SWOT analysis and ranked by themes.

For ethical considerations, informed consent was obtained from all participants to ensure they understood the study's purpose and their right to withdraw at any time, including risks, benefits, reimbursement, processes, etc., for the transparency of stud. The confidentiality of participants was strictly maintained, with responses being anonymized to protect their privacy. Instruments and materials are properly cited and authorized by the authors/sources.

Results and discussion

Profile of the mariculture operators

The age range of the respondents was 25 to 50, with the majority (58.82%) falling between 35 and 50 years of age. People in this age range are usually those who actively participate in aquaculture and local decision-making. The fact that all responders were men (100%) reflects the historically male-dominated character of aquaculture. The findings show a noteworthy degree of participation, especially in positions pertaining to the marketing and processing of aquaculture products. Respondents' educational backgrounds ranged widely: 40% had finished elementary school, 35% had finished secondary school, and 25% had completed postsecondary education, which

included technical or vocational aquaculture training are shown in Table 1 and Fig. 1.

Table 1. Profile of the mariculture of operators in established mariculture park in Calape, Bohol as potentials for IMTA towards island diversification

Description		Frequency	Percentage (%)
Age	Below 25	5	14.70
	25-35	3	8.82
	36-50	20	58.82
	Above 50	6	17.64
		34	100.00
Gender			
	Male	34	100.00
	female		0.00
		34	100.00
Educ. Background			
	Primary	14	41.17
	Secondary	12	35.29
	Tertiary	8	23.53
		34	100.00
Occupation			
	Aquaculture /fisheries	22	64.70
	Seaweeds farming	8	23.53
	shellfish collection	2	5.88
	local trade or retail	2	5.88
		34	100
Experience			
	Below 5	14	41.17
	5-10	11	32.35
	11 above	9	26.47
		34	100.00

Fig. 1. Demographic assessment of the mariculture operators including alturas group of company representative

The majority of responders (65%) worked primarily in aquaculture or fisheries, with the other participants engaged in adjacent fields like seaweed farming (15%), clam collection (10%), and local trading. The results are supported in the study of Salayo *et al.* (2012) that mariculture creates social gains through livelihoods and fish supply at low prices and the existing of profile of the mariculture operators can contribute on the success of fisheries management in regulated mariculture systems.

Additionally, a follow assessment on the experience and involvement in IMTA, about 55% of respondents were familiar with the concept of IMTA, having been introduced to it through government programs, NGOs, or training workshops. The remaining 45% had limited knowledge or were unaware of IMTA before the study. Only 30% of respondents were actively practicing IMTA at the time of the study, mainly involving the co-cultivation of fish with seaweeds or bivalves. The other 70% were involved in monoculture but expressed interest in transitioning to or experimenting with IMTA systems and the primary motivations for adopting IMTA among respondents included environmental benefits (40%), economic diversification (30%), and improved resilience to market and climate fluctuations (20%). A smaller group (10%) was motivated by external incentives, such as grants or subsidies. The results also had supported the best practices of the Alturas group and company in the culture of both marine and brackish water for sustainable development.

Fig. 2. The IMTA concept and the situation of Mariculture in Calape, Bohol

In the recent activities in the island, this is the concept used in the mariculture farming in Pangangan, Calape, Bohol. The Integrated Multi-Trophic Aquaculture (IMTA) is a sustainable approach to aquaculture that involves the cultivation of species from different trophic levels within the same system, where the waste produced by one species is utilized as a resource by another. When applied to island settings, IMTA becomes particularly relevant due to the unique ecological and socio-economic characteristics of island communities. Below is the Fig. 2 of the MTA concept in Calape, Bohol.

