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Measures Used for Water Quality Management in Intensive *Pangasius* Catfish Production in Vietnam's Mekong Delta: Experiences from Household Practices and Gender Roles

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Abstract

Intensive aquaculture on a household-scale in Vietnam's Mekong Delta region often decreases the quality of the water. The consequences are a negative effect on the yield of Pangasius catfish, which in turn reduces the income generation potential. Water quality management has become an important consideration, not only for sustaining livelihoods from household-scale aquaculture but also for mitigating the impacts on the surrounding water bodies. The purposes of this paper are to identify strategies for improving water quality management in households practicing aquaculture and to understand the role gender plays in water management in the Mekong Delta. The effectiveness of existing household approaches to water quality management was found through analyzing data gathered through interviews. The primary data consisted of interviews with 32 operators of different household-scale aquaculture systems. It was found that in 46% of these households, water quality had declined over the last three years. Several causes were identified including the accumulation of chemicals and antibiotic residues, excessive stocking rates, and a lack of a water treatment system. Several strategies to better manage water quality in these ponds were identified including changing the clean water more frequently, removing sediment after each harvest, planting trees around the ponds, and applying lime to the base of the pond, or using potassium permanganate for disinfection before use. Although many water quality management approaches were in use by households, more than 90% of these activities were implemented by men.

Keywords

Intensive Pagasius catfish, water quality management, household practice, gender role, Mekong delta

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Introduction

Aquaculture production of catfish is a thriving rural industry in the Mekong Delta region of Vietnam, with an estimated annual production capacity of around 1.1 million tons from an area of 5,412ha (DOF, 2019). Intensified production in pond-based aquaculture systems for two popular catfish species, namely Tra (*Pangasius hypoththalmus*) and Basa (*Pangasius bocourti*), has been common at a household level since 2005. Catfish have been successfully exported to the European and US markets since 2006 causing a jump in demand for production. To facilitate growth in the industry to meet the new global demands, the Vietnamese government started developing feed-mills and processing factories in 2007. New breeding and growing technologies have enabled a shift from caged-production to intensive production in ponds. This has allowed for a wider adoption of aquaculture systems by households in the Mekong Delta region (Bosma & Verdegem, 2011). These technological developments have led to a rapid increase in aquaculture production of *Pangasius* catfish in a short time frame. While this has resulted in the consolidation of parts of the industry, significant levels of production still occur at a household level (Marschke & Wilkings, 2014).

Despite a remarkable increase in catfish production, poor water quality has been stated to undesirably affect catfish production households, mostly by affecting fish growth, production, quality, and profitability (Kirya, 2011). Catfish production has been reduced by contaminated waters that impair the development, growth, and reproduction or even cause mortality to the cultured fish species (Umesh *et al*., 2008). As a consequence, catfish households have been obliged to manage water quality to provide a good environment that meets the physical, chemical, and biological standards for catfish health and growth (Tumwesigye *et al*., 2021). Intensive catfish households apply several common methods for controlling water quality such as pond design, fertilization, supplemental feeding, increased stock density, disease control, and strategic harvesting. Incorrect execution of these methods in terms of the product amount used can cause problems for the farmers and the surrounding environment. The negative impacts associated with intensive systems include nutrient and organic matter enrichment of wastewater resulting in a build-up of anoxic sediments, changes to the benthic environment, and the eutrophication of ponds (Kongkeo, 2001). Practices used in intensive aquaculture of *Pangasius* catfish by households in the Mekong Delta region often result in water culture of low quality due to the build-up of food, chemicals, and antibiotics as well as biological excrement from the fish. This has resulted in negative impacts on the health of the surrounding environment, affecting the long-term sustainability of the industry.

The development of sustainable production models for aquaculture systems should consider three main views. Firstly, the amount of land, water, and energy resources used for production, as well as water quality and effluent control need to be considered. From an economic perspective, there are questions about profitability, market supply and demand, and feeding efficiency. Finally, a sociological perspective might examine the creation of jobs, and the local sourcing of inputs such as feed, labour, and investments (Wurts, 2007). In the context of the intensive household production of *Pangasius* catfish in the Mekong Delta, efforts to ensure the sustainability of these systems should focus on water quality monitoring, the effectiveness of measures to improve water quality, and the division of labour by gender in managing water quality.

