Integrated Adaptation Management Approach toward Sustained Fish Production by Fish Farmers of Marilao-Meycauayan-Obando River System

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ABSTRACT

This study was conducted to profile the fish farm owners/operators (known as fish farmers) at the Marilao-Meycauayan-Obando River System (MMORS) and to determine their current fish farm management practices (FFMPs) and concerns encountered in fish farming. Characterizing the fish farmers enabled the formulation of appropriate adaptation interventions that may serve as inputs for management strategies and rehabilitation efforts to address water pollution. In doing so, sustainable fish production could be assured. Focus group discussions, key informant interviews, and a survey were conducted. The survey sampling size was proportionally allocated among municipalities covered in this study.

Half of the respondents were full-time fish farmers and received an estimated monthly income of USD 125–250. The majority (60%) managed small ponds (4 ha and below), which were used for rearing and nursery or rearing and transition of fingerlings or fry. Many rented fish farms through lease agreement with private owners (78%); they mostly grew milkfish (74%) and tilapia (41%), but a few also raised prawns (18%) and shrimps (12%). The fish farmers' major issues include flooding due to changing climate patterns (74), water pollution (21), and presence of invasive species (20).

Their adaptation strategies include technological changes including FFMPs. However, institutional arrangements are crucial to ensure sustainability and productivity. The study recommends the adoption of an integrated social-technological approach called CARE solution, which refer to Community Action by organizing the fishery sector; long-term Rehabilitation by integrating efforts *of all stakeholders through the MMO Water Quality Management Area Board; and Enforcement of environmental laws. This approach is congruent with the Ecosystem Approach for Aquaculture that integrates ecosystem, human well-being and equity, and incorporates other sectors for aquaculture development and management.*

The fish farm management baseline study results could be an input in developing specific interventions using the CARE solution framework in the MMORS cleanup and rehabilitation. This approach could help in the design of interventions that aim to achieve enhanced socio-ecological health and ecosystem services for improved and sustained socioeconomic productivity.

Keywords: fish farmers, fish farm management, river rehabilitation, MMORS
JEL Classification: Q22

INTRODUCTION

The fishing industry is an important sector in the Philippines. In 2010, the country produced 0.745 million tons of fish, crustaceans, and mollusks; it ranked tenth in terms of global aquaculture production and was one of the five highest fish producing countries in the world (BFAR 2011). According to the Bureau of Fisheries and Aquatic Resources (BFAR), the fishing industry generated more than USD 5.03 billion (USD 1=PhP 43.95). Three regions contributed about three-fourths of this revenue: Region III (Central Luzon, USD 534 million), Region VI (Bicol Region, USD 507 million), and Region IX (Zamboanga Peninsula, USD 449 million).

Aside from its direct economic contribution, the fishery sector provides substantial employment. BFAR (2013) and FAO (2014) report that Bulacan (a fish producing province in Region III) alone has about 15,910 people working in the sector: 2,623 aquafarm operators, 13,287 municipal fisherfolks, and 4 licensed commercial fishers.

The 52-km long Marilao-Meycauayan-Obando River System (MMORS) traverses Bulacan province. MMORS provides ecosystem services to several urban and rural communities, as well as industrial enterprises that deal with heavy metals, notably tanneries, gold smelting shops, and hazardous materials recycling facilities (BSI 2008). For the communities in the towns of Marilao, Meycauayan City and Obando, and those residing near MMORS, this resource serves as a lifeline, providing ecosystem services, economic benefits, and food and nutritional security. It connects human activities of MMO, hence, serving as a medium of cultural interaction and identity.

Pollution has been a major challenge to the sustainability of ecosystem services derived from MMORS. MMORS is highly polluted mainly due to untreated municipal wastewater from sewers and poorly operating septic systems; heavy metals (chromium, lead, cadmium, etc.) and chemical discharges from industries; solid wastes dumped into the rivers from feeding drainage ditches; and silt, wastes, oil and other contaminants discharged as part of general urban storm runoff in the area (BSI 2008; Mendoza et al. 2012). While the people in MMO are aware of the extent of pollution in the rivers system, they also recognized the economic contributions to their communities by the industries that cause the pollution (Visco et al. 2013).