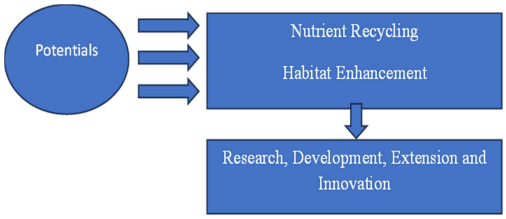

Fig. 3. Flow on the potentials for IMTA

Potentials for IMTA

For the environmental aspect it includes nutrient recycling: IMTA systems can significantly reduce the environmental impact of aquaculture by recycling nutrients. The waste produced by fed species (e.g., finfish or shrimp) serves as a nutrient source for extractive species (e.g., seaweeds and shellfish). This reduces nutrient accumulation in the environment, decreases the risk of eutrophication, and improves overall water quality. Habitat enhancement (Fig. 3) by integrating multiple species, IMTA systems create diverse habitats that support various marine organisms. Seaweeds and shellfish provide important ecosystem functions, such as habitat structure and food sources for other aquatic life, contributing to enhanced biodiversity; and reduced impact on wild stocks that MTA can lessen the pressure on wild fish stocks by providing alternative sources of seafood. For example, shellfish and seaweeds can be cultivated in IMTA systems without relying on wild fisheries, helping to protect marine ecosystems and promote sustainability and resilience to environmental stress that IMTA systems can increase resilience to environmental stressors, such as climate change. Diverse systems are often more adaptable to changes in water temperature, salinity, and nutrient levels compared to monoculture systems, which can be more susceptible to disturbances.

While it is good for research and development where IMTA encourages the development and testing of innovative aquaculture practices and technologies. Research into species interactions, system design, and environmental monitoring can drive advancements in aquaculture science and practice and offer a platform for adaptive management approaches, where farmers can experiment with different species combinations and management strategies to optimize performance and sustainability.

In situ operations

Since milkfish is regarded as the national fish of the Philippines, it is a popular seafood dish. With the exception of the Cordillera Administrative Region, it is grown throughout practically the whole nation (CAR). The earliest type of aquaculture in the Philippines is milkfish farming. Actually, research and literature suggest that milkfish farming originated in the Philippines around 400–600 years ago and then expanded to Taiwan, Indonesia, and the Pacific region (FAO, 2009).

Table 2. Ranges on the estimates of the cost of production in in situ IMTA concepts in Calape, mariculture

Description	Production	Net income
Bangus (minimum of 4 cages with 5×5m)	Total fingerlings stocked per cage: 1000-1200 fingerlings Surviving fish per cage: 900-1000fingerlings×0.85=850fish Total weight per Cage: 400-425kg Total weight for Four Cages: 1700kg	93-100,000.00
Seaweeds (Estimated area of 1 ha)	10,000 area; monoline	200-275,000 per cropping
Other like Tilapia crabs and shrimp (vannamie)	From Alturas but some of the data are confidential	-

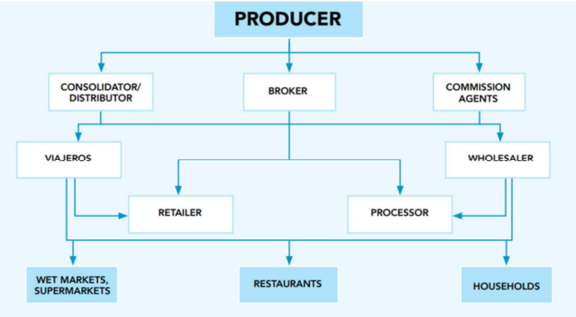

Fig. 4. The actual marketing channels for bangus and other common fish in the town of Calape

Results in Table 2, showing the actual income of the mariculture operators showing the applications of IMTA with the condition of 4 cages with an area of 5×5 meters or 25 m2, had an estimated value of 93,000–100,000.00, and to include the seaweeds, which is the Eucheuma, with an estimated value of 200–270,000.00. Another key informant from Alturas Group and Company, which is one of the biggest exporters in the province, shared remarkable information on the sustainability of the production and its good potential (Miyata *et al.*, 2017) for adopting IMTA in the culture and overall production. Below is the Fig. 4 showing the actual set-up of the market channels as applied to the fish operators of the mariculture in Calape, Bohol.

Conclusion

The integrated multi-trophic aquaculture (IMTA) in mariculture showed potentials as indicated based on the profile of the mariculture operators, potentials, and in-situ as a strategy for island diversification amidst global changes.

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