Women in the Mekong Delta region of Vietnam play a significant role in aquaculture production. However, the contributions of women to household aquaculture production often go unrecognized and the benefits of their participation are often not objectively considered in sustainability assessments (Ahmed *et al*., 2012). Because of this, recognizing women's roles in the management of water quality in household *Pangasius* catfish production has the notable potential to contribute to more sustainable practices for aquaculture in the region.

According to the Vietnam Institute of Aquaculture Economics and Planning, *Pangasius* catfish cultured by farm households accounted for more than 48% of the production area in the Mekong Delta in the years prior to 2015. However, after 2015, 88% of the production in the region was consolidated by large companies, while 12% was cultured at the household level (Thanh Cong, 2015). The typical size for an intensive aquaculture pond is 0.4ha. Less than 10% of producers have more than four ponds (World Bank, 2010). Households engaged in producing *Pangasius* catfish usually apply various management approaches to improve water quality. These include the treatment of the pond base, regular replacement of the water in the pond, aeration, feed controls, or the chemical treatment of the water (Vo *et al*., 2015).

Since early 2015, the total export of catfish to key markets has declined. For example sales to the US have declined by 6.3%, while sales to the EU have declined by 17.2%. This was caused, in part, by competition from other fish exporting countries and the comparatively poor quality of Vietnamese *Pangasius* species in these markets. The decrease in demand for Vietnamese cultured *Pangasius* and the reputation of inferior quality resulted in a decline in value for the industry. This particularly affected the farm households with the loss of income due to production costs being higher than the value of the product (VASEP, 2016). In response, households attempted to reduce the production costs of *Pangasius* by prioritizing the expenditures of feed and medicines, rather than water quality treatment. With limited financial resources, households were primarily concerned with measures that could improve the economic output of their aquaculture systems.

This paper addresses the lack of knowledge about water quality management employed by household aquaculture systems in the Mekong Delta. This knowledge is intended to assist local government officials in increasing their understanding of issues connected to water quality management in the Mekong Delta.

Materials and Methods

Research site selection

In the Mekong Delta, *Pangasius* catfish are primarily cultured intensively in ponds with earthen walls, which are situated adjacent to a river source. This facilitates the exchange of large volumes of water from these ponds to the adjacent river (World Bank, 2010). To investigate the water quality issues that result from this practice, Can Tho, An Giang, and Dong Thap provinces were considered because *Pangasius* catfish production in these three provinces accounts for more than 75% of the total *Pangasius* production in the country (DOF, 2019).

Thot Not district in Can Tho province was later selected as an appropriate study location. The district has the largest (330ha) intensive *Pangasius* catfish area, which accounts for more than 50% of the catfish production area in Can Tho province (Can Tho Statistical Year Book, 2019). Thot Not is also located adjacent to the Hau River, which is a distributary of the Mekong River. Households practicing aquaculture in this district have advantages over other areas in terms of access to water (**Figure 1**). However, they also face some difficulties in controlling the quality of this water, particularly during the wet season.

Data collection

Field survey: As approximately 95% of the *Pangasius* catfish produced in the Mekong Delta are currently cultured in ponds, this research primarily focused on analyzing household approaches to water quality management in these ponds (World Bank, 2010). There were a total of 32 households producing *Pangasius* catfish species in Thot Not district. Previously, this number was much higher, however during the wet season between October 2018 and April 2019, saline intrusion in the Mekong Delta had strong impacts on aquaculture production. This occurred simultaneously with a sharp decline in the price of catfish, causing many households to pursue other livelihood sources.

A baseline survey found that the intensive small-scale production of *Pangasius* catfish was having a significant environmental impact.