MMORS is a Class C river system (DENR DAO #34). This means that its surface water could be used for fishery, recreational activities (but not those that entail direct skin contact), and industrial purposes (DENR 1990). The change in the quality of water has had socio-ecological consequences for both the river organisms and the communities that depend on this river resource for food and livelihood because the aquaculture farms directly use the contaminated river water. According to Field (1997) (as cited in Ancog et al. 2008), the productivity of a natural environmental asset lies in its ability to support and enrich human life as well as in its capacity to assimilate and render waste products of the economic system.

It is important to conduct baseline studies to characterize the stakeholders, their livelihoods, and their social-ecological system in order to design appropriate and relevant programs or interventions for the communities involved. Along this vein, this study was conducted to profile the fish farm owners/operators and their farm management practices in Meycauayan City and the towns of Obando and Marilao, all in Bulacan; and Valenzuela City, Metro Manila, Philippines. Information gathered served as input in designing management strategies to address MMORS pollution and help ensure sustainable fish farming in the area.

Specifically, the study aimed to: (1) characterize the fish farmers, their households and their farms; (2) determine their current fish farm management practices; (3) determine the fish farming issues in the area; and (4) discuss adaptation interventions that the communities could apply to address water pollution and sustain fish farm productivity.

METHODOLOGY

The study used a mixed method research design to characterize the MMORS fisherfolk in terms of their socioeconomic characteristics, their fish farms and farm management practices, and the problems they faced in fish farming. The research team, together with the Program Management Team of Blacksmith Institute, conducted site visits and courtesy calls to introduce the research and outputs of the study to the local gatekeepers such as the local government units (LGUs) and local Fisheries and Aquatic Resources Management Council (FARMC) representatives. They also obtained the stakeholders' consent for the conduct of the research during these visits.

Data were obtained using both quantitative and qualitative methods of inquiry. Existing secondary data on fish farm operations in the study areas, including profile and list of fish farm owners, registration and fisheries programs were gathered from the LGUs (e.g., Municipal Agriculturist Office). Also, the research team conducted a document review of studies conducted on fish farm management and the aquaculture industry in the area as well as in similar areas in the Philippines and in the Southeast Asian region. The data and literature review analysis served as input in developing a structured survey instrument to assess the (1) sociodemographic and socioeconomic profiles of fish farm owners and operators and their households; (2) respondents' fish farm management practices (including inputs and outputs of fish farming as well as pond preparation, production, and maintenance); (3) market and distribution of the produce; (4) respondents' perception of the effects of MMORS water quality on fisheries; (5) respondents' problems in fish farming and other threats and their impact on the fishing industry; and (6) organizational profile and dynamics of these stakeholders as empowered communities are largely linked to improved environmental governance (Lagos, Bibee, and Malenab 2014).

The survey instrument was reviewed by an expert, and then pretested. Pretesting in a similar setting was conducted to determine the instrument's usability and viability. The questionnaire was revised based on the pretest results and the expert's judgment. It was then field-tested by four field enumerators (two males and two females), who were supervised on-site by a senior researcher. The field enumerators were oriented on the research and its data requirement. They were also trained in the protocols and ethics in data collection, data cleaning, database formulation, and use of the coding manual.

The sampling size was proportionally allocated among the municipalities. A stratified random survey was administered to 100 fish farmers/operators: 32 in Meycauayan, 14 in Marilao, 36 in Obando, and 18 in Valenzuela.

Moreover, focus group discussions (FGDs) and key informant interviews (KIIs) were conducted using a semi-structured interview guide. The FGDs covered an organizational diagnosis of FARMCs, sectoral issues and problems, resources and hazards, and suggested interventions from the fisheries sector. The KIIs, on the other hand, were conducted to capture sustainable fisheries management strategies. The key informants were determined based on their knowledge, experience, and skills in fish farming.

Tables, graphs, and measures of central tendency were generated from the survey results. Responses from the FGDs and KIIs were subjected to content and thematic analyses to serve as basis for analysis and interpretation. Also, the case study approach was employed to validate the cited problems/issues encountered by fish farmers/operators managing small (4 ha and below), medium (5–14 ha), and large ponds (15 ha and above).

The research results were presented to the communities and project stakeholders for validation and additional inputs. The validated results, inputs, and comments were incorporated in the analysis.

RESULTS AND DISCUSSION

Socioeconomic Characteristics of the Respondents

Most of the respondents were male (89%), more than 60 years old (51%), married (79%), and finished elementary school (48%). Half (50%) of them were involved full time in fish farm management; 44 percent reported having a monthly income of USD 150–250, (USD 1=PHP 44.10).

