Proceedings of the
JIRCAS-SEAFDEC/AQD Joint Workshop on IMTA Research
Tigbauan Main Station, Iloilo, Philippines
6–8 August 2019

Understanding Current Challenges and Future Prospects in Integrated Multi-Trophic Aquaculture (IMTA) Research

Jon P. Altamirano
Ryogen Nambu
Nerissa D. Salayo
Masashi Kodama
Editors

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FOREWORD (JIRCAS)

Aquaculture is one of the fastest growing food-producing industry. Currently, approximately 50 % of the world's aquaculture production is accounted for by fish aquaculture. However, although aquaculture provides the solution for the growing demand in fish production, it has also become a major source of environmental problems associated with extensive use of commercial feeds, excretion of fish, leftover from feed inputs, and other waste. It is therefore necessary to apply sustainable culture methods with less environmental burden in the future.

Beginning in 2021, the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan has launched the "Strategy for Sustainable Food Systems, MeaDRI (Measures for achievement of Decarbonization and Resilience with Innovation)." This medium- to long-term strategy aims to achieve food productivity and sustainability through innovations with zero or minimal impact to the environment. One way to contribute to the overall goal of this strategy is through innovation of sustainable aquaculture in Japan and the Asian monsoon region.

The Integrated Multi-Trophic Aquaculture (IMTA) is an aquaculture technology combining organisms that are at different trophic levels in the food chain, thus creating a balanced system that effectively utilizes the nutrients discharged from fish feeding and aquaculture. Moreover, it promotes environmental purification, economic stability, and social acceptance, with the aim of developing sustainable aquaculture.

In 2011, the Japan International Research Center for Agricultural Sciences (JIRCAS), in collaboration with the Southeast Asian Fisheries Development Center (SEAFDEC), Aquaculture Department (AQD) in the Philippines, the IMTA research project was implemented covering two 5-year phases that culminated in 2020. The project's aim was to promote the sustainable and equitable production of aquatic products in the Asian region.

This proceeding is a compilation of the 10-year achievements in IMTA research conducted by JIRCAS and SEAFDEC/AQD researchers and their collaborators, covering topics such as ecological characterization of target species, evaluation of environmental impacts, and socio-economic analysis. We hope that the research outputs we have obtained so far will provide reference information that can be useful to researchers, fisheries administrators, aquaculture farm owners, and small-scale farmers to stimulate further interest that may lead to the dissemination and practical utilization of IMTA. We also hope that IMTA development rooted in environmental harmony will lead further to sustainable and equitable production of aquatic products in tropical coastal areas as environmental protection becomes more important.

NAKASHIMA KAZUO
Program Director, Food Program
Japan International Research Center for Agriculture Sciences

FOREWORD (AQD)

For more than 20 years now, SEAFDEC and JIRCAS have been partners in promoting fisheries and aquaculture research and development. In 2001, SEAFDEC's Aquaculture Department in Iloilo, Philippines has been part of JIRCAS' five-year research project "Studies on sustainable production systems of aquatic animals in brackish mangrove areas," launched in 2001 which covered five collaborative research studies.

From then on, the two institutions have been working together in research projects on aquaculture with the common goal of achieving food security through the promotion of sustainable aquaculture. In 2011, a collaborative project on the Integrated Multi-Trophic Aquaculture (IMTA) was implemented. This is a 10-year collaboration divided into two 5-year projects namely "Development of Integrated Multi-Trophic Aquaculture Techniques for Livelihood Improvement" and "Demonstration and Verification of Sustainable and Efficient Aquaculture Techniques by Combination of Multiple Organisms."

The accomplishments of this 10-year project were presented during the "JIRCAS-SEAFDEC Joint Workshop on IMTA Research: Understanding Current Challenges and Future Prospects" on 6–8 August 2019 and are now compiled in this proceedings.

We hope that this publication would serve as useful reference material for researchers, fisheries officers, aquaculturists, and other aquaculture stakeholders.

DAN D. BALIAO
SEAFDEC/AQD Chief

About the Workshop

JIRCAS and SEAFDEC/AQD have collaboratively explored the development of Integrated Multi-Trophic Aquaculture (IMTA) which involves a sustainable system of fish culture applying polyculture techniques appropriate for aquatic organisms from various trophic levels.

In this system, an appropriate combination of various aquatic organisms, such as deposit feeders, filter feeders, and plants, may show potential for mitigating the environmental impacts of effluents from aquaculture operations, while diversifying yield and increasing income.

In 2011, the JIRCAS-SEAFDEC/AQD collaborative engagement on IMTA research started with the project, entitled: "Development of Integrated Multi-Trophic Aquaculture Techniques for Livelihood Improvement."

In 2016, the collaboration continued with another 5-year project, entitled: "Demonstration and Verification of Sustainable and Efficient Aquaculture Techniques by Combination of Multiple Organisms."

As the year 2020 approached to mark the tenth year of the IMTA research project collaborations, the "JIRCAS-SEAFDEC Joint Workshop on IMTA Research: Understanding Current Challenges and Future Prospects" was convened. The objective of the workshop is to wrap-up the 10 years' achievements of the projects, to scrutinize the feasibility and applicability of the IMTA system, and to discuss future research plans and the way forward, particularly for small-holder aquaculture.

Acknowledgements

We are grateful to Mr. Dan D. Baliao, Chief of SEAFDEC/AQD and to Dr. Leobert de la Peña, Head of the Research Division, for continuing to host the IMTA project of JIRCAS in the Philippines and for providing counterpart personnel, facilities, and logistical resources. We equally appreciate Dr. Yukiyo Yamamoto, Project Director, Dr. Tetsuo Fujii and Dr. Osamu Abe, Project Leaders at JIRCAS for their consideration and full support to the project by facilitating the needed funds.

We express sincere thanks to Honorable Chairman Jose S. Magon and the Barangay Councilors of the local government of Barangay Pandaraonan, the Pandaraonan Unified Association (PUA) and the villagers for their cooperation and support to the IMTA demonstration project at Guimaras.

We especially recognize the significant role of former JIRCAS scientist, Dr. Satoshi Watanabe, for initiating the IMTA project from 2011. We also acknowledge the valuable insights from Dr. Tuyoshi Sugita and Dr. Tsutom Miyata that helped in the development of the Project. Similarly, we also appreciate the former and present scientists and staff at SEAFDEC/AQD for their useful contributions in the management and operation of the IMTA project: Dr. Joebert D. Toledo, Dr. Felix G. Ayson, Dr. Evelyn Grace de Jesus-Ayson, Ms. Ma. Rovilla J. Luhan, Dr. Ma. Junemie Hazel Lebata-Ramos, Dr. Roger Edward P. Mamauag, Dr. Joemel G. Sumbing, Ms. Rose Margaret A. Cabrera, Ms. Raisa Joy G. Castel and Ms. Quenie S. Montinola. We also thank Mr. Elmer Tiñas and Mr. Ancil John Tibudan for their assistance in the field. We are very grateful to Ms. Rose Ann Diamante for her significant assistance in the implementation and monitoring of the experiments.

We especially acknowledge all of the authors and participants of the IMTA workshop for their valuable contribution in writing the main contents of this proceedings.

The Editors

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The Ecology of Prospective Species for IMTA

Overview and history of IMTA, from ancient to modern times

Masashi Kodama [1,2]

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[2]Japan International Research Center for Agricultural Sciences (JIRCAS)

Concept and history of IMTA study

According to one of the advocators of modern IMTA (Integrated Multi-Trophic Aquaculture), Thierry Chopin, the origins of IMTA can be traced back to ancient civilizations, thousands of years ago, such as those in China and Egypt where farmers practiced a form of agriculture integrated with fish culture. It seemed like a natural course of action for people to think of utilizing waste of fish culture, not only to produce secondary crops, but to earn secondary income as well. IMTA is a concept of hitting two birds with one stone. It deals with problems of environmental pollution and insufficient profitability by mitigating the environmental impact of feeding aquaculture through diversifying nutrient flow and increasing the source of income from secondary species at the same time. A popular design of IMTA is integrating fed species, such as fish, with organic-extractive species (*i.e.* deposit feeder and/or suspension feeder) and inorganic-extractive species (*e.g.* common seaweeds) to utilize nutrients from the excrements of the primary fed species (**Figure 1**). As mentioned above, a similar concept had been practiced from ancient times, through the centuries, and up to modern times (**Figure 2**). In the 1970s, the research group of Woods Hole Oceanographic Institution developed the "integrated waste-recycling marine polyculture systems" which is considered as the grandfather of modern IMTA. They combined different trophic level organisms which realized the basic concept of IMTA.

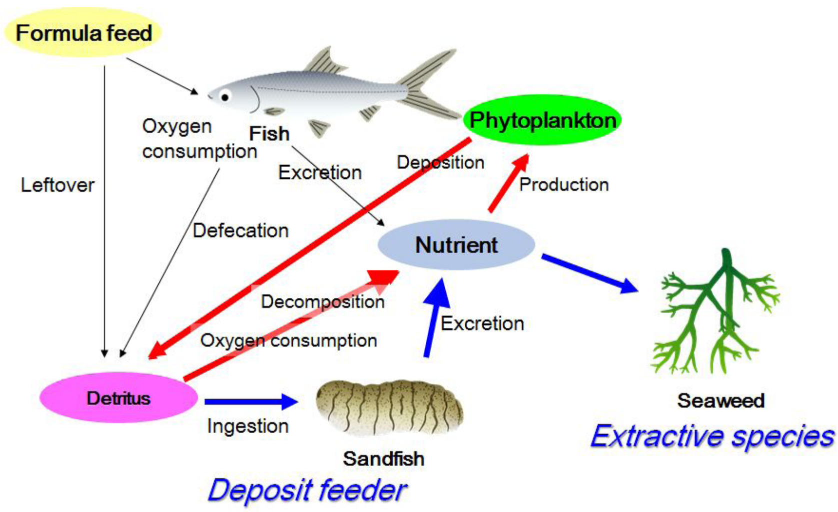

Figure 1. Schematic diagram of IMTA. Case study in Guimaras Island, Philippines

Modern IMTA

After the above-mentioned studies made in the 1970s, more IMTA practices with various modifications had been made in the 20th century. Troell *et al*. (2003) reviewed decades of these studies which could be categorized as IMTA. They summarized the achievements, problems and pointed out the future direction to implement the concept and technology of IMTA. Some of the important points in their review are the advantages (effectiveness of nutrient removal and ease of maintenance) and limitations (*e.g.* profitability) of closed circulation systems derived from the early prototype of IMTA. Hence, IMTA practices were shifted to open water systems at broader scales in the 21st century. Other examples of IMTA systems were developed over the world, reflecting the endemic geographic, climatic, and cultural features in each region. For instance, China developed the bay-scale IMTA in Sanggou Bay called "transitional IMTA" which is contrastive with "engineered IMTA" in western countries. There was also the community-based and small-scale practices such as the "*Satoumi*" in Japan and Southeast Asia.

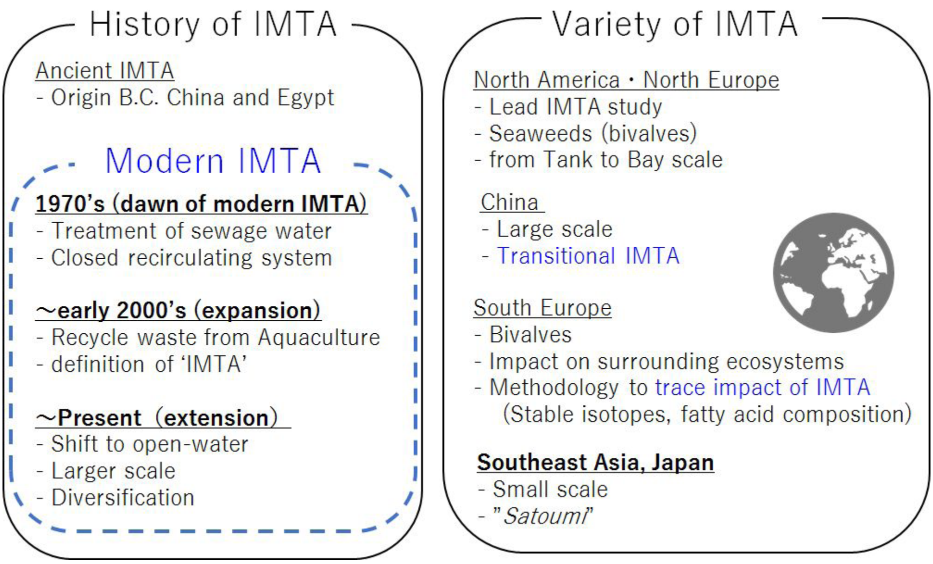

Figure 2. History and variety of IMTA practices.

Challenges for implementation of IMTA

Many concerted and dedicated efforts were made to develop IMTA by those forerunners. However, it was very difficult to evaluate the performance of IMTA systems. By way of example and extension, Sanz-Lazaro *et al*. (2017) concluded that extractive species like mussels do not directly assimilate fish farm wastes. Chopin *et al*. (2012) also discussed the increase of biodiversity near aquaculture sites could also be considered as an impact of IMTA. Recently, development plans of multi-use systems of offshore waters like in wind farms, for example, which combines IMTA. Such an integration opens the perspective of multiple stakeholders, not only of the fisheries sector but also those of other sectors including energy development, shipping, and tourism. These concepts may encourage the future implementation of IMTA in a broader sense.

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Sandfish Biology and Ecology: Prospects and Challenges for IMTA in the Tropics

Jon P. Altamirano
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Introduction

Sea cucumbers are highly valued in China and Southeast Asian markets for food and nutraceutical uses (**Figure 1**). This has caused overfishing in many parts of the tropics, and combined with poor fisheries management, has resulted in severe declines in wild stocks (Anderson *et al*. 2011; Purcell *et al*. 2013). As such, interest in the aquaculture of these commercially-valuable echinoderms has spread throughout the world (Bell *et al*. 2008; Juinio-Meñez *et al*. 2017; Purcell *et al*. 2012; Purcell and Wu 2017).

Figure 1. Expensive dried sea cucumbers for sale in a Chinese market

The sandfish *Holothuria scabra* is among those with the highest potential for aquaculture because the technology for production in hatcheries has been established (Agudo 2012; Battaglene 1999; James *et al.* 1994; Pitt and Duy 2003). In terms of value, dried sandfish commands over US$1,500 per kilo in Chinese markets, coming in as a close second to the most valued sea cucumber, the Japanese spiky sea cucumber *Apostichopus japonicus*, with prices reaching over US$ 2,000 per kilo in its dried form (Purcell *et al.* 2014) (**Figure 2**). Since the latter is a temperate species, it leaves the sandfish *H. scabra* as the most suited choice for tropical aquaculture.