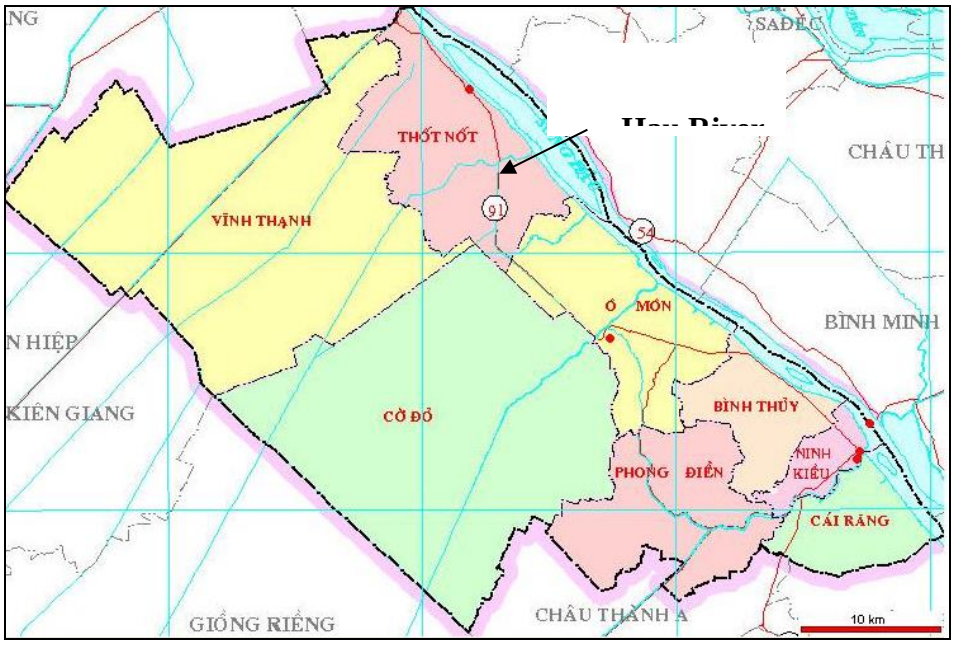

Figure 1. Location of the case study area in Can Tho province

Based on these results, a questionnaire was developed to gather more detailed information about the water quality management practices used by the 32 households culturing catfish in the province. The questionnaire included the number of catfish ponds, the area of each pond, catfish production, catfish price and production costs, perception of producers about water quality, methods applied to control water quality, etc. The questionnaire also included a section on gender roles in *Pangasius* catfish production to better understand the impact gender roles may have on the sustainability of household aquaculture systems. This section was designed to allow men and women to respond separately. Interviews were conducted over the first two weeks of December in 2019. Local staff from the Thot Not district office facilitated access to the households and two-hour interviews were conducted based on the questionnaire.

Focus group discussions (FGDs) with key-informants were used to check the reliability of information gathered from the questionnaire. This is a commonly-used method in qualitative research to collate the individual and collective understandings of issues experienced by participants in a case study, as well as gather further information to answer research questions. FGDs with women who were members of households producing *Pangasius* catfish or who were hired laborers were conducted to obtain information about the role of gender in water quality management in these aquaculture systems. FGDs were also held with male heads of households to identify which factors were affecting water quality management practices in these households. The FGDs also considered the barriers to improving water quality management in the future and their implications.

Key informant interviews were conducted with participants from the three local government authorities in Thot Not district to better understand how the water quality in intensive aquaculture ponds is monitored, and which measures are applied to improve water quality.

Data analysis

Primary data were collected and analyzed using a combination of quantitative and qualitative methods. Descriptive statistics were calculated for the absolute number, average number, and frequency of use of the practical measures of methods used to manage water quality in each household. Besides, the Mann-Whitney U test was used to compare differences in the role of male and female labor in water quality management. A qualitative analysis of the interview data was also completed using data

from the FGDs with women to understand gender roles in household aquaculture systems, with a specific focus on the management of water quality.

Results and Discussion

The production of catfish in Thot Not district

Pangasius catfish production using water sourced from the Hau River in Thot Not district is concentrated in adjacent communes, such as Tan Loc, Thuan An, Trung Kien, Thuan Hung, and Thoi Thuan. Each household was found to have on average 2.68 ponds (standard deviation of 1.42), with a surface area of 1.04 ha per pond (standard deviation of 0.55). In 2019, the annual average yield from one pond was 233.51 tons. In 2019, households reported that the market price for *Pangasius* catfish ranged between 17,000 and 20,000 VND/kg. With this price point, farmers struggled to cover operating costs and this resulted in limited expenditures on water quality management.