Socioeconomic Characteristics of Households

Almost half (45%) of the households had 1–3 members; another 45% of them had 4–6 members. Fishing was the primary source of income of the majority (66%) of households. Similar to the respondents' monthly income, almost half (49%) of the households reported a monthly income of USD 250 and below; 17 percent indicated an income of USD 250–500; and few (5%) earned more than USD 250 and above.

These fish farmers are considered non-poor, according to the criterion cited by Balamban et al. (2013): a Filipino family of five members requires USD 178/month for both basic food and non-food needs. On the other hand, the fish farmers and their households had limited capacities based on their monthly income and non-diversified means of employment; they are perceived to be more vulnerable to the adverse effects of weather disturbances, changes in climate patterns, and other environmental hazards.

Profile of Fish Farms

Scale and structure of fish ponds. The majority (60%) of respondents managed small ponds (4 ha and below); a third (33%) had medium-sized ponds (5–14 ha); and a few (6%) managed large ponds (15 ha and above). The structure of small ponds can be either netted or diked only or a combination of earth or concrete dike and nets. In Marilao, small ponds made from dike were common (57.1%). Ponds using nets were the dominant structure in Obando (41.7%) and Valenzuela (66.7%). More than a third (37.5%) of ponds in Meycauayan were made from earth dike and nets.

Most of the medium and large ponds were usually made from nets. Because fishnet fences allow water to flow freely into the ponds/cages, the influx is not easily controlled by the fish farmers, especially by the small-scale farmers. This was articulated to pose a danger as water quality varies depending on the season. Based on case studies, indicators of poor water quality in MMORS include change in texture (becomes thicker), change in color (from milky white to rust-like or from milky white to black/dark color), and presence of a noxious smell (usually in June or July).

Some fish farmers with medium and large ponds used remediation technology (e.g., filtration system or pump system) to manage the influx of polluted water. Fish farmers who were not using remediation technology had to harvest their produce immediately when a change in the color of the water was observed to mitigate income losses.

Pond ownership and use of fish ponds. Only about a fifth (19%) of the respondents owned their fish ponds. The majority (78%) rented their ponds through a lease agreement with the private owners. The annual rent per hectare ranged from USD 250 to USD 680. Many of the respondents used their ponds for rearing and nursery or rearing and transition; 19 percent of them used their ponds exclusively for nursery and another 19 percent for transition only. The pond operator made the decision to apply fertilizer most (73%) of the time, but only half or almost half the time for the other activities, such as when to harvest (51%), apply pesticide (50%), stock fry/fingerlings (49%), drain (44%), and feed (43%). Pond owners had minimal participation in these activities in terms of labor.

Kinds and volume of harvest per cycle. The majority (74%) of fish farmers reared milkfish and tilapia (41%); some of them also raised prawn (18%) and shrimp (12%). On the average, many respondents produced at most 8,000 kg of bangus (72%) per cycle (3–4 months), at most 1,500 kg of tilapia (58%), less than 500 kg of shrimp (50%), and less than 3,000 kg of prawn (89%). Some respondents did not indicate their average harvest per cycle, citing several instances of flooding of their ponds and fish kills during the early part of production, resulting in production losses.

Current Fish Farm Management Practices

Fish farm management practices refer to fish pond preparation and maintenance activities undertaken by fish farmers.

Pond preparation. The type of fish pond affects the management practices of a fish farmer/operator. Most respondents preferred the earth-dike pond with net support because this structure enables them to control the influx and outflow of water, thus preventing overflow of produce, as well as regulate the water quality. However, the majority of them were using nets as fish cages at the time of the study because this structure requires lesser cost and maintenance. The fish farmers said that repairing earth-dikes damaged by flooding is costly for fish farmers.

Farmers who had earth-dike farms employed the following practices: draining/pumping, growing of phytoplankton *(lablab),* stocking, feeding, fertilizer application, and repairing of pond dikes. Those who used fish cages did stocking and direct feeding only. The operation of netted fish cages involved fewer processes.

Also, as earlier mentioned, the pond operators mostly made the decision on fertilizer application, but shared the decision making when it came to activities such as the schedule of harvesting, pesticide application, stocking of fry/fingerlings, draining, and feeding.