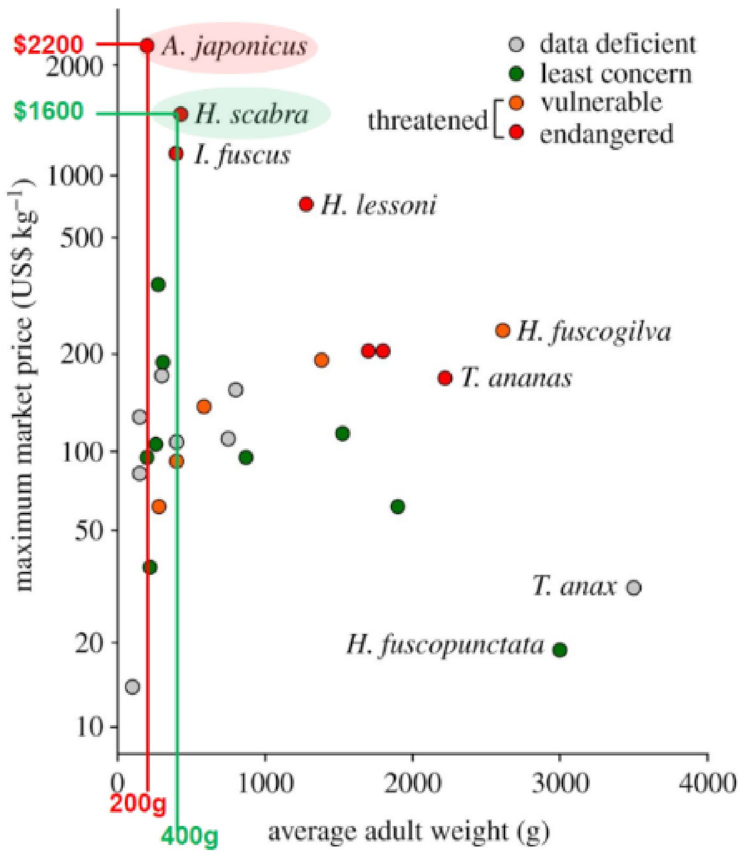

Figure 2. Species of sea cucumbers and their prices (US$) at given weight (fresh wet weight in g), highlighting *A. japonicus* and *H. scabra* (Adapted from: Purcell *et al.* 2014).

Biology and ecology of sandfish relevant to aquaculture

Sandfish are echinoderms that belong to the Order Aspidochirotida with oral tentacles to feed on the rich biofilm that coats most sandy intertidal shores. Their diet involves microalgae, small animals, bacteria, and organic matter that may be present on the substrate's surface. This aspect of omnivorisity is an advantage to the aquaculture potential of this species, where they can be grown even without supplemental feeds. Non-feeding culture systems are the general practice in existing sandfish aquaculture ventures and sea ranching.

Sandfish generally feed on natural biofilm on the sediment surface during the night which peaks at 15:00–03:00 h, and are mostly buried during the day (03:00–09:00 h) (Altamirano *et al.* 2017; **Figure 3**).

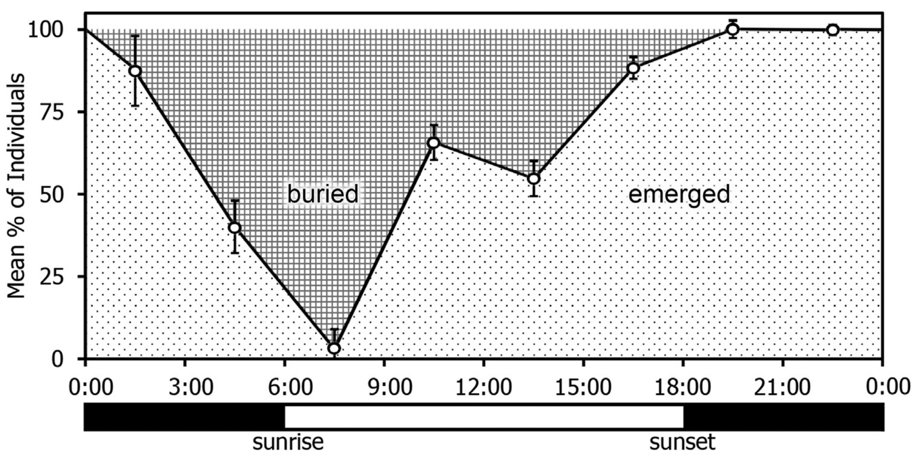

Figure 3. Daily feeding and burying schedule of sandfish (Source: Altamirano *et al.* 2017)

Altamirano *et al*. (2017) reported that, especially for sandfish juveniles, sandy mud substrate is preferred for both burying and feeding, and that substrate preference was not influenced by the presence of seagrass. It is also important to note that silty-mud sediments associated with muddy mangrove areas, culture ponds, and aquaculture areas seemed to be not an ideal substrate for sandfish culture (**Figure 4**). Basically, sandfish are sediment-dwelling animals and therefore require loose sandy substrate to feed on, and bury in. So, culture systems for this species will need to consider the required sediments like in ponds, or sea ranch in natural intertidal areas.

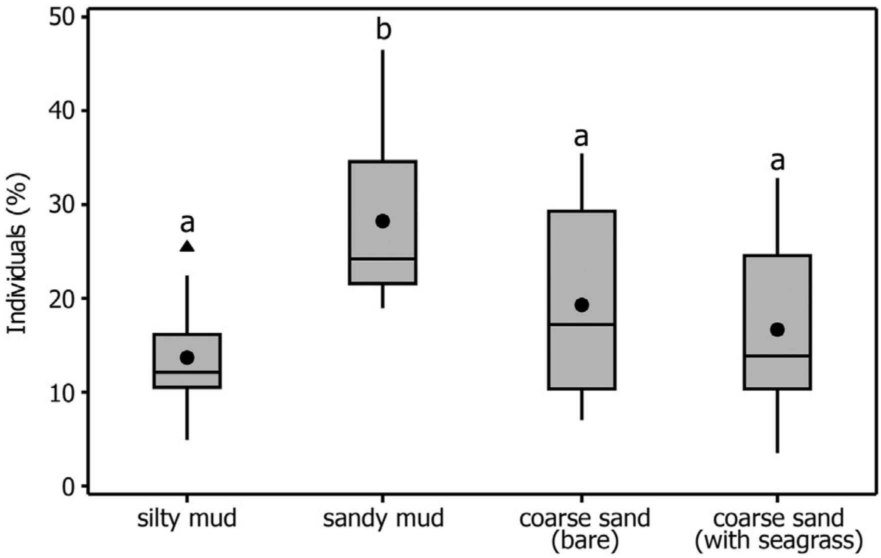

Figure 4. Sandfish substrate preference for burying (Source: Altamirano *et al.* 2017)

Like all other echinoderms, sandfish is purely marine. They can tolerate only as low as 20 ppt of salinity but should ideally be grown in around 30–35 ppt of clean seawater. Preliminary studies show that confinement of sandfish in tanks for longer periods (*e.g.* >2 months) will render them unproductive, where they tend to lose weight and shrink. Wider tanks and lower stocking densities can mitigate this shrinkage but not indefinitely. It is therefore recommended that culture areas will need to be wide (*e.g.* hectares) in order to promote better growth and survival of sandfish.

Aquaculture options for sandfish

Sandfish is an emerging species for aquaculture. There are currently a number of factors favoring the culture of this species. These include the well-established market acceptance in Asia, very high market value, declining wild stocks, availability of suitable species, low disease risks, availability of commercial technology, and a range of culture system options (Azari *et al.* 2010). Because of the development of hatchery technology for sandfish, the needed seedstocks for aquaculture are already available in some countries. Grow-out culture is being done in small-scale earthen ponds in Viet Nam, intertidal pens in Madagascar, open sea ranch in the Philippines, wide large-scale pond polyculture in China, and even in in-land tanks in Saudi Arabia (**Figure 5**).

Figure 5. Some grow-out culture systems for sandfish.

Prospects & challenges of sandfish in IMTA

In a traditional IMTA system, the major species (typically fish) is the only one being fed, while the other lower-trophic species being polycultured in this system are expected to "feed-on" inorganic and organic wastes. Like many other deposit-feeding holothurians, sandfish feed on decaying organic matter (OM) in the sediments and can potentially alleviate the deposition of too much wastes from a fed species. However, studies have shown that sea cucumbers seem to have low OM assimilation potential (Orozco *et al*. 2014; Zamora and Jeffs 2011). In some cases, when OM is low to start with, sea cucumber feces can even have higher OM or Total Organic Matter (TOM) levels (**Figure 6**). Sandfish also cannot tolerate very high levels of OM. Initial culture trials in aquaculture ponds and below aquaculture cages with OM reaching >20 % resulted in total mortality for sandfish. Ideally, sandfish will live well in sediments with organic matter of <5 %.

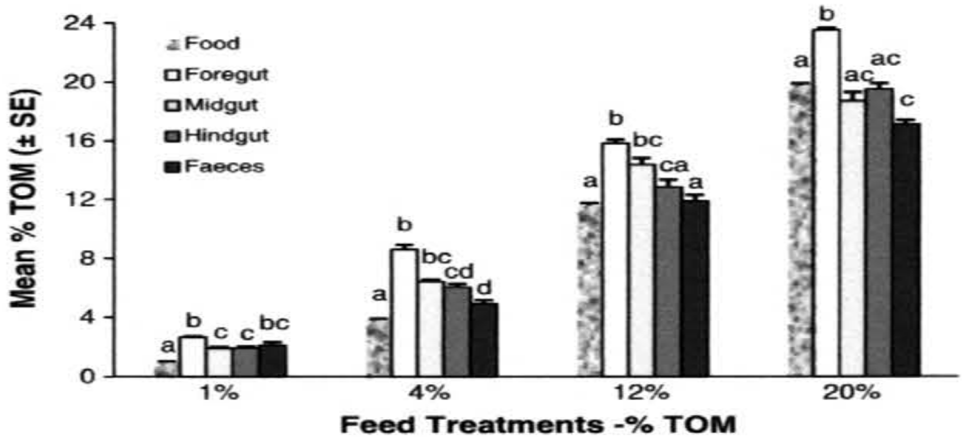

Figure 6. TOM content from food, gut and feces of *A. mollis*.
(Source: Zamora and Jeffs, 2011)

Sandfish promotes bioturbation of sediments as they bury into the substrate, as part of their daily behavior. This potentially aids in oxygenation of the lower sediment layer, much like compared to earthworms in terrestrial soil. In most cases, however, the depth at which sandfish bury is only proportional to its body depth, because they need their anus to still be above the surface for respiration. This depth can only be up to 5 cm for adults and may not be deep enough to really bio-turbate down to the anoxic layer.

The growth of sandfish can be augmented by proximity to aquaculture farms (Dumalan *et al*. 2019), thus the possibility of enhanced growth when polycultured in an IMTA system. However, although sandfish may grow faster, survival may still be low, especially in open and semi-open culture systems like pens or in a sea ranch because of predation and fluctuating environmental conditions.

Concluding Remarks

Sea cucumbers are expensive marine commodities and the aquaculture technologies for species like *Holothuria scabra* or sandfish is rapidly being established. Because of the inherent capacity of sandfish to feed on the organic matter of sediments, they remain a strong candidate for IMTA. However, the prospects for this can be overshadowed by the many challenges that still need to be overcome in order to optimize the growth and survival of this echinoderm in an integrated multi-trophic polyculture system.

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Gracilariopsis heteroclada as an extractive species in an aquaculture system

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Introduction

In intensive aquaculture systems, the quality of water in the culture environment usually deteriorates fast when not properly managed because of excessive chemical inputs. The accumulation of various forms of metabolites or wastes in the rearing environment becomes toxic when they reach very high levels. This condition can then lead to mass kills of the cultured organisms and to the deterioration of the surrounding environment if these toxic compounds are released without prior treatment.

Some species of marine algae have been utilized as biofilter in wastewater treatment of an aquaculture system. Here, *Gracilariopsis heteroclada* (**Figure 1**) was grown in filter tanks to determine the growth, agar quality, and uptake pattern of nitrogen and to observe the water quality in a recirculating water system with seaweed.

Figure 1. *Gracilariopsis heteroclada* grown in a tank

Materials and Methods

The study was conducted within the integrated finfish broodstock facility complex of SEAFDEC/AQD at Tigbauan, Iloilo, Philippines. The broodstock facility has a water recirculating system. The 500-ton capacity broodstock/spawning tanks were stocked with 25 grouper (*Epinephelus coioides*) and 90 milkfish (*Chanos chanos*) breeders. Water from the broodstock tanks passes through the sedimentation tank, then through the filter tank before it goes back to the broodstock tanks. The filter tank has an area of 20 m^2, a water depth of 25 cm, and a water flow rate of 43 L sec^{-1} ($\approx$3720 m^3 day^{-1}).

Results and Discussion

The rapid uptake of nitrogen in *G. heteroclada* was observed within the first 24 h of culture. Filling up of the nitrogen pools in the cell may have continued until the 5th day of culture. This suggests that, upon intracellular saturation of nitrogen on the 5th day, the plants started to increase in weight, proportionate to the uptake rate of nitrogen during the experiment.

G. heteroclada stocked at 1 kg m^{-2} achieved an SGR of approximately 10.4 % day^{-1} during 15 days of culture, at total ammonia-nitrogen and nitrite-nitrogen levels of less than 0.27 mg L^{-1} and 0.19 mg L^{-1} respectively in the filter tank.

G. heteroclada stocked at 1 kg m^{-2} in the filter tank has achieved an SGR of approximately 10 % day^{-1} in 15 days of culture at total ammonia nitrogen and nitrite levels of not less than 0.03 mg L and 0.04 mg L^{-1}, respectively. *G. heteroclada* required approximately 3.35 g N kg^{-1} (f.w. *G. heteroclada*) day^{-1} and attained an SGR as mentioned above in this study.

Integrating bivalves in IMTA system using earthen ponds

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Introduction

The demand for aquatic resources increases with increasing population. However, production from capture fisheries plateaued as early as the mid-90s (FAO, 2019a). With limited production from natural sources, aquaculture has become an important source of fisheries products and production has been steadily increasing (FAO, 2019b) (**Figure 1**). Despite the sustainability of aquaculture, studies have shown of its negative impacts to the natural environment. Because of these negative impacts of aquaculture, scientists are finding ways to eliminate or at least minimize these impacts to improve environmental quality and productivity while keeping production sustainable.