Stocking and harvesting. Each production cycle usually lasted 3–4 months for small- and medium-scale farms, to 6 months for large-scale farms. As such, stocking was done within January to September. This will facilitate harvest in December and January and in April-May to meet the demand for the higher volume of produce due to holidays and celebrations, thus permitting higher market price and profits.

In other case studies, stocking started in September until December for harvest by April to June (Atole 2014). It was explained that during these months the climate was conducive for rearing of produce, especially prawns and tilapia as well as for harvesting of those that were grown in the earlier production cycle.

As for stocking density, 42 percent of the milkfish growers and 29 percent of the tilapia growers use less than 25,000 pieces per cycle/ha; 25 percent of the shrimp growers and 50 percent of the prawn growers raise 25,000 pieces or more per cycle/ha. Tilapia and shrimp stocks cost less than PHP 1 (USD 0.020) a piece while milkfish and prawn cost PHP 1–2 a piece.

The respondents also deemed it beneficial to stock prior to the onset of the dry season as the fry/fingerlings grow faster due to the presence of natural food. This shows dependence on the presence of natural resources in the area. Other food sources include commercial feeds (30%), bread (31%), and crispop[1] (23%). Due to the high cost of commercial feeds, the fish farmers used natural feeds; they provided synthetic feeds only near harvest time to boost the growth and size of the produce.

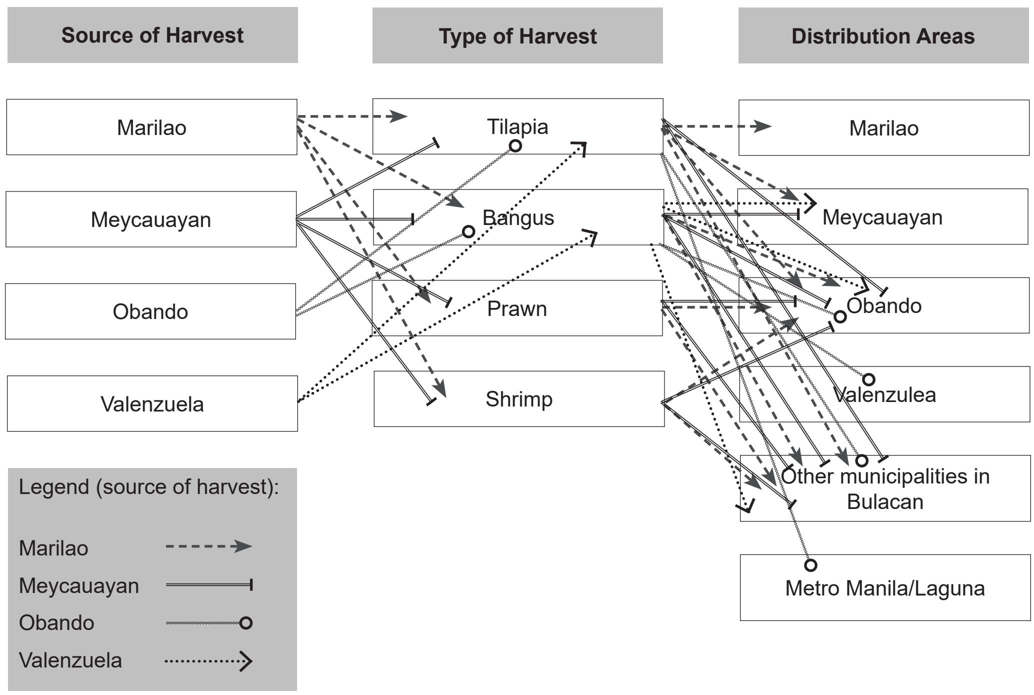
Pathways of produce distribution. The harvests were mostly distributed in various areas of Bulacan, including the towns of Obando, Bocaue, and Hagonoy. The milkfish harvests were delivered also to Metro Manila and Laguna. Figure 1 shows the sales distribution pathways of the harvests. Because the aquaculture produce in MMORS was not only locally consumed but exported also to nearby communities, Metro Manila, and other areas, the use of contaminated MMORS water for aquaculture has posed significant health risks to many other people (almost one million in 2008) living in all these areas (BSI 2008).