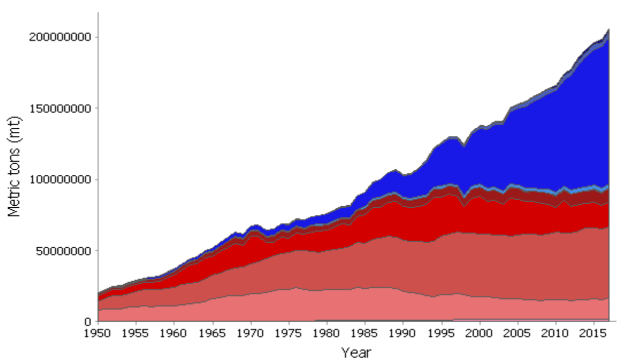

Figure 1. Total world capture (shades of red) and aquaculture (shades of blue) production (FAO, 2019a; FAO, 2019b).

Integrated multi-trophic aquaculture, popularly known as IMTA, is a system where one species finds a feeding niche in the waste generated by another species. The concept of integrating species into one culture system originated from Asia and the Middle East and the development of integrated aquaculture involving marine bivalves is relatively new, around the 1980s in China and 1990s in Western countries (Strand *et al.*, 2019).

This study aimed to integrate the mangrove clam *Anodontia philippiana* (**Figure 2**), which has the capacity to assimilate sulfide (Lebata, 2001; Lebata, 2000), in a pond culture system with milkfish *Chanos chanos* and seaweeds *Gracilariopsis heteroclada*. Specifically, it aimed to know the effects of integrating other commodities on the growth and survival of milkfish, the primary culture species in IMTA in ponds.

Figure 2. The mangrove clams, *Anodontia philippiana*, used in integrated culture with milkfish in earthen ponds in Concepcion, Iloilo, Philippines.

Materials and Methods

The study was conducted in Concepcion, Iloilo, Philippines. An earthen pond with 4 compartments, each measuring 320 m^2 was utilized for the experiment. The experiment had 4 treatments, as follows, and distribution of cultured species is shown in **Table 1**:

Treatment 1 = milkfish only
Treatment 2 = milkfish + seaweeds
Treatment 3 = milkfish + mangrove clams
Treatment 4 = milkfish + seaweeds + mangrove clams

Table 1. Density of milkfish, seaweeds and mangrove clams in 4 compartments of the earthen pond. Each compartment represents one treatment.

Pond	Milkfish	Seaweeds	Mangrove clams
1	320 pcs	None	None
2	320 pcs	32 kg	None
3	320 pcs	None	160 pcs
4	320 pcs	32 kg	160 pcs

The experiment commenced on 24 May 2013 and was terminated when the milkfish attained harvestable size of 300 g average body weight (ABW) at 82 days of culture (DOC). During the experiment, milkfish were fed commercial diet starting at 8 % of the total biomass tapering gradually to 3 % towards harvest, equally rationed three times a day. Sampling of stocks was done every 3 weeks by weighing individually 10 % of the total stocks per compartment/treatment. Mortality was recorded daily and during sampling.

Water temperature and salinity were monitored daily while pH, dissolved oxygen (D.O.), sulfide, phosphate, nitrate, nitrite and ammonia every 3 weeks.

Results and Discussion

Milkfish growth did not significantly differ during the first two months of culture but apparently during harvest, milkfish reared with mangrove clams had significantly higher ABW than those reared with mangrove clams and seaweeds (ANOVA, $p<0.05$) (**Figure 3**).

Upon harvest, survival was higher when milkfish was reared with seaweeds and mangrove clams (98.1 %) while lowest when monocultured (92.5 %) (**Figure 4**). The lowest ABW upon harvest of milkfish reared with other commodities may be attributed to the higher stocking density because of the highest survival in this compartment. Average survival from four compartments was 95.1 %

Feed conversion ratios were 1.9, 1.9, 1.7 and 2.0 in ponds 1 (milkfish only), 2 (milkfish + seaweeds), 3 (milkfish + mangrove clams) and 4 (milkfish + seaweeds + mangrove clams), respectively.

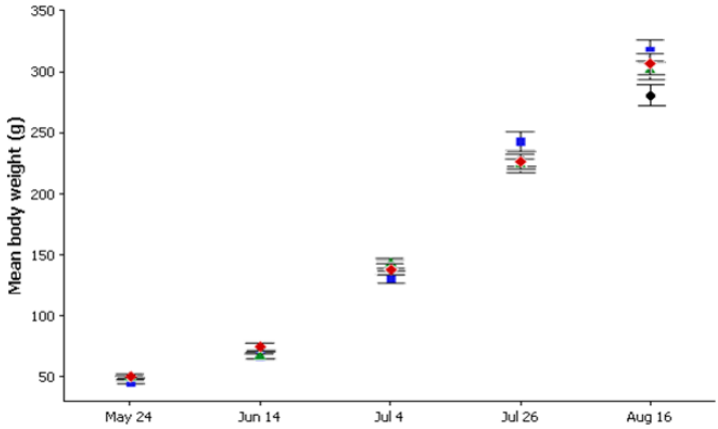

Figure 3. Monthly average body weight (ABW) of milkfish reared with or without other aquaculture commodities in earthen ponds in Concepcion, Iloilo, Philippines; red-filled diamonds = milkfish only, green-filled triangles = milkfish+seaweeds, blue-filled squares = milkfish+mangrove clam, black-filled circles = milkfish+seaweeds+mangrove clams.

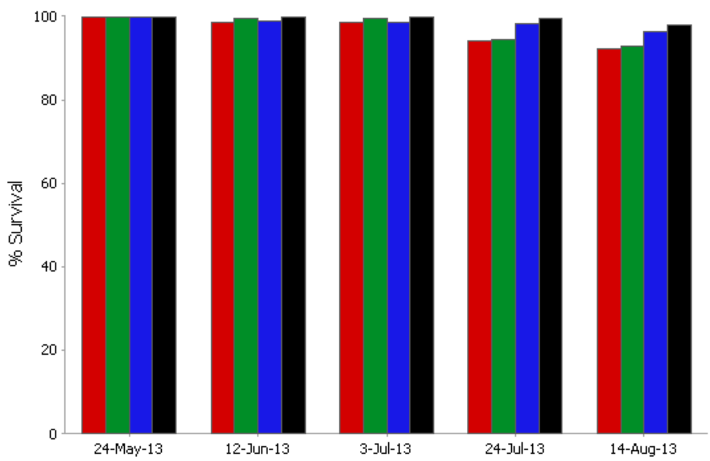

Figure 4. Milkfish survival (%) every 3 weeks when reared with or without other aquaculture commodities in earthen ponds in Concepcion, Iloilo, Philippines; red-filled bars = milkfish only, green-filled bars = milkfish+seaweeds, blue-filled bars = milkfish+ mangrove clam, black-filled bars = milkfish+ seaweeds+mangrove clams.

There was not much difference in temperature, salinity and D.O. between pond compartments. pH was higher in ponds with milkfish and mangrove clams and lower in milkfish and seaweeds. The elevated pH in compartments with mangrove clams may be due to the sulfide assimilating property of the clams. Towards harvest, ammonia and phosphate were higher in compartment with milkfish only.

Conclusions and Recommendations

Although this one run may not be conclusive, the results showed that milkfish may be cultured with extractive species in an IMTA system without significantly affecting its growth and survival. Integrating mangrove clams and seaweeds in the system may help improve water quality. However, studies on species combinations and ratio of the different species to be incorporated in the system should be done to establish a sustainable and effective IMTA technology.

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Cage and pen culture of milkfish *Chanos chanos*

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Introduction

The culture of milkfish (*Chanos chanos*) is the largest fish aquaculture industry in the Philippines (Marte 2010). Milkfish continues to be a top aquaculture commodity primarily because they are easy to culture and can be grown in a wide range of environments (Samson 1984). They thrive in freshwater, brackishwater, marine, and even hypersaline habitats. Milkfish production is increasing rapidly with much of the production moving away from the traditional culture in brackishwater ponds to fish cages in coastal marine waters (Gaitan *et al.* 2014).

Milkfish culture has been practiced in the Philippines, Indonesia, and Taiwan for centuries and has been the focus of aquaculture research in a number of institutions for several decades. Innovations in culture practices based on research data and farmers' experiences have been adopted by industry practitioners across Asia (Liao & Leano, 2010). In general, the full production cycle of milkfish from induced spawning and hatchery operations to pond nursery and cage grow-out culture can take 7–10 months (**Table 1**).

Table 1. General stages involved in milkfish aquaculture production

Culture Stage	Larval stage	Nursery stage	Grow-out stage
Days of Culture	1–21 days	60–75 days	4–6 months
Culture System	inland hatchery	earthen nursery pond	floating sea cage or pond
Output Product	fry	fingerlings	market-size milkfish

Recent concerns about the rapid growth of aquaculture, possible environmental impacts, and risks that can threaten the sustainability of this expanding industry have also been the subject of many research. These come with the end view of developing good management practices in marine fish cage culture (Gaitan *et al*. 2014).

Materials and Methods

The project which involves the commercial farming of milkfish, *Chanos chanos*, in floating net cages and pens at the coastal water of Barangay Sto. Domingo, Nueva Valencia Guimaras started in March 2018. Four units of floating net cages were fabricated (15 m dia. x 6 m deep) and set up with concrete moorings at the deeper (15–20 m) area of the bay. Meanwhile, 5 units of bamboo pens (15 m dia. x 6 m deep with net flooring) were installed at the shallow (5–10 m) coast (**Figure 1**). Double layer netting were used to ensure the safety of fish stock from escaping. Milkfish fingerlings (average weight of 25–30 g; 4–5 in long) from the earthen nursery ponds were stocked at 30 fish/m^3 in the pens and at 40 fish/m^3 in the floating net cages. Stocks were fed with commercially available milkfish feed starting from crumbles, starter, grower and finisher pellets at 6-8 % of body weight per day and gradually decreased to 3 % when fish reached the average body weight of 400 g until harvest. To avoid feed wastage and to ensure that feed ration is consumed, broadcasting of feed is done slowly depending on the appetite of the fish. Replacement of nets was done monthly. One hundred fish were sampled monthly to determine the average body weight (ABW), which was used in adjusting the required feed ration. After attaining an average body weight of 500 g, the milkfish are harvested and sold at the nearby Iloilo Fish Port Complex.

Figure 1. Floating net cages (left) and bamboo pens (right)

Results and Discussion

After two production cycles, growth and survival of fish from the pens started to decline due to the deteriorating condition of sediments as shown by the black and smelly sludge on the substrate. The accumulation of fish waste and uneaten feeds has greatly affected the performance of milkfish culture in pens. The net flooring sits on the bottom substrate, and obstructed the flushing effect of the underwater current. The low water current velocity in the shallow area and the cumulative build-up of sludge may have stressed the milkfish stocks and decreased their feeding rates, thereby lengthening the culture period to 7–8 months.

Moreover, nets get clogged up easily with fouling organisms causing very limited water exchange. Periodic net changes was done at least once a month, although net changing was also difficult in pens because bamboo poles were obstructive. Fouling organisms on the bamboos like barnacles had to be cleaned off every production cycle, which adds to more labor costs.

In addition, pens are fixed and the daily tidal level fluctuations resulted in irregular water depth and volume inside the culture nets which was especially decreased during low tide. This caused additional stress to the fish stock especially when they are approaching marketable size. At low tide, crowding may result to decreased dissolved oxygen levels. In effect, milkfish vigorously moved about and gasped at the water surface for oxygen, and caused some mortalities.

On the other hand, floating net cages have been found to be the best culture system for milkfish in a bay. Growth and survival of milkfish in floating cages at the deeper area of 15–20 m was much better than those in the pens. The economic life of bamboo raft and flotation setup used in floating cages can be much longer (2–3 production cycle) than that of bamboos in pens (one production cycle only). Capital requirements for floating cages was much higher in terms of materials and initial labor costs but eventually be more cost-effective because of longer potential use.

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Evaluation of Environmental Impacts and Current Challenges in IMTA

IMTA as a possible countermeasure for reduced aquaculture productivity in Japan

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Introduction

Aquaculture is a growing industry worldwide, and it is all the more becoming an important source of food and income for people. Intensive aquaculture, however, can have adverse effects to the environment. Aquaculture effluents may cause eutrophication of the water and sediment, resulting in consequent occurrence of algal bloom, hypoxia of the bottom water and production of toxic hydrogen sulfide. These may then lead to mass fish kills and oceanic dead zones. Intensive fed aquaculture of finfishes and crustaceans, for instance, can therefore be detrimental to the environment. Environmental deterioration are becoming increasingly problematic in many parts of the world.

On the other hand, eutrophication has been reduced in the coastal waters of Japan as a result of mitigation efforts over the past thirty years. In other words, "oligotrophication" is progressing in Japan. The Ministry of the Environment implemented the "Total Pollutant Load Control System (TPLCS)" in 1979 to mitigate the eutrophication of the enclosed sea areas (*i.e.* Tokyo Bay, Ise Bay and Seto Inland Sea). The TPLCS regulated the allowable discharge of chemical oxygen demand (COD, which is the amount of oxygen needed for the oxidation of all organic materials in water), total nitrogen (N) and total phosphorus (P) to the enclosed sea areas with poor seawater exchange.

Relative to the past, this oligotrophication of the coastal waters is considered to have caused a decline in the productivity of the coastal environment, resulting in a continuous decrease in some coastal fishery resources in some parts of Japan. For example, fisheries production of benthic finfishes in Seto

Inland Sea has decreased markedly, and the fishery production was found to be negatively correlated with the dissolved inorganic nitrogen (DIN) level in the coastal water (Handa and Harada, 2012). Productivity of unfed aquaculture of mollusks and seaweeds is also affected by the nutritional conditions of the coastal waters. Bleaching of cultured nori (*Pyropia yezoensis*) thalli has become problematic in Japan (*i.e.* darker color commands a higher price), and it is attributable to insufficient supply of nutrients (*i.e.* N and/or P depending on the area) to the coastal culture areas, especially at the end of the culture season in winter (Yamamoto, 2003).

In addition to TPLCS regulations that have reduced terrestrial nutrient loads, diminished production and improved feeding management of coastal finfish aquaculture, these have also contributed to the reduced nutrient levels in the seas.

Dwindling aquaculture production in Japan

The volume of aquaculture production of many aquatic organisms, including finfishes, bivalves, crustaceans and seaweeds, are on a long-term decreasing trend in Japan. Based on the national statistical data issued by the Ministry of Agriculture, Forestry and Fisheries, the total marine aquaculture production decreased by 20 % by volume between 1996 and 2016. In fed aquaculture of marine finfish, productions of the red seabream (*Pagrus major*), Japanese flounder (*Paralichthys olivaceus*) and horse mackerel (*Trachurus japonicus*), for instance, have declined markedly in both volume and value.

Eutrophication caused by fed aquaculture effluent has been regulated by Sustainable Aquaculture Production Assurance Act (APAA) issued by the Fisheries Agency since 1999. With the assistance of the prefectural extension workers, fisheries cooperative associations as a group or individual farmers are required to submit an Aquaculture Area Improvement Plan to the respective government office every five years. Typically, appropriate maximum culturing density of finfishes is set to be less than 95 % of the trimmed mean excluding the largest and the smallest values of the density from the previous five-year term. The reduced production also intends to prevent oversupply and subsequent price drop of the products. This may also be one of the causes of Japan's decreasing aquaculture production, along with various other socio-economic factors.

As for unfed aquaculture, production volume of many seaweeds which include nori, kelps (*Saccharina japonica* and *S. angustata*), wakame (*Undaria pinntifida*) and oysters (*Crassostrea gigas* and *C. nippona*) have decreased over the past twenty years. Fisheries production inclusive of bottom culture of transplanted seeds of the Manila clam (*Ruditapes philippinarum*) has decreased drastically in Japan. The production volume of the Manila clam peaked at 1.7 × 10^5 t in 1983, and it has gradually and continuously dropped to 7.1× 10^3 t in 2017 (*i.e.* 96 % decrease in 34 years). One of the reasons for this extreme decrease is considered to be reduced primary productivity due to oligotrophication of the coastal waters (Uchida, 2014).

Oligotrophication and reduced primary productivity

Statistical data for environmental parameters in Ise Bay, central Japan, reported by Mie Prefecture Fisheries Research Institute (1972–2016), showed that DIN level has a long-term decreasing trend over the past thirty years. The annual mean DIN level was 11.2 μM and 4.6 μM in 1985 and 2015, respectively (*i.e.* 58.9 % reduction in 30 years). P level, on the other hand, did not decrease between 1985 (0.59 μM) and 2003 (0.63 μM) and had a decreasing trend with large fluctuations between 2004 (0.79 μM) and 2015 (0.27 μM).

The difference observed in N and P levels between 1985 to 2004 might be attributable to the introduction of P-free detergents and establishment of coagulation-sedimentation method that were implemented at wastewater treatment systems in the late 1970s, which had already reduced the P level before 1985 (Washio, 2015). The denitrification method for N removal, on the other hand, did not become widely used until 1990s, resulting in over supply of N relative to P (*i.e.* N-P imbalance) during this period.

The ratio of N and P in seawater is known to alter phytoplankton species compositions (*e.g.* Rhee, 1978), which may subsequently affect aquaculture production of bivalves that feed on the phytoplankton.

Occurrence of harmful algal bloom (HAB) is closely linked with seawater nutrient levels (Honjo, 1994). The occurrence frequency of HAB has been markedly reduced in Ise Bay (Mie prefecture, 1972–2016). HAB was observed 31 times (*i.e.* gross number and not necessarily equals the actual occurrence) in 1985, whereas it was observed only once in 2015. Reduced nutrient level is probably one of the key causes of the long-term subsiding HAB.

Similarly, the surface chlorophyll *a* level has been in a decreasing trend in Ise Bay (**Figure 1**), indicating the reduced primary productivity of not only HAB species but also other phytoplankters which may play important roles in supporting the food web in the area.

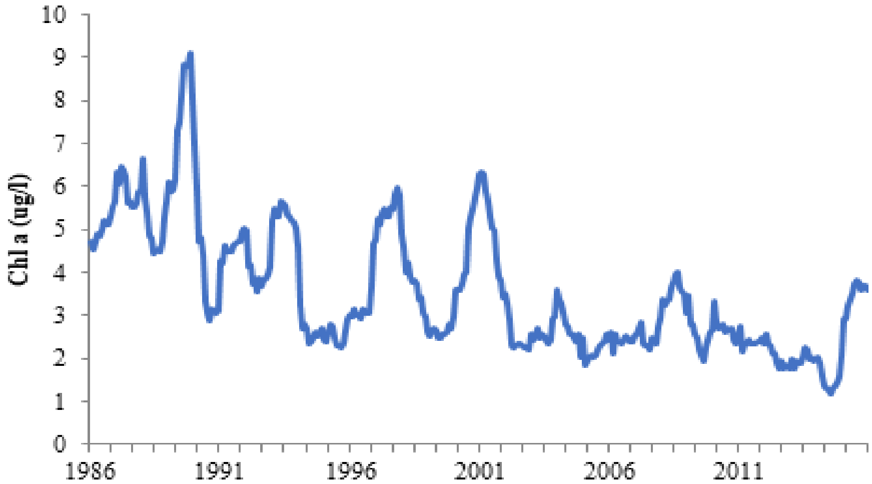

Figure 1. Trend in chlorophyll *a* level in Ise Bay

IMTA as a possible countermeasure for oligotrophication

Our hypothesis is that putting fed aquaculture effluent into practical use enhances the production of coastal fisheries and unfed aquaculture of bivalves and seaweeds. In addition, income from unfed aquaculture and added ecological value may revitalize fed aquaculture of finfishes.

Integrated multi-trophic aquaculture (IMTA) is an aquaculture approach that combines culture of economically important species from different trophic levels, typically finfish, organic extractive species (e.g. bivalve) and inorganic extractive species like seaweeds (Chopin, 2006). IMTA is usually operated to mitigate eutrophication of water and sediment as a responsible approach to environmental integrity. However, it should also be used as a counter measure for reduced primary productivity due to oligotrophication.

Our ongoing study on IMTA

To acquire basic information on the influential extent of aquaculture effluent on carrying capacity of coastal waters, we have been conducting environmental surveys to investigate the behaviour of nutrients and primary production covering the whole bay area and more intensively around the red seabream aquaculture cages in Gokasho Bay, Mie, Japan.

Seawater samples were collected monthly at 19 points within the bay. In addition, 47 points were seasonally sampled, from around the red seabream aquaculture cages to analyze the concentration of the following nutrients: dissolved inorganic nitrogen (DIN: NH_4-N, NO_2-N, NO_3-N), PO_4-P and SiO_2-Si. A CTD is used to obtain the vertical profile of temperature, salinity, dissolved oxygen (DO), and chlorophyll *a* from the surface to the bottom.

Results showed that there were general trends of higher DIN-N and PO_4-P levels near fish cages and deeper parts of caves in Gokasho Bay.

DIN-N and DO levels observed in the red seabream culture area in December 2016 were comparable to those from the same month in 1980s (National Research Institute of Aquaculture, 1991), when aquaculture was more prosperous. However, PO_4-P level was an order of magnitude lower (**Figure 2**), probably due to diminished aquaculture production and improved feeding management, including the switch from raw bait to formulated feed.

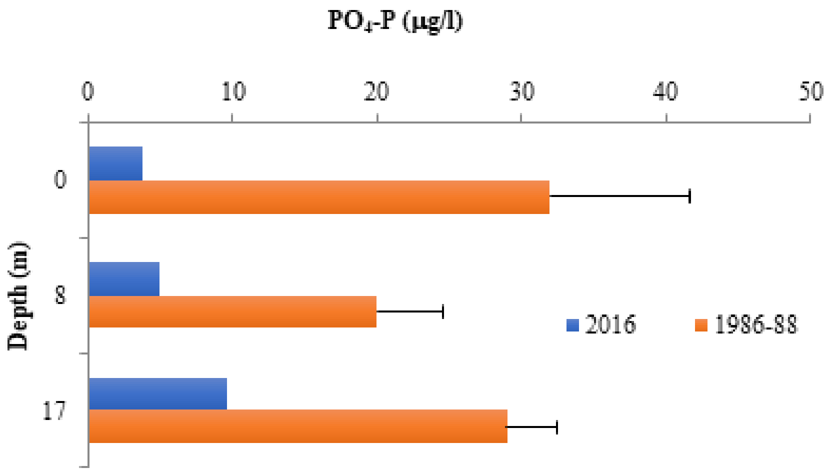

Figure 2. PO_4-P concentration in the vicinity of red seabream aquaculture cage, comparison with late 1980s.

During a diatom bloom observed in November 2016, the depletion of SiO_2-Si implied that the availability of Si, but not N or P, was the limiting factor for the diatom growth in Gokasho Bay.

There were spots with a higher NH_4-N level at the center and 20 m outside the red seabream cage area in January 2017. The chlorophyll *a* level was higher around the cages than in the surrounding water (**Figure 3**), and NO_3-N was lower around the cages conversely. The observed lower NO_3-N concentration may indicate that the enhanced primary production triggered by the NH_4-N supply from the aquaculture effluent rapidly consumed not only NH_4-N but the background NO_3-N in the area. This indicated that DIN-N excreted by the red seabream stocks may not travel a long distance from the cages before being absorbed by primary producers.

In order to fertilize seaweed with red seabream aquaculture effluent, the seaweed should be cultured in the vicinity of the fish cages. The elevation of chlorophyll *a* indicates the possibility of productive co-culture of red seabream and bivalves.

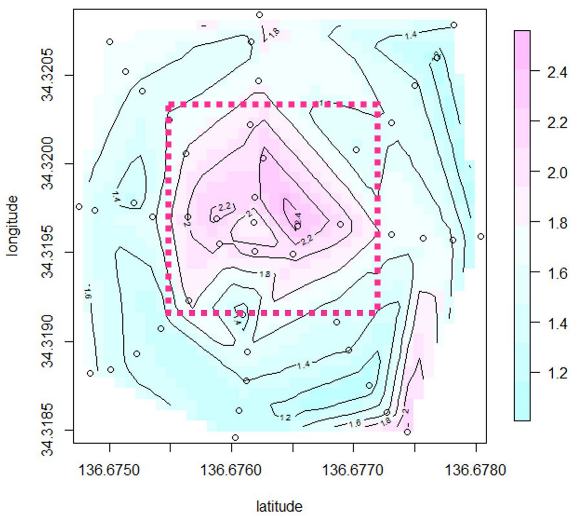

Figure 3. Chlorophyll *a* level in red seabream aquaculture area in January 2017. Dashed line indicates the area with fish cages (110 m × 150 m)

Therefore, IMTA has a potential to enhance aquaculture production by using what would otherwise be fish waste to be utilized by other organisms. However, for the practical realization of IMTA, there are challenges to be overcome. For example, our study so far showed that biofouling intensity is higher near a red seabream cage than in an oyster culture raft area (**Figure 4**). There was also a tendency that more crustaceans, such as *Caprellidae*, attaching to the culture containers near the fish cages.

Further studies are underway on aquaculture techniques to provide useful information for the establishment of effective IMTA systems to utilize aquaculture effluent in oligotrophic waters.

Figure 4. Intensive biofouling on an oyster culture basket hanged from a red seabream culture cage.

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Growth Performance of Milkfish (*Chanos chanos*) Cultured in Marine Pen Designed for Integrated Multi-Trophic Aquaculture (IMTA)

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Introduction

Milkfish (*Chanos chanos*) is one of the most economically important cultured fish in Southeast Asia with distribution in the tropical and subtropical area centered in Indo-Pacific at waters with temperatures greater than 20°C, as defined by the winter surface isotherms (Bagarinao, 1991). In the Philippines, it is one of the major contributors to aquaculture production next to seaweed with an annual production of 411 metric tons in 2017 (PSA, 2017). Its euryhaline nature made it viable for culture in different systems, such as freshwater (*e.g.* lakes), brackish water (*e.g.* ponds), and marine systems (*e.g.* coastal areas).

The growth information of cultured fish is important for planning and management in aquaculture. Indicators such as specific growth rate (SGR) and condition factor (CF) provides basic information in evaluating the specific conditions for the growth of the organism.

In this study, common models were tested to determine the best-fit model for milkfish cultured in marine pen and the controlling factors of specific growth rate and condition factor were investigated.

Materials and Methods

The study was conducted during a series of experimental farming trials of milkfish in pens at the coastal water of Baranggay Pandaraonan, Nueva Valencia, Guimaras, in the Philippines from August 2015 to January 2018. There were two runs conducted during the dry season (*i.e.* Run 2 and Run 4) and two runs during the rainy season (*i.e.* Run 1 and Run 3).

Monthly, 10 % of the fish population was sampled for body weight (g) and body length (cm) measurements. Three common models were tested to describe growth performance of milkfish based on monthly data, namely: Linear, Logistic and Gompertz. The p-value of r^2 and AIC (Akaike's Information Criterion) were used to evaluate and compare the fitness of the models.

Results and Discussion

Among the three tested models, logistic model was found to be best for both weight-based and length-based growth. Reasonably, daily specific growth rate in weight ($DSGR_w$) and length ($DSGR_L$) were positively correlated with water temperature while both $DSGR_w$ and $DSGR_L$ were correlated negatively with size of the fish which supported the findings in the growth model fitting (**Table 1**).

Table 1. Fitting of growth models in Weight. Values highlighted in bold indicates smallest (best fit) among comparison of three models.

Model	Indicator	Run 2	Run 3		Run 4		Run 5	
		Pen 1 n=4	Pen 1 n=4	Pen 2 n=4	Pen 1 n=3	Pen 2 n=4	Pen 1 n=4	Pen 2 n=4
Linear	AIC	363.6	347.3	347.3	340.3	355.2	262.4	269.7
	r^2	0.987	0.994	0.995	0.992	0.990	0.999	0.996
	p value	0.05265	0.03736	0.03465	0.18297	0.04647	0.05798	0.11435
Logistic	AIC	131.0	163.5	144.0	120.0	147.9	125.2	179.5
	r^2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	p value	0.00090	0.00312	0.00158	0.00264	0.00200	0.00106	0.00746
Gompertz	AIC	184.0	209.7	193.6	123.0	227.7	170.4	132.2
	r^2	1.000	1.000	1.000	1.000	0.999	1.000	0.997
	p value	0.00508	0.01044	0.00644	0.02105	0.01685	0.00661	0.00162

Condition factor (CF) of milkfish exhibited positive correlation with feed conversion ratio (FCR) (**Figure 1**) and significant seasonal variation, lower during the relatively fast-growing season (dry season) and higher in slow-growing season (rainy season) (**Figure 2**). Integrating these controversial findings, low temperature and inefficient feeding makes 'fat' fish and vice versa. Water temperature seemed to be explained the changes of proximate body composition (*e.g.* protein and water content) and metabolic rate of the fish.