Market and distribution strategies. As a whole, only 20 percent of the fish farmers had a contract for market distribution. This comprised seven fish farmers each in Meycauayan City and Obando, four fish farmers in Marilao, and two in Valenzuela City. Having a contract provides a relatively more stable source of income to the fish farmers.

Bulk purchasing is a usual practice of traders in this fishing industry. In this study, the majority (81%) of fish farmers sold their produce wholesale through secret oral bidding (41%), open bidding (24%), and contract selling (16%). Almost half (43%) of the respondents indicated that in these bidding transactions, the agent/trader/consignee wielded the greatest power in pricing the goods; 19 and 13 percent indicated fish farmers/producers/owners and other consumers, respectively.

1 Crispop is stale bread used as a cheaper fish feed alternative (Yap 1999).

Figure 1. Sales distribution pathways of the harvests in the Meycauayan-Marilao-Obando River System



Players involved and factors considered in setting the market price. The majority (75%) of respondents identified agents or consignees as the key players in setting the market price; only 15 percent of them indicated producers as key players. The major factors influencing price setting, which were cited by respondents, were supply and demand of the produce (40%), size of the fish produce (40%), and freshness of the produce (29%). The small size of the fishes may be attributed to the quality of the fish stocks (fry/fingerlings); with most of the stocks coming from the *singaw* system or just within Bulacan and nearby provinces. *Singaw* refers to stocks that come from the water that flows into the pond.

Results show that fish farmers individually sold their products to the market. This had put them in a disadvantage vis-a-vis consignees and buyers who could the fish price. The fish farmers had weak bargaining power as their perishable products had to be sold before they lost their freshness.

Problems/Concerns Encountered by Fish Farmers and Adaptive Strategies Employed

Environmental problems. The fish farmers identified changing climatic pattern (74 responses), water pollution (21 responses), and presence of invasive species (20 responses) as the environmental problems they had encountered. The majority of fish farmers (71%) attributed the observed decrease in volume of fish production and catch to the deteriorating quality of water in MMORS; some of them (14%) attributed the incidence of fish kills also to the water quality. Almost two-thirds of the respondents (62%) believed that domestic wastes and industrial and commercial effluents mainly contributed to the pollution of water in MMORS. A medium-scale fish farmer said that solid and toxic wastes from neighboring areas, including Malabon, Navotas, and Quezon City, were causing the discoloration of the river water.

The respondents also cited the presence of black chin tilapia *(Sarotherodon melanotheron)*, commonly known as "arroyo" tilapia, as a factor causing a decrease in fish catch. The black tilapia is smaller in size and has lesser weight but more prolific compared with other tilapia species grown in the area. It is reported to compete with the main fish products for natural food and commercial feeds. An increase in its population would thus constrain the carrying capacity of the ponds/ cages. It also commands a lower selling price in the market because locals do not like its taste.

The respondents' major concerns included flooding due to changing climate pattern, high salinity of water, and increase in water temperature during transition of seasons (Atole 2013). A small-scale farmer said that there had been instances when the combination of high water salinity and increase in water temperature had led to the death of reared species, specifically prawns, resulting in decreased volume of produce. Also, a large-scale farmer observed an incidence of fish kill due to change in water temperature. Some medium-scale farmers did not experience these problems because they first acclimatized the fry/fingerlings to the water condition in the transition pond before releasing them in the rearing pond.

Social problems. The respondents identified two concerns: point source of the pollutants and lack of institutional support. The fish farmers in MMORS were well aware that the majority of pollutants came from both households and industries. These systems were benefitting at the expense of the natural resource, but the fish farmers were bearing the losses and unintended consequences due to the degradation of the resource.

A few of the respondents (4%) also mentioned the lack of institutional support, including programs for the aquaculture industry and support for fish farmers, as a concern. In Marilao, fish farmers and some small players in the fish industry availed themselves of financial assistance amounting to USD 125 from the LGU. The payment scheme was weekly at USD 5 for 12 months, of which USD 1.25 was set aside as their savings. However, this subsidy program was not sustained; it was reported that payment collections were not properly turned over. The respondents suggested that the local government may employ subsidy as a form of economic policy instrument for the improvement of aquaculture industry in MMORS.