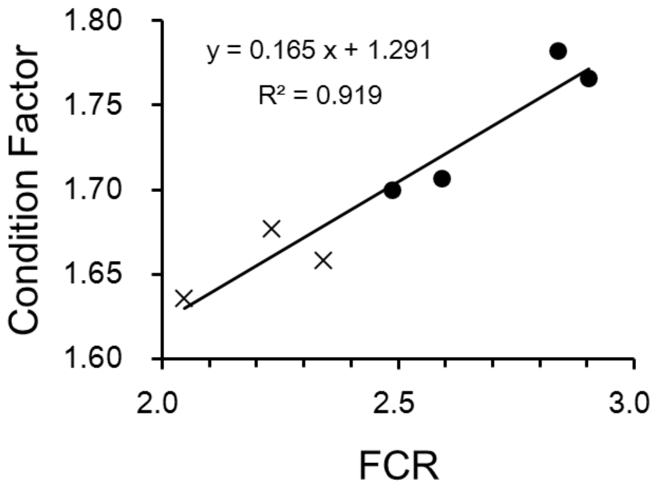

Figure 1. Relationship between Feed Conversion Ratio (FCR) and Condition Factor (CF) in dry season (×) and rainy season (●).

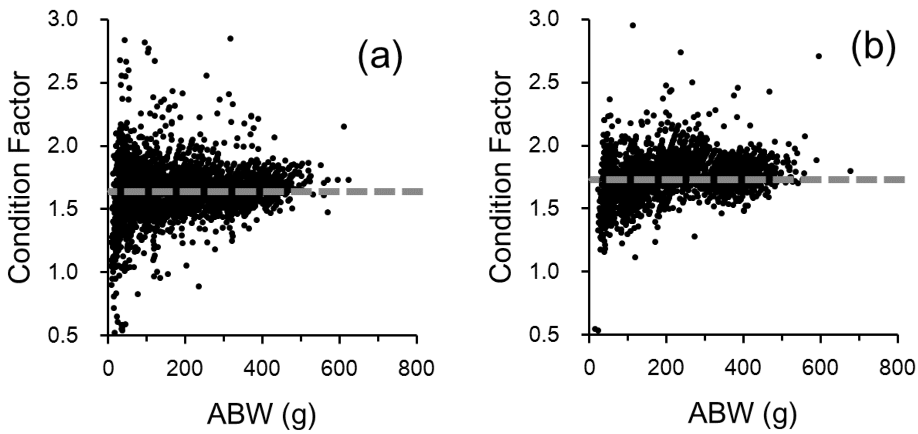

Figure 2. Condition factor of all sampled fish. (a) dry season and (b) rainy season. Gray dashed lines indicate mean values of dry season (= 1.64) and rainy season (= 1.73), respectively.

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Environmental Impact and Growth Performance of IMTA species in Marine Pen Culture System

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Introduction

Marine aquaculture as a potential solution to problems of overfishing and declining supply from capture fisheries is expanding worldwide. It offers various opportunities and benefits particularly to coastal communities, serves as a protein source, provides income and employment, and some areas entirely depend on it as a source of livelihood. However, its effect on the surrounding environment has been a growing concern in this industry particularly on the intensive use of commercial feeds. In the Philippines, the production of milkfish through aquaculture consistently tops the list among finfishes with an annual production of 411 metric tons in 2017 (PSA, 2017).

The grow-out of milkfish is dependent on the feeding of formulated feeds. Thus, uneaten feeds, aside from the fecal matter, were observed to cause deterioration of the environment in the culture enclosure and surrounding areas. In this context, the concept of Integrated Multi-Trophic Aquaculture (IMTA) emerged. It uses not only commercially-important commodities, but also environmentally sustainable species from different trophic levels. The wastes products, consisting of uneaten feed, fecal matter and metabolic excreta of one species become beneficial inputs for the growth of another species through natural self-cleansing mechanism (Chopin *et al*. 2001). This is an ecosystem approach in mariculture, particularly applied in temperate waters that has been proven to solve problems in sea pollution associated with fish culture (Troell 2009). However, although it is possible to adopt the IMTA system concept in tropical waters, it is suggested that site-specific practices be implemented because there might not be a universal system for IMTA (Lander *et al*. 2013).

In this study, locally available marine species were tested, milkfish (*Chanos chanos*) as the fed species, seaweed (*Kappaphycus alvarezii*) as inorganic-extractive species for the water column, and sandfish (*Holothuria scabra*) as organic-extractive species on the sediments. This study aims to verify and improve IMTA systems suitable for farm conditions in coastal areas in the Philippines, with emphasis on mitigating the environmental impacts of mariculture of milkfish.

Methodology

The IMTA study was conducted in the waters of Barangay Pandaraonan, Nueva Valencia Guimaras in the Philippines with a series of experimental runs from August 2015 to October 2018. The setup consist of pen enclosures for milkfish (150 and 162 m^2) and sandfish (25 m^2), while seaweed was cultured around these pens through the floating monoline method using polyethylene ropes.

The stocking density of the cultured species was dependent on their availability. Milkfish stocks were sourced from the local ponds in Guimaras. Seaweed seedlings during the initial runs were obtained from the laboratory of SEAFDEC/AQD. Some seedlings were also sourced out from seaweed farms in nearby Panobolon Island which is also in Guimaras province. Sandfish juveniles were provided by the sandfish hatchery in SEAFDEC/AQD. The growth and survival of the cultured species were monitored monthly. Meanwhile, monthly collection of water samples within the pens and at a control site (50 m and 200 m away from the pen) was done for nutrient analysis. Sediment samples were analyzed for acid volatile sulfides (AVS) and organic matter (OM) content through Loss on Ignition (LOI) menthod.

Results and Discussion

IMTA Species Culture

Milkfish was cultured in pens with an initial average body weight of 20 to 50 g. They reached the commercial size at an average weight of 300 to 400 g after 112 days from stocking in pens (**Table 1**). These results were obtained for all runs conducted from 2016 to 2018. The results were comparable to those that are grown in monoculture. The highest survival achieved was around 99 % but only for Runs 2 to 4 (April 2016 to August 2017) in only one pen. Runs 5 and 6 (October 2017 to October 2018) showed an average survival for both pens at <70 % due to high mortality and some unaccounted fish that was probably associated with social factors.

Table 1. Growth performance of IMTA species from 2015 to 2018.

Specification	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
Culture Period	Aug–Dec 2015	Apr–July 2016	Sept–Dec 2016	May–Aug 2017	Oct–Feb 2018	May–Oct 2018
Days of Culture	124	95	108	54,96	121,121	103,160
No. of Pens						
Milkfish	3	1	2	2	2	2
Sandfish	3	1	2	2	2	4
Area (m^2)	25	144	150,162	150,162	150,162	150,162
Milkfish						
ABW (g)	261	384	378,403	329,342	228,277	313,329
Survival (%)	55	99	80,99	88,98	68,87	76,45
Sandfish						
ABW (g)	115	82	45	35	191,127	81,86,102,99
Survival (%)	6	5	1	5	14,38	62,53,55,59
Seaweed						
Biomass (kg)	76	244	1	2	0	0

Seaweed (*Kappaphycus alvarezii*) was cultured in surrounding areas adjacent to the milkfish pen thru the long line method using PE rope with floaters. Seaweeds were only successfully grown during Run 2 (April 2016 to July 2016). The seaweeds proliferated at the start of the milkfish culture period, from initial biomass of 10 kg to 244 kg in 100 days. This impressive growth might be due to factors such as the season (dry season) and the overnight soaking of the seaweed plantlets in a fertilizer bath prior to stocking in floating longlines. However, seaweeds stocks had very low survival, primarily because of grazing by herbivorous fish, such as rabbitfish which were abundant in the area. The small-scale nature of our experimental setup has made our seaweed stocks very vulnerable to predatorion. In addition, the remaining seaweeds became infected with what is known as the *ice-ice* disease. After this run, the culture of seaweed in the IMTA site was not sustained due to factors such as predation, and unavailability of sufficient quantity of seedlings from laboratory. In later runs, the seaweed seedlings were sourced from the nearby Panobolon Island where seaweed farming is practiced. However, growth performance of such seaweed was poor, compared with that of Run 2. Perhaps, the incompatibility of the seedlings sourced from another site was a factor for the poor growth, in additiona to predation and diseases.

Sandfish (*Holothuria scabra*) cultured inside the milkfish pen during Runs 2 to 4 (April to July 2016) grew but at very low survival rates. This suggests that they may not withstand direct nutrient load from milkfish culture. With this observation, a separate pen enclosure was installed adjacent to the milkfish pen for sandfish culture from Run 5 (November 2017). This modification in the culture design allowed better growth and survival for sandfish. In Run 5, initial stocks with an average weight of 7 g reached 191 g after 15 months with an average survival rate of 26 %. In Run 6, initial stocks with an average weight of 16 g reached 90 g after 9 months with an average survival rate of 57 %. These results indicate that the size of sandfish at stocking may be an important factor for survival, as well as the nutrient load.

Environmental Impact

Environmental indicators such as dissolved inorganic nitrogen (DIN), comprised of nitrate, nitrite and ammonia, were analyzed monthly. These forms of nitrogen are readily available to phytoplankton and often are controlling the formation of blooms. These are the most bio-available and abundant forms of nitrogen that contribute to coastal eutrophication and should be monitored. The concentration at the control (50 m far from the pen) site ranged from 0.03 to 0.04 mg/L. The 2nd Control site (200 m far from the pen) measured at 0.01mg/L. DIN concentrations inside the milkfish pens ranged from 0.03 to 0.06 mg/L (**Figure 1**). These monthly monitoring results show that the IMTA practice did not create a significant impact in the water environment, based on nitrogen loading.

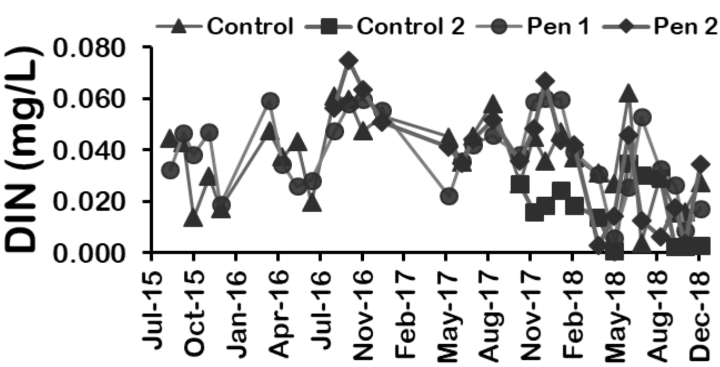

Figure 1. Monthly monitoring results of dissolved inorganic nitrogen (DIN) concentrations in IMTA site from Run 1 to 6 (2015 to 2018)

On the other hand, sediment quality was found to deteriorate as the intensity of culture increases. This was supported by the increase in acid volatile sulfide (AVS) levels (**Figure 2**). Organic matter content (**Figure 3**) had the same increasing trend with increasing farming intensity. From the results of these analyses, it is suggested that after two continuous culture periods of milkfish, a fallow period is recommended, wherein the pen will be left empty for 3–5 months to allow for the natural recovery of the sediments.

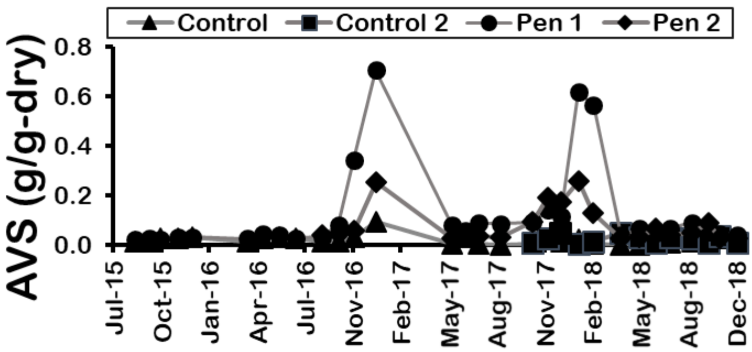

Figure 2. Monthly monitoring result of acid volatile sulfide (AVS) in IMTA site from Run 1 to 6 (2015 to 2018)

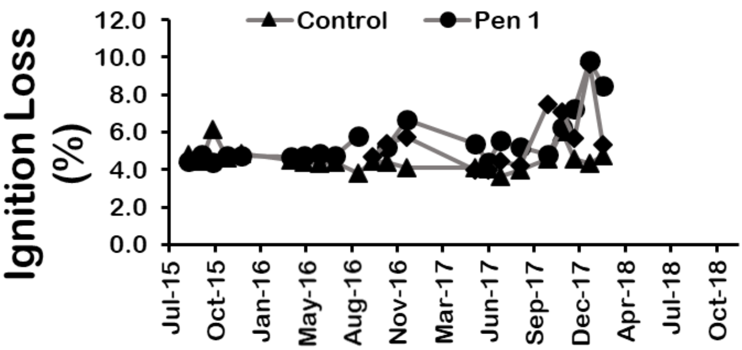

Figure 3. Monthly monitoring results of OM thourgh loss on ignition (LOI) in the IMTA site from Run 1 to 5 (2015 to 2018)

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Economic Evaluation and Social Implementation of IMTA for Small-scale Aquaculture

Economic performance and roles of local communities in the adoption of multi-species aquaculture

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Introduction

In a review of about 100 previous studies on multi-species aquaculture, it has been revealed that aquaculture increases profits, however, those profits were only realized in a few cases and places (Barrington *et al*. 2009). The success or failure of the practical use and adoption of a multi-species aquaculture technology depend on an economic rationality and utility (such as a value that cannot be converted into money) of stakeholders. In other words, it is important that the synergistic effect of implementing a multi-species aquaculture is clearly elicited in aquaculture management areas at a local or regional scale.

Many fields of research and aquaculture businesses were implemented but eventualy failed because they might have insufficient planning, discussions and understanding about the new multi-species aquaculture system. In order to increase the chances of success, a multi-species aquaculture venture will require to be fully analyzed, evaluated, and improved through a socioeconomic perspective. Only after such comprehensive planning can stakeholders of aquaculture research or business expect to potentially enjoy the benefits. Sometimes, if it is evaluated that there can be no synergistic benefits in a multi-species aquaculture, then the stakeholders can prevent a potentially wasteful spending of resources and investments.