Adaptive Strategies and Interventions

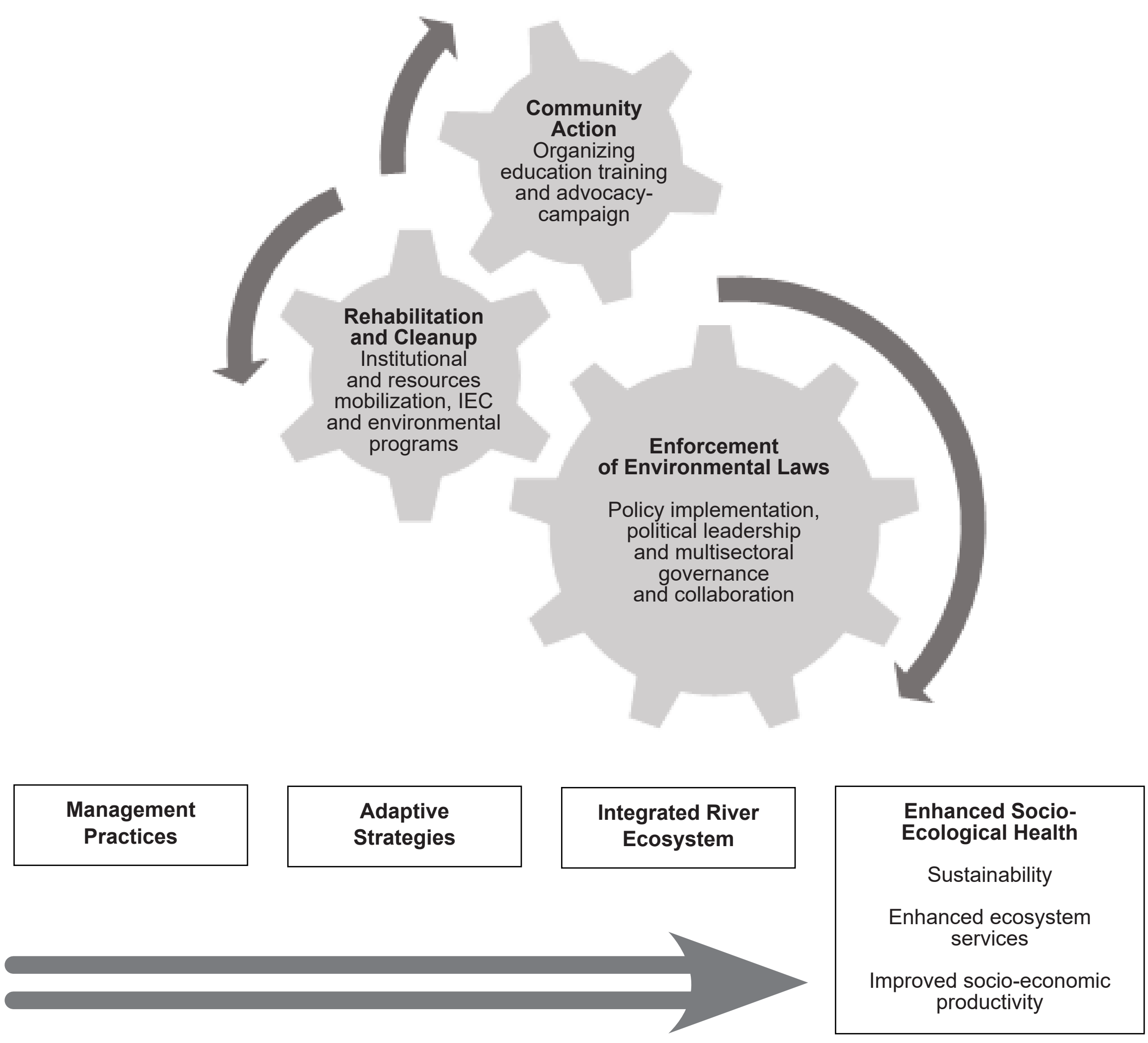
The MMORS experience reveals that the fish farmers' management practices responded to the changing socioeconomic and environmental conditions. Most of the responses to change pertained to technological interventions and fish farm management. However, institutional support and arrangements seemed to be lacking to fully address the challenges faced by the MMORS fish farming industry.

The current technological adaptations include change in pond structure (i.e., use of nets), timing of feed application (i.e., near harvest time), regular monitoring of water quality using simple parameters (e.g., color, smell, temperature), use of good quality fry/ fingerlings, and change in harvest period. Large-scale fish farms could purchase water treatment equipment such as aerator.

On the other hand, the study team observed that some of the current adaptation strategies employed by the fish farmers may aggravate pollution of the river. For instance, while changing the pond structure to one using nets may be economical in the short term, the unconsumed feeds are carried by the water current and settle at the river bottom, creating apoxic conditions. Moreover, the nets could be easily swept during floods, posing risks to other freshwater and marine life that could get entangled in these nets. Fish farmers use commercial fish feeds near harvest time to promote fish growth and weight, but this may lead to overfeeding, with extra feeds settling at the bottom, increasing risk of eutrophication and nutrient enrichment (Bouwman 2013).

Nevertheless, some of these technological adaptations, together with the physical infrastructure, are crucial for fish farming development. However, these should be accompanied by institutional arrangements that would reduce market risks and transactions costs (Gulati et al. 2007). The MMORS fish farmers were observed to have weak bargaining power in the market, largely relying on intermediaries. Furthermore, although they had been identified as one of the most affected sectors in the

Figure 2. CARE Solution for the Marilao- Meycauayan-Obando River System, an integrated approach for development



MMORS river pollution, fish farming has not been highlighted in the current river cleanup and rehabilitation plans and programs (Malenab et al. 2016).

The fish farmers recognized that in order to improve fish farming in the area, the river needs to be cleaned and rehabilitated. Based on the survey results, the study developed an intervention framework called CARE solution (Figure 2), which is short for Community Action, Rehabilitation and Cleanup, and Enforcement of Environmental Laws. The framework was presented to the MMORS water quality management board and key FARMC leaders for feedback. It served as an input in the review of the Ten-Year Action Plan for the cleanup of the river system.

The CARE Solution

Community action is expressed through the fish farmers' knowledge-sharing and capacity-building practices. As discussed earlier, the fish farmers have developed adaptation strategies to address challenges faced by their sector. In this regard, the respondents suggested the following be implemented: (1) active sharing of experiential insights among co-fish farmers, (2) participation in technical training provided by the government and other organizations, and (3) community organizing for the fishery sector. The latter includes organizing meetings and information, education, and communication (IEC) campaigns, organizing the *Bantay Ilog* or river guardians, and forming and revitalizing the Barangay FARMC. FARMCs are local multi-sectoral groups whose formation is mandated by the Fisheries Code to promote co-management of fisheries and aquatic resources in the country. FARMCs are an essential part of local development planning, thus they could forward and actively campaign for the concerns of the fishery sectors in policy and development. They could also serve as a platform to consolidate fish farmers so they could have a stronger bargaining power in marketing their produce.

Rehabilitation and Cleanup cover river cleanup and rehabilitation projects implemented by the government and nongovernment organizations. Rehabilitation includes environmental programs and research on remediation technologies to improve water quality and institutional and resources mobilization. Long-term rehabilitation of MMORS is possible through the integrated efforts of all stakeholders through the Meycauayan-Marilao-Obando Water Quality Management Area (MMO WQMA) Board. Among others, this means having a monitoring and evaluation system and conducting river quality monitoring to decrease the pollution level and safeguard the environment and people's health.

Enforcement of Environmental Laws refers to policy implementation, political leadership, and multisectoral governance and collaboration. Fish farmers believed the closure of the factories causing pollution in upstream MMORS was a result of the government leadership having the political will to enforce environmental laws. More than two-thirds (78%) of the respondents suggested the continued closure of these factories. About a third (30%) of the respondents suggested that factories as well as pig and chicken farms should install water treatment facilities. These could be done through political initiative; interagency and multisectoral coordination is needed to effectively implement such policies.

The CARE Solution is a social and technological approach, which is congruent with the Ecosystem Approach for Aquaculture (EAA) advocated by the Food and Agriculture Organization. EAA refers to "a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems" (FAO 2007). It accounts for the ecosystem functions and services of the aquaculture area and the fish farmers' well-being and equity, and integrates fish farming concerns into other sectors (e.g., industry, urban planning, among others) (FAO 2007).

As an approach the CARE Solution recognizes the different scales of interventions, particularly the role of the individual (fish farmer) and the state of the water body or aquaculture zone. Hence, the current fish farm management practices in MMORS and their adaptive strategies must be reviewed as part of the integrated river ecosystem management that aims to enhance socio-ecological health through improved ecosystem services, socioeconomic productivity, and sustainability. Failure to integrate the fish farming issues in a broader river quality management would affect the achievement of the overall socio-ecological health goal of the MMORS.