External diseconomy (external expenses) and external economy

In general, excrement and residue of feed discharged from fish farms lead to environmental pollution (Naylor *et al*. 1998), and potentially damage other fisheries and aquaculture industries (**Figure 1**). Also, the eutrophication effect can enhance “green tide” like the over-growth of seaweeds such as *Ulva,* that can cover over a wide area of the shore or beach that can eventually decay and stink, causing discomfort to nearby residents. This becomes a form of “disutility.” If there is this adverse effect of aquaculture, then farmers have a social responsibility to reduce the discharged wates from their aquaculture activity. In addition, if the local government in this area defrays the cost to solve this problem, or if the citizens or a non-profit organization (NPO) pays money for it, then the cost becomes an “external expense”.

In order to improve the aquaculture environment, some farmers need to pay for reducing the environmental burden caused by the pollution, in terms of its own conscience and CSR (Corporate Social Responsibility) (**Figure 1**). For example, there are measures to build a feeding system that does not waste feed by automatically regulating the amount of feed based on the exact weight of the cultured fish in the fish cage (Aslesen, 2009).

Alternatively, there is a way to reduce environmental burden by imposing a kind of environmental tax (Naylor *et al*. 1998). In order to reduce environmental effects, some aquaculture farmers may implement measures to reduce the discharged wates and residue, while the local government carries out measures to improve the environment using the collected tax (**Figure 1**).

The added expense for the farmer may be offset by some other ways. One such option is the use of use “eco-labels” whereby premium selling prices can given to products that are produced sustainably and more environment-friendly. The challenge is to gain consumers’ understanding of the environmental conservation action by aquaculture farmers and to realize the added value of the farmed products (**Figure 1**). The aquaculture eco-labels in Japan include the international aquaculture eco-label ASC (Aquaculture Stewardship Council), AEL (Aquaculture Eco-Label) and SCSA (Seedlings Council for Sustainable Aquaculture). However, the Japanese consumers’ awareness of eco-labels are still low at the present (Asano, 2018), but should be encouraged some more.

Organic and inorganic wastes from aquaculture commonly perceived as an environmental problem. However, these substances are also beneficial nutrients to promote biomass growth of algae and phytoplankton.The productivity of non-feeding aquaculture and resources of small fish also increase due to the abundant biomass of phytoplankton around the farm. In this sense, aquaculture creates an “external economy”. In addition, if a farmer starts a non-feeding aquaculture venture with a seaweeds or bivalves, he will benefit from the nutrients emitted from the adjacent fed aquaculture farms. This reduces the burden to the environment and increases profit for the non-feeding aquaculture.

In a way, this is the main purpose and concept of IMTA (Integrated Multi-Trophic Aquaculture), whereby multiple species are used for optimal benefit.

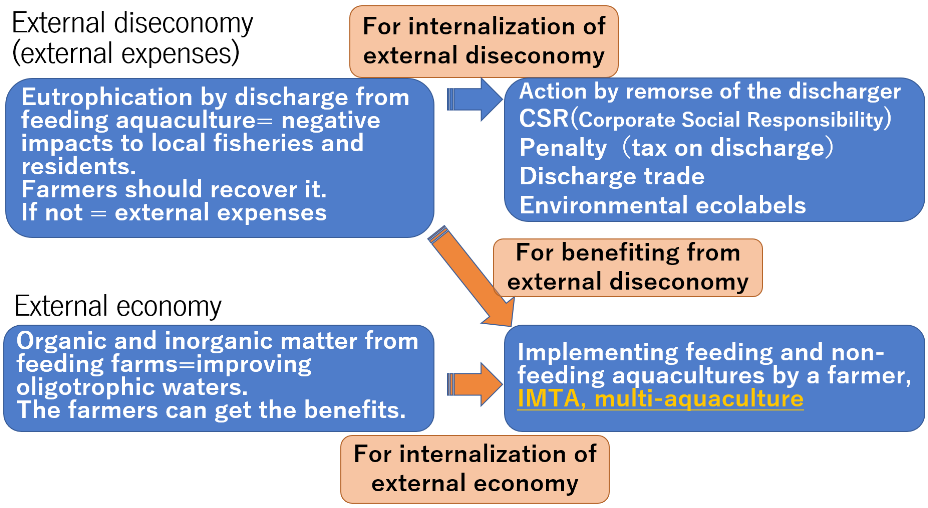

Figure 1. External diseconomy and economy in a feeding aquaculture scenario

Business analysis complexity for multi-species aquaculture

Business analysis of aquaculture of a single species may be relatively easy. It can be calculated from the total income and expenditures of the aquaculture management body. However, in the case of multi-species aquaculture, the business analysis is required for each species, which can becomes considerably difficult and tricky to calculate because it is necessary to "properly" determine cost rates of each cost item relevant to each aquaculture species.

Some indirect labor costs, salesperson salary, clerk salary, welfare expenses, and indirect material expense tend to be overlooked when a planner or researcher estimates the expenses in a multi-species aquaculture. In order to adopt the new multi-species technology, it is essential to estimate appropriate expenses such that an overestimate expense is allowed, but an underestimate expense is not allowed.

Another risk for farmers is that prices of farmed fish, bivalve and algae can fluctuate. Prices are influenced by quantities and prices of domestic products and importation of each species, national income, quantities and prices of substitute species, as well as the prices of common goods like chicken and pork (Ariji, 2013). To reduce this risk, multi-species aquaculture can be an advantage from the point of view of “risk hedging”, because one species may be vulnerable low price, but chances are that the other cultiured species are not. Of course, the risk of mortality and other losses can also be alleviated in a multi-species aquaculture.

Furthermore, farmers tend to experiment through trial and error while adopting and improving a new aquaculture technology. This oftentimes lead to very low initial productivity and many wasteful costs. This is a risk in the multi-species aquaculture venture where many aspects are uncertain. If the initial low profitability is prolonged, the loss due to the initial costs will be difficult to defray, and the period to cover all losses will be extended. Eventually, the management body of the multi-species aquaculture is become exhausted, and the farmer will conclude it to be an unacceptable aquaculture technology. Such a negative notion can then spread throughout the region. Therefore, researchers should work up a new technology to a high degree of confidence even at the research stage. In order to achieve this, the researcher should collaborate with aquaculture farmers and conduct more practical research activities.

Multi-species aquaculture as a whole

As mentioned above, feeding aquaculture has a negative impact on the surrounding environment of the farms, which is difficult to contain in open aquaculture facilities. It also affects the surrounding aquaculture grounds and sometimes, the local community.

In the actual aquaculture areas, there are multiple types of aquaculture operations interacting and affecting each other. This seems comparable to large-scale multi-species aquaculture (Watanabe, 2016). Multi-species aquaculture and IMTA are often discussed in terms of profitability and rationality of an individual aquaculture operation. It is quite un-realistic to ignore the benefits and rationalities of other operations within the whole aquaculture area, as in the case of mariculture. In other words, it is necessary to implement modifications that optimize a combination of different types of aquaculture, with the proper placement of aquaculture facilities, and maximize total benefit of all farmers and stakefolders in the aquaculture area and local communities.

A new type of IMTA

In many developing countires like the Philippines, most fishing families were considered to be in the poverty group as defined by the government. Moreover, the resource level of the main target species for fisheries is usually low because of overfishing. In order to improve the deteriorating resources, it is necessary to implement some fisheries management strategy in these areas, and enforce fishing regulations to control catch efforts. However, our survey results showed that the implementation of the regulation with catch restriction leads to a strong backlash from fishers in poverty, so it is very difficult to implement such a policy (Miyata *et al*. 2017). Therefore, some alternative income sources to make up for the decrease in catches due to regulations is required. This is where I recommend the Integrated Multi Trophic Aquaculture for Marine Protected Area or IMTAMPA to these villages (**Figure 2**). The concept is to set up oyster farming facilities using bamboo poles in and/or around a nursery area of fish and shellfish. The potential profit from oyster harvests may compensate for the loss of catch from the fishing grounds (nursery area). Furthermore, fishers can still catch fish and shellfish spilling over from the facilities when the fishery resource have recovered.

In addition, some support from the government or NGOs may supplement the resources through stock enhancement of other species like shrimps and sea cucumbers. Local universities and resaerch institutions can also support the implementation by sharing facilities and research resources. Through a collaborative partnership of the local government, NGO and/or NPO, and universities, IMTAMPA can be a good prospect towards providng incentives to local fishers in sustainably managing their resources while benefiting from multiple harvests from various species from the same area.

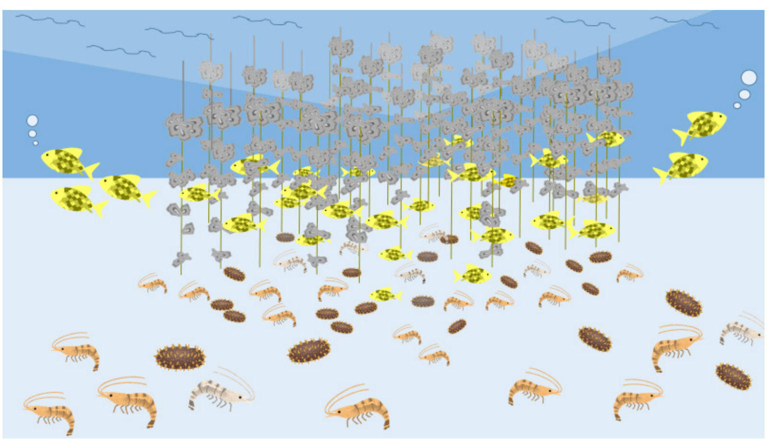

Figure 2. IMTAMPA Integrated Multi Trophic Aquaculture for Marine Protected Area), (Miyata *et al*. 2017)

Conclusion

Currently, the income level of many aquaculture farmers is low because of high costs of feeds and materials, so they try to avoid taking risks associated with multi-species aquaculture. However, the benefits clearly contributed to the success of a few cases of aquaculture management bodies (Barrington *et al.*, 2009).

In order to adopt this new technology widely, it needs good research results of not only the biological aspect but should also include profit analysis in order to convince farmers of "the benefits that clearly contribute to their management efforts". In addition, it will be necessary to seek support of local governments in providing subsidies to extend the technology. In other words, the officers need to also understand the usefulness of the multi-species aquaculture technology.

It will be difficult for a farmer to have a complete understanding of the whole mariculture system, especially from an economic point of view where there are external diseconomy and external economy, as discussed above. Hence, it is significant to have a bird's eye view of the all the interacting aquaculture systems in an aquaculture area or community. The concept of IMTAMPA was also born from such viewpoint.

Among the remaining IMTA research issues are the practical research for sustainable community-based fishing and aquaculture such as IMTAMPA. However, it is clear that more research is needed to clarify various aspects of the system like the flow of organic and inorganic substances discharged from feeding aquaculture ground to non-feeding aquaculture ground. These researches also need to be conducted through interdisciplinary approaches that involves both natural and social sciences.

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Small-scale IMTA of Milkfish in Pens: The Pandaraonan, Guimaras, Philippines Experience

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Introduction

Milkfish, *Chanos chanos* is one of the most economically-important farmed fish species in the Philippines and in Southeast Asia. Milkfish, being a eurythermal and euryhaline species, may be cultivated in various environments such as freshwater, brackishwater, and marine (Yap *et al*. 2007). Milkfish culture, next to seaweed, comprised 19 % of the total aquaculture production in the Philippines with an annual production of 411 metric tons in 2017 (PSA, 2017) and still continues to grow. The increasing interest in milkfish mariculture farming paved the way to intensive culture systems motivated by high profits and strong competition. Intensification in fish farming tend to contribute to a crucial environmental threat. The introduction of integrated multitrophic aquaculture (IMTA) is said to mitigate further degradation of the coastal environment and may potentially increase income from cultivating various species.

This study examines IMTA as an option for small-scale fish farmers to grow multiple species in the same area in the coastal waters of Barangay Pandaraonan in Nueva Valencia, Guimaras, Philippines. The study aimed to explore the feasibility of an economically profitable IMTA system where milkfish is grown with sandfish and seaweeds.

Methods

The study collaborated with the fisherfolks and women of the Pandaraonan Unified Association (PUA) and the local government of Barangay Pandaraonan, a coastal village in the municipality of Nueva Valencia in Guimaras province, Philippines. We implemented a milkfish grow-out culture in pens using the milkfish culture techniques developed at SEAFDEC/AQD and discussed in another paper by Diamante *et al.*, in this Proceedings. It also integrated the indigenous knowledge of fisherfolks on small-scale fish farming. The socio-economic component of the study aimed to improve the potential economic benefits from fish farming as a supplemental income source for artisanal fishers. It also aimed to enhance skills on value-adding of milkfish harvest (*e.g.,* milkfish in oil and sun-dried milkfish) through participatory training activities. Value-adding through processing was applied, especially when economic losses in the grow-out phase where incurred due to mortalities, inclement weather and social factors.

Results and Discussion

The IMTA demonstration implemented six production cycles from July 2015 to October 2018. Run 1 (July to Dec 2015) was not included because its pen design, set-up and activities were on an exploratory phase. Run 2 was conducted during the summer season (March to July) while the production cycles 3, 5, and 6 were done in the wet season (August to February). Run 4 was during a transition from dry to wet season (May to August). The six production runs produced an average marketable size of milkfish at ≥300g at harvest. Run 2 had the best production performance, in terms of total biomass at harvest and growth compared to the other production runs (**Table 1**).

Seaweeds growth and yield also performed better in the initial run (Run 2), but deteriorated in the succeeding production runs. This may be attributed to the sudden increase of sea surface temperature that caused the seaweeds thalli to be easily infested with epiphytes, "*ice-ice disease*" and predation of herbivore fish (*i.e.,* rabbitfish). Sandfish growth and survival showed improved outcome in subsequent production runs (Runs 4, 5, and 6) but either lower or zero recapture rates were recorded during the initial runs as may be caused by predation (*i.e.* crabs, goby, etc.).

As shown in **Table 1**, the milkfish yield can drastically decline, as in Run 6. So, some inteventions on value-adding may address the problem of low income due to poor harvests. The women members of the Pandaraonan Unified Association (PUA) were introduced to post-harvest processes such as value-adding of milkfish into sun-dried form (locally known as *lamayo)*, deboned milkfish and cooking in oil. Notably, the women preferred "*lamayo"* because of the lower cost of input requirements compared with cooking in oil.