SUMMARY AND CONCLUSION

Fishery is an economically important sector in the Philippines. It provides direct economic contribution as well as employment and livelihood. Bulacan, a province in Region III (Central Luzon) is a significant fish producer in the country. The MMORS provides ecosystem services, economic benefits, and food security to the communities, especially fish farmers, in Meycauayan City, Marilao and Obando, all in Bulacan province, and others residing near it. It connects human activities of MMO in Bulacan and serves as a hub of cultural interaction and identity.

This study was conducted to profile the socioeconomic characteristics of 100 fish farm owners/operators (collectively known as fish farmers) and to determine their current fish farm management practices and concerns/problems encountered in fish farming. The sampling size was proportionally allocated among the four municipalities. The survey results were validated through focus group discussions, key informant interviews, and case studies.

Using the fish farmers' socioeconomic profile and their management practices, the study formulated appropriate adaptation interventions that may serve as inputs to potential management strategies and rehabilitation efforts to address water pollution.

Half of the respondents were involved full time in fish farm management and the majority managed small ponds (4 ha and below). They reared milkfish, tilapia, prawn, and shrimp. Most households had a monthly income of about USD 250 and below. Their low monthly income level and non-diversified means of employment limited their capacities and increased their vulnerability to the adverse effects of weather disturbances, changes in climate patterns, and other environmental hazards experienced in MMORS.

Most of the respondents managed small, earth-dike with net ponds (4 ha and below); the rest managed medium (5–14 ha) and large (15 ha and above) ponds with fishnet fence. The fishnet fence structure allows water to flow freely into the ponds/cages, posing a concern as regards the control of water quality in the pond. Some fish farmers reported that during water influx, the color of water in the fish cages changed from milky-white to rust-like or a darker/black shade, the water became thicker, and there was a noxious smell. Some medium- and large-scale fish farms used technologies like filtration system and pump system to manage the influx of polluted water. The use of contaminated MMORS water by the fishing industry in the area poses health risks to consumers of the produce, particularly people living along the MMORS as well as those in nearby provinces and cities (including Metro Manila and Laguna) where the produce is delivered.

Though the fish farmers preferred the earth-dike type of pond with net support, most of them shifted to using nets as fish cages, which cost less in terms of maintenance, repair, and labor operations. Fish stocking was done throughout the year, usually timed so that they could harvest for upcoming occasions and events such as Christmas, New Year, and Holy Week, during which the demand for the produce is higher, allowing for higher market price and profit. The fish farmers also considered the prevailing climate during stocking and harvesting periods to avoid production losses.

Only a few fish farmers had contracts for market distribution and they had weak bargaining power in price setting. Also, most traders/agents/consignees practiced bulk purchasing.

The fish farmers' major issues/concerns with respect to fish farm management were water pollution; decrease in volume of harvested fish due to fish kill especially during transition of seasons and presence of black chin tilapia, an invasive species; and lack of institutional support for the fish farmers. Other concerns include changing climate pattern, increase in water temperature, and high salinity of water.

The fish farmers implemented some infrastructural and technological adaptation strategies to address the above-mentioned concerns and issues, which include changing their pond structure and manner of pond preparation. However, aside from infrastructural and technological strategies, changes in institutional arrangements are also needed. In this regard, the research team developed a social and technological approach/framework called CARE Solution to integrate fish farming concerns in the river rehabilitation program. The approach was based on the respondents' suggestions and the Ecosystem Approach for Aquaculture (EAA) principles.

CARE Solution is a social and technological approach that highlights the integration of community and organizational development components throughout the process of river rehabilitation. It comprises community action, long-term rehabilitation and cleanup, and enforcement of environmental laws (including controlling pollution at source, which may mean closing some factories that dump pollutants into MMORS).

The results of the baseline study of the current fish farm management strategies practiced by fish farms in MMORS could serve as basis for designing specific interventions for river rehabilitation. Such rehabilitation should integrate community development, cohesive institutional mobilization, and community organizational consolidation in effective natural resource governance and sustained development, as summarized in the CARE Solution. This approach could help in the design of interventions that aim to achieve enhanced socio-ecological health and ecosystem services for improved and sustained socioeconomic productivity.

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