Table 1. Comparison of IMTA in milkfish pen culture operations (Run 2 to 6; Run 1 excluded) in Barangay Pandaraonan, Nueva Valencia, Guimaras, Philippines

	Run 2	Run 3	Run 4	Run 5	Run 6
	2016		2017		2018
Culture period	Apr – Jul	Sept – Dec	May – Aug	Oct– Feb	May – Oct
Days of culture	95	109	Pen 1: 54 Pen 2: 55	P1: 120 P2: 121	P1: 103 P2: 160
Number of pens	1	2	2	2	3
Area per pen, m^2	144	Pen 1: 150	P1: 150	P1: 150	P1: 150
		Pen 2: 162	P2: 162	P2: 162	P2: 162
Stocks					
Milkfish, pcs	3,354	Pen 1: 3,138	P1: 3, 832	P1: 4,353	P1: 3, 568
		Pen 2: 3,712	P2: 5, 498	P2: 4,760	P2: 4,500
(Stocking density, pcs/m^2)	23	Pen 1: 25 Pen2: 27	P1: 25 P2: 27	P1: 25 P2: 27	P1: 25 P2: 27
• seaweeds, kg	20	30	4	4	4
• sandfish, pcs	92	Pen 1: 100 P2:100	150	150	400
(stocking density, pcs)		(Control: 100)		Re-stocking after typhoon: 163 pieces	100 pieces per pen
Harvest					
Milkfish, pcs	3,321	Pen 1: 2,532	P1: 3,372	P1: 2,025	P1: 2,720
		Pen 2: 1,270	P2: 5,405	P2: 3,395	P2: 586
Milkfish, pcs (*incl. unaccounted*)		***Pen 2: 3,138***	***P1: 3,823***	***P1: 2,726*** ***P2: 3,425***	***P1: 3,361*** ***P2: 3,144***
Milkfish, kg	1,176	Pen 1: 822	P1: 928	P1: 596	P1: 692
		Pen 2:1, 241	P2: 1,511	P2: 841	P2: 155
Milkfish, kg (*incl. unaccounted*)		***Pen 1: 1,051***	***P1: 1,659***	***P1: 749*** ***P2: 887***	***P1: 951*** ***P2: 999***
seaweeds, kg	250	0.97	1.8	0	0
sandfish, pcs	0	0	8	150	160
Feed consumed, kg	2, 329	5,625	5, 975	5, 895	3, 700

Table 2 compares the cost and returns profile of IMTA of milkfish with sandfish and seaweeds from Runs 2 to 6. Run 1 was also excluded being an exploratory or training phase. The profitability indicators such as net income, gross sales, total costs, and feed conversion ratio (FCR) overall showed economic losses. Run 2 gained a minimal net income while the subsequent production runs showed an increasing negative profit. Unaccounted milkfish and high mortalities were reported to be the major causes of huge income loss.

In the daily logbook of the collaborators, fish mortalities in the earlier runs (Runs 2 to 5) usually occur only within a week during the acclimatization at stocking of fingerlings, possibly due to stress induced during transport of fingerlings. However, in Run 6, a total of 207 pieces of milkfish was unaccounted after harvest which could be attributed either to natural mortality, escapees, negligent guarding of the pens, and poaching during the culture period. Diseases were discounted as cause of loss, because fish samples were submitted to SEAFDEC/AQD Fish Health Diagnostic Laboratory and showed non-occurrence of fish diseases as associated with any bacterial and parasitic infections. These poor results were discussed with the local government officials, the PUA officers and the fisherfolk collaborators, especially in order to address any social problems such as poaching that could have caused these unaccounted milkfish stocks.

The large number of unaccounted milkfish revealed after harvest further contributed to huge losses in Run 6 amounting to Php143,257. FCR was 2.8 in Pen 1, but it was disappointingly highest at 21.9 in Pen 2 where most of the unaccounted milkfish were recorded. The FCR was high because the unaccounted milkfish was still included in the computation of feeds to be administered for both pens. Factors such as quality of fingerlings, weather conditions, and social responsibilities also contribute to the huge decline of stocks, total biomass yield, and net income. Nonetheless, to alleviate losses, the women members of PUA showed sustained interest and participation by undertaking value-adding options. The benefits from value-adding were mainly in terms of non-cash benefits for the community members. The women honed their skills in food preservation and value-adding, especially of the undersized milkfish. Meanwhile, the school children had samples of the cooked milkfish to influence their food intake and nutritional improvement.

Table 2. Cost and returns analysis of IMTA in milkfish pen culture operations (Run 2 to 6, from 2016 to 2018; Run 1 excluded) in Barangay Pandaraonan, Nueva Valencia, Guimaras, Philippines.

	Run 2	Run 3	Run 4	Run 5	Run 6
Cost profile (Php)					
Milkfish fingerlings	16, 300	47, 813	46, 944	48, 875	46, 750
Sandfish Juveniles	552	1,800	900	900	2,400
Seaweed	300	750	80	80	300
Feed cost	82, 450	172, 025	184, 915	192, 005	114, 375
Labor	9,500	20, 000	24, 000	24, 000	51, 000
Pen depreciation	4, 202	7, 455	7, 455	7, 455	10, 004
Other costs	5, 407	2, 625	2, 625	2, 625	2, 625
Total cost	**121,040**	**258,093**	**266,919**	**275,940**	**227,454**
Gross sales (Php)					
Milkfish	123, 480	197, 970	231, 900	129, 450	83, 115
Seaweeds	2, 342	24	0	0	0
Sandfish	0	0	0	145	1, 082
Total Sales	**125,822**	**197,995**	**231,900**	**129,595**	**84,197**
Economic Indicators					
Net Income	*4,782*	*-60,098*	*-35,019*	*-146,345*	*-143,257*
FCR (kg feed/kg harvest)	2.23	Pen 1: 3.90	P1: 2.40	P1: 4.57	P1: 2.80
		Pen 2: 2.90	P2: 2.36	P2: 4.40	P2: 21.90
Total feed cost (Php) /harvest kg *(including unaccounted pieces)*	70.11	Pen 1:163.68	P1: 111.46	P1: 256.35	P1: 120.27
		Pen 2: 138.61	P2: 122. 38	P2: 236.41	P2: 114. 49

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Yap, W.G., A.C. Villaluz, M.G.G. Soriano and M.N. Santos. 2007. Milkfish production and processing technologies in the Philippines. Milkfish Project Publication Series No. 2, 96 pp.

Evaluation of Livelihood Assets in Community-Based On-Farm Demonstration of IMTA in Milkfish Mariculture in Guimaras, Philippines

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[3] Japan International Research Center for Agricultural Sciences (JIRCAS)

Introduction

The aquaculture of milkfish, *Chanos chanos* Forsskal, continues to contribute towards sustaining the fish food needs of the country in the midst of emerging food security issues, increasing food prices and environmental problems in the Philippines. Hence, one of the key targets of the country's Comprehensive National Fishery Industry Development Plan (CNFIDP) is to increase the annual production of milkfish by 4 % per year and to improve its processing and value-adding options (BFAR-NMC, 2019). Milkfish, being a euryhaline species, has been successfully cultured throughout the country in brackishwater, freshwater and marine water environment using a variety of culture systems or enclosures such as ponds, pens, cages, tanks and raceways. However, farming of milkfish in these environment types is often confronted by economic and environmental challenges. The adoption of IMTA by many small-holder mariculture operators is envisioned to help mitigate pollution of coastal areas while providing livelihoods that make milkfish available to consumers, and address the "price squeeze" confronting milkfish farmers (due to increasing feed cost vs. stagnant market prices) by deriving additional income from co-culture of high-value non-fed species.

However, prior to adoption of a selection of livelihood strategies, people, either as individuals or grouped as a household or working as a community, contend that they had to be equipped with an array of assets categorically distinguished as natural or environmental, human, physical, financial and social assets (IFAD, undated). In the dynamic utilization and transformation of these assets into goods and services, the sustainable livelihoods approach (SLA) places people at the center of a web of these inter-related influences that affect how they create or adopt a livelihood for themselves and their households. The SLA is applied as a tool for determining the main factors that influence the adoption of new development activities, such as the introduction of IMTA. The SLA enables the integration of concepts in the discussions about poverty, food and livelihood security, and enhancing sustainable culture practices that comprise the complex concerns of traditional producers (Lewins, 2004; Garrido and Moreira, 2017).

Methods

SEAFDEC/AQD, in collaboration with JIRCAS, initiated an on-farm demonstration of IMTA in milkfish mariculture in pen in July 2015 by signing an agreement with aquaculture stakeholders in Barangay Pandaraonan in the municipality of Nueva Valencia, Guimaras province, Philippines. Stakeholders in this small-holder aquaculture livelihood demonstration comprise of the local government units (LGU) at the municipal and barangay (village) levels, and the Pandaraonan Unified Association (PUA). Thus, a tri-party collaboration model is applied to implement the community-based on-farm demonstration of IMTA. Selected fisherfolk-members of PUA perform the day-to-day operation in the IMTA setup in the nearshore waters in the village. The LGU, having the governance jurisdiction over its constituents and the project location, guarantee and oversees the participation of PUA. SEAFDEC/AQD and JIRCAS provide the technical direction, and financial and structural requirements of the on-farm IMTA demonstration while addressing the IMTA research questions. Six (6) culture runs were implemented from July 2015 up to December 2018. In all of these runs, 4–6 male fisherfolks were engaged and trained in day-to-day activities in milkfish mariculture starting from site assessment; pen construction; stocking of milkfish and co-culture species such as seaweeds and sandfish that absorb excess nutrients in IMTA system; feeding the milkfish with commercial diet at recommended rates; monthly sampling to evaluate growth and changes in environmental parameters; harvesting; and selling to provide fisherfolks with entrepreneurial experience. Women were trained on value-adding of milkfish harvest, such as deboning, marinating, cooking in oil, and sun-drying (locally called *lamayo*). Stakeholder meetings were held as needed, including a workshop in aquaculture project planning and financial management.

The Sustainable Livelihoods Approach (SLA) was applied as an impact assessment framework in promoting and evaluating the adoption potentials of IMTA in milkfish mariculture. Using a structured questionnaire, 52 stakeholder-respondents rated the changes in livelihood assets in the community-based IMTA project.

Results and Discussions

The SLA as applied in the evaluation of the IMTA project in Guimaras showed that there were some increments, but variable, in the acquisition and development of five livelihood assets during the three evaluation periods considered in this study (**Figure 1**). Human, financial, environmental and social livelihood assets were perceived to have improved significantly in some stages, but physical assets did not (**Table 1**). Results of SLA as an impact assessment framework in promoting and evaluating the adoption potentials of IMTA in milkfish mariculture showed an array of long-standing concerns, especially on the limited physical and financial assistance. Research, industry, governance and policy recommendations all require collective public attention and action to secure benefits from IMTA in milkfish mariculture.

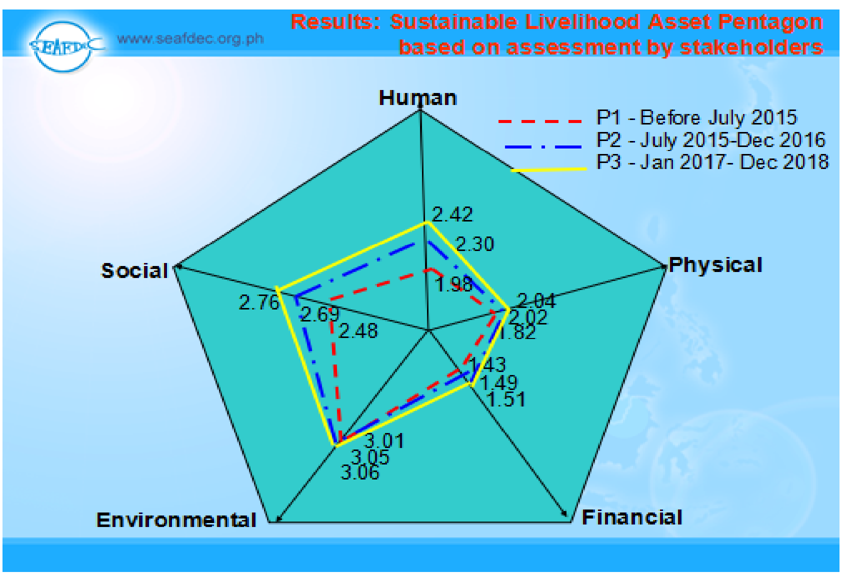

Figure 1. The sustainable livelihood asset pentagon before, during and at the end of the on-farm demonstration of IMTA in milkfish pen culture in Barangay Pandaraonan, Nueva Valencia, Guimaras, Philippines, 52 stakeholder-respondents, February 2019.

Table 1. Changes in sustainable livelihood assets in the on-farm demonstration of IMTA in milkfish pen culture, Brgy Pandaraonan, Nueva Valencia, Guimaras, Philippines, 52 stakeholder-respondents, February 2019.

Perceived change in livelihood asset level	F-value					
	P1 to P2		P2 to P3		P1 to P3	
Human	0.562		0.981	**	0.546	
Environmental	0.906	***	0.884		0.978	**
Physical	0.789		0.898		0.889	
Financial	0.972	**	0.957	**	0.975	**
Social	0.850		0.957	**	0.808	

*Significant at 1 %, ** Significant at 5 %, ***Significant at 10 %

Conclusion and Recommendation

This study showed the need to develop the livelihood assets of rural communities to enable them to engage in aquaculture-based income generating activities. The SLA evaluation showed that the benefits in terms of its contribution to livelihood asset build-up is generally positive. While human, social and environmental capacities were improved, the financial and physical assets were dissipated and insufficient for many stakeholders with keen interest to participate in the communal project. Therefore, the recommendation is to organize more and bigger collaborative projects, such as this IMTA of milkfish, with emphasis on sustainable livelihood asset development to create significant economic impact to target beneficiaries.

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BFAR-NMC. 2019. Consolidated Report of BFAR Offices and National Mariculture Centers. Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines.

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Annex

Program

Day 1 - Tuesday, 6 August 2019, SEAFDEC/AQD, Tigbauan Main Station

8:30 - 9:30 Registration

9:30 – 9:35 Opening Remarks Dr. Osamu Abe, PL JIRCAS

9:35 - 9:40 Welcome remarks SEAFDEC/AQD

Session 1 The Ecology of Prospective Species for IMTA

(chaired by Satoshi Watanabe, Ph.D.)

9:40 - 10:10 Keynote Speech 1: Masashi Kodama, PhD, Research Coordinator, FRA
"Overview and History of IMTA Study, from ancient to modern"

10:15 - 10:45 Presentation 1: Jon Altamirano, Ph.D., SEAFDEC/AQD
"Ecology of Sandfish, prospects and challenges for IMTA"

10:50 - 11:15 Presentation 2: Maria Rovilla J. Luhan, SEAFDEC/AQD
"Biological Features of Seaweeds as IMTA Species"

11:20 - 11:45 Presentation 3: Ma. Junemie Hazel Lebata-Ramos, Ph.D., SEAFDEC/AQD
"Integrating Bivalves in IMTA system"

11:50 - 12:15 Presentation 4: Albert Gaitan
"Cage and pen culture of milkfish *Chanos chanos*"

12:20 - 1:20 Lunch Break

Session 2 Evaluation of Environmental Impacts and Current Challenges on IMTA

(chaired by Masashi Kodama, Ph.D.)

13:30 - 14:00 Keynote Speech 2: Satoshi Watanabe, Ph.D., Chief Scientist, NRIA, FRA
"IMTA as a possible countermeasure for reduced aquaculture productivity in Japan"

14:05 – 14:30 Presentation 5: Masashi Kodama, Ph.D., Research Coordinator, FRA
"Growth Performance and Condition Factor of Milkfish Cultured in Marine Pen in relation to Body Size and Temperature"

14:35 – 15:00 Presentation 6: Rose Ann Diamante, SEAFDEC/AQD

"Environmental Impact and Growth Performance of IMTA species in Marine Pen Culture System"

15:00 – 15:15 Coffee Break

15:15 – 16:30 General Discussion

Moderator: Dr. Nerissa Salayo

Rapporteur: Ms. Raisa Joy Castel

16:30 – 16:50 Group Picture

16:50 – 17:40 Tour of Facilities at TMS

18:00 – 21:00 Banquet in Iloilo City

Day 2 - Wednesday, 7 August 2019, SEAFDEC/AQD, Tigbauan Main Station

7:00 – 8:00 Departure from Hotel in Iloilo City to SEAFDEC/AQD, Tigbauan

8:10 – 9:00 Arrival at SEAFDEC/AQD Tigbauan and Registration

9:00 – 9:15 Opening Remarks: Osamu Abe, Ph.D., Project Leader JIRCAS

Session 3 Economic Evaluation and Social Implementation of IMTA for Small-scale Aquaculture

(chaired by Masashi Kodama, Ph.D.)

9:15 - 9:55 Keynote Speech 2: Tsutom Miyata, Ph.D., Chief Scientist, NRIFS, FRA

"Economic performance and role in local community using multi-species aquaculture"

10:00 - 10:25 Presentation 7: Raisa Joy G. Castel, SEAFDEC/AQD

"Small-scale IMTA of Milkfish in Pens: The Pandaraonan, Guimaras, Philippines Experience"

10:30 – 10:55 Presentation 8: Nerissa D. Salayo, Ph.D., SEAFDEC/AQD

' 'Evaluation of Livelihood Assets in Community-Based On-farm Demonstration of IMTA in Milkfish Mariculture in Guimaras, Philippines''

11:00 - 12:00 General Discussion

Moderator: Dr. Jon Altamirano

Rapporteur: Rose Ann Diamante

12:00 - 13:30 Lunch Break

Session 4 Future Prospects of IMTA and Creation of IMTA Guidelines

(chaired by Ryogen Nambu, Ph.D.)

13:30 - 15:15 Break-out Session (Discussion): Bio-Environmental Group

(Leader: Dr. Jon Altamirano)

Socio-Economic Group

(Leader: Dr. Nerissa Salayo)

15:15 – 15:45 Coffee Break

15:45 – 16:00 Presentation by Bio-Environmental Group

16:00 – 16:15 Presentation by Socio-Economics Group

16:15 – 16:30 Synthesis by Dr. Satoshi Watanabe and Dr. Masashi Kodama

16:30 - 16:35 Closing remarks: Dr. Osamu Abe, PL, JIRCAS

End of Workshop

List of Participants

Name	Position and Affiliation
Dr. Satoshi Watanabe	Chief Scientist, National Research Institute of Aquaculture Japan Fisheries Research and Education Agency
Dr. Tsutom Miyata	Chief Scientist, National Research Institute of Fisheries Science Japan Fisheries Research and Education Agency
Dr. Masashi Kodama	Research Coordinator, Planning and Coordination Department Japan Fisheries Research and Education Agency
Dr. Osamu Abe	Director, Fisheries Division Japan International Research Center for Agricultural Sciences
Dr. Ryogen Nambu	Senior Researcher, Fisheries Division Japan International Research Center for Agricultural Sciences
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Dr. Nerissa Salayo	Section Head, Socio-Economics Section, Research Division, Aquaculture Department, Southeast Asian Fisheries Development Center
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Ms. Rose Ann Diamante	Technical Assistant, Farming Systems and Ecology Section, Research Division, Aquaculture Department, Southeast Asian Fisheries Development Center
Ms. Quenie Montinola	Technical Assistant, Socio-Economics Section, Research Division, Aquaculture Department, Southeast Asian Fisheries Development Center

Working Committee

Program Committee	Dr. Osamu Abe Dr. Ryogen Nambu Dr. Masashi Kodama Dr. Jon Altamirano Ms. Rose Ann Diamante
Organizing Committee	Dr. Ryogen Nambu Dr. Jon Altamirano Ms. Rose Ann Diamante Ms. Raisa Joy Castel
Secretariat	Ms. Rose Ann Diamante Ms. Roselyn Baylon Ms. Quenie Montinola Mr. Jose Francisco Aldon
Venue and Food Committee	Ms. Rose Ann Diamante Ms. Raisa Joy Castel Ms. Roselyn Baylon Mr. Ron Subaldo

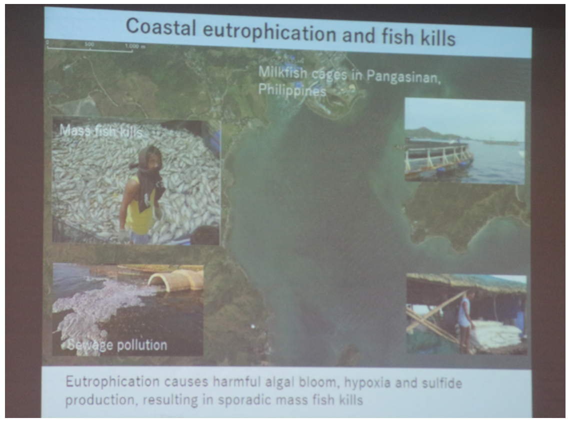
Workshop Photos

The workshop proper starts 6 August 2019 with Dr. Jon P. Altamirano of SEAFDEC/AQD as the Facilitator

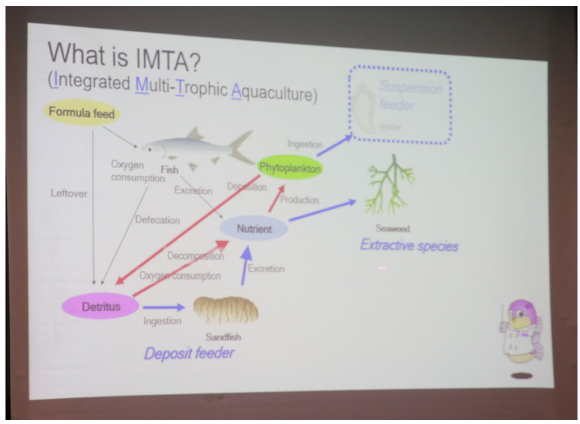
Dr. Osamu Abe, then as Program Leader at JIRCAS, delivering his Opening Remarks.

Dr. Leobert dela Peña, Head of Research Division at SEAFDEC/AQD, delivering his Welcome Remarks.

The core participants of the JIRCAS-SEAFDEC/AQD Joint Workshop on IMTA Research.

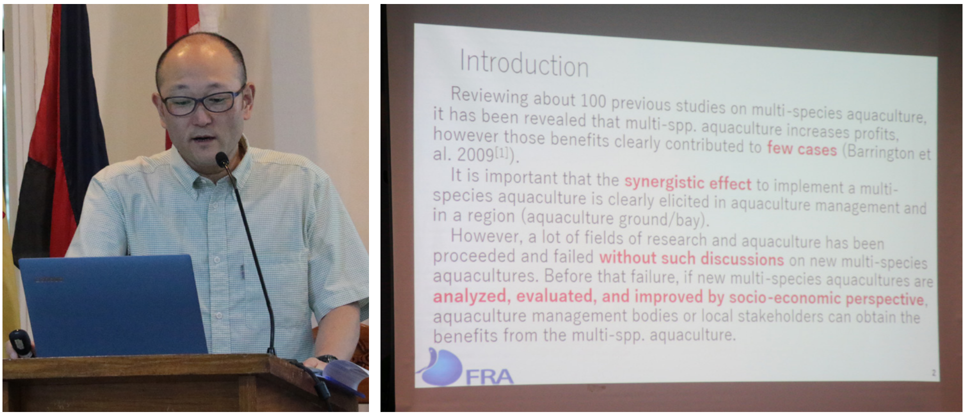
Dr. Satoshi Watanabe, Chief Scientist of the Japan Fisheries Research and Education Agency (FRA), presents the keynote talk on IMTA and aquaculture in Japan.

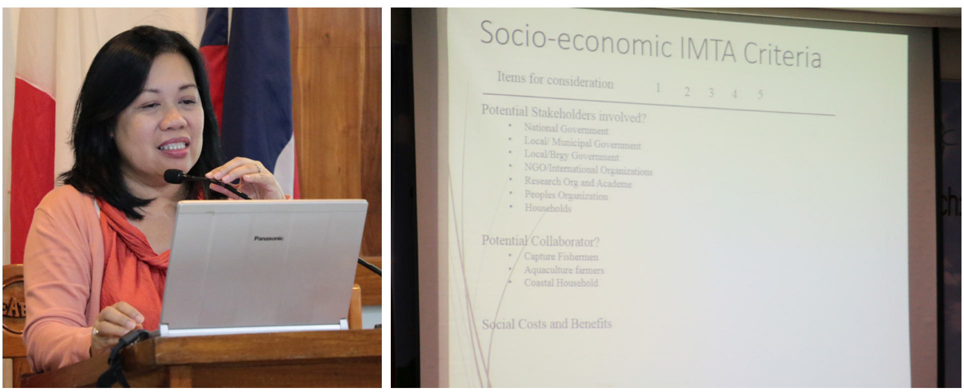
Dr. Masashi Kodama giving his talk on the "Overview and History of IMTA."



A series of presentations on the biology of prospective IMTA species are given by Dr. Jon P. Altamirano (left) on sandfish, Ms. Ma. Rovilla J. Luhan (middle) on seaweeds, and Dr. Ma. Junemie Hazel Lebata-Ramos (right) on bivalves, all from SEAFDEC/AQD.



The keynote talk on the socio-economics of multi-species aquaculture is being delivered by Dr. Tsutom Miyata, Chief Scientist of the Japan Fisheries Research and Education Agency (FRA).



Dr. Nerissa D. Salayo of SEAFDEC/AQD, presenting results of the socio-economic aspects of the IMTA Project.


Active discussions on the biology and ecology of IMTA species being led by Dr. Masashi Kodama (JIRCAS) and Dr. Jon P. Altamirano (SEAFDEC/AQD)



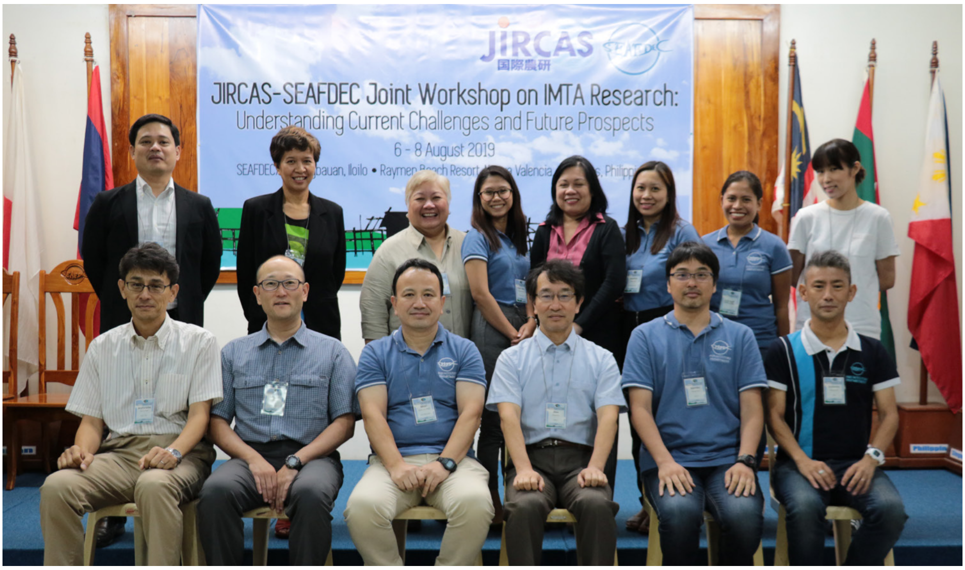
Discussions on the socio-economic aspects of IMTA being led by Dr. Nerissa D. Salayo (SEAFDEC/AQD), Dr. Tsutom Miyata (FRA) and Dr. Osamu Abe (JIRCAS)


Dr. Satoshi Watanabe (FRA) and Dr. Koh-ichiro Mori (SEAFDEC/AQD and FRA) participate in the discussions on the biology and ecology of IMTA.

Break-out session for the socio-economic component

Break-out session for the biological and environmental component

Wrap-up discussions are concluded on 7 August 2019



The core participants of JIRCAS-SEAFDEC/AQD Joint Workshop on IMTA Research

About the Editors

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Dr. Jon P. Altamirano is a Scientist at the Southeast Asian Fisheries Development Center or SEAFDEC, Aquaculture Department. Dr. Altamirano leads the Program on "Maintaining Environmental Integrity through Responsible Aquaculture" at SEAFDEC/AQD. He is also the Head of the Farming Systems and Ecology Section of the Research Division. He works in various aspects of aquaculture systems from hatchery, nursery and grow-out with particular focus on invertebrates and sea cucumbers. His research interests span from basic research in biology and ecology of aquatic animals, to larger ecosystem-scale studies that involves mangroves, seagrass and coral reefs. He finished his Bachelor's Degree in Fisheries from the University of the Philippines Visayas in 1999, and completed both his Masters and Ph.D. studies at the University of Tokyo, Japan from 2005–2010.

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