Water quality management situation in aquacultural ponds of Thot Not district

The Fisheries Department of Can Tho City put into effect regulations that catfish producers (Guide No. 126/HD CCTS) were required to build a sediment holding pond to store water when dredging the culture, rather than discharging it untreated. This was done to protect the surrouding rivers and canal systems from aquacultural waste. The treatment pond was required to be 15-20% of the area of the production ponds. However, in practice, only four households were able to comply with these regulations. Production costs being higher than the production yield did not give the profits required to afford investing in the sediment holding ponds. This meant that the impact of water pollution from household aquaculture systems continued to be an issue.

As no recent assessments of the water quality of these household systems in Thot Not district were available from the Fisheries Department of Can Tho province, domestic *Pangasius* catfish producers were asked to conduct a self-assessment of changes to the water quality in their aquaculture systems in the past three years. While the Fisheries Department of Can Tho province does not require households to have the water quality of their ponds assessed, four householders were willing to pay for this assessment, with a view to improve their production volumes and the quality of their product. These assessments were performed by contracted technicians, employed by aquacultural companies in the district.

Interviews were also conducted on the households' perceptions of changes to their water quality over the past three years. Almost 47% of households reported that the water quality in their systems had declined, 41% believed there had been no change, and only 12% claimed that the water quality had improved (**Table 1**). These differences in perception were assumed to occur as household heads have different levels of experience. On average, each household had practiced *Pangasius* catfish production for ten-years. However, some had fifteen-years of experience, while others had less than seven.

Table 1. Household self-assessment of the change in water quality compared to three years ago

Type of assessment	Observation (n = 32)	Percentage (%)
- Household head self-assessment	28	87.5
- Hired technicians assessment	4	12.5
Change in water quality compared to 3 years ago		
- No change	13	40.6
- More pollution	15	46.9
- Less pollution	4	12.5

Households reported that the impacts from water pollution manifested themselves as health problems within the culture. For example, in the early stages of a culture, when the catfish weigh less than 500 grams, diseases can often occur, affecting the yield of the system. In 2019, 37% of households reported problems with diseases, such as cephaledema, hemorrhages, and purulent livers or kidneys. According to the interviews, the frequency of disease outbreaks has gradually increased over the last three years. It was perceived that this was directly related to water quality. Households reported a preference for managing these problems by using antibiotic treatments, rather than water quality treatments due to a need to reduce operating expenses.

Following the self-assessment of water quality changes to intensive aquaculture ponds, the questionnaire focused on the major causes of poor water quality as understood by *Pangasius* catfish producers. **Figure 2** illustrates the number of producers who perceived each cause. Twenty householders (62.5%) identified residual food left in the ponds after feeding as the major cause of declining water quality. Other factors included the overuse of antibiotics or overstocking of the ponds. Eight households reported that the water in the ponds had become stagnant. In these instances, not even a reduction of the amount food added would prevent the discoloration and bad smells coming from the pond. Most households reported discharging this water directly into local canals or rivers to reduce costs. They also reported being unaware of any water quality monitoring being conducted by either households or local authorities.

Water quality management practices by households managing intensive aquaculture ponds

From a key informant interview with the leader of the Thot Not Extension Station, household heads have been advised to participate in annual training courses on *Pangasius* catfish production. These courses are led by extension staff, who disseminate knowledge about topics such as fry selection, the detection of diseases, and water quality control. Households also reported learning techniques from their peers. Ensuring effective water quality management measures requires distributing information to all households. These measures include: the selection of appropriate pond locations; the post-harvest treatment of a pond prior to establishing a new culture; selecting suitable fry to ensure good production levels; using appropriate stocking densities and material inputs; using an appropriate water source; and the treatment of wastewater. In the questionnaire, these measures were assessed in terms of their applicability for improved water quality management outcomes for intensive *Pangasius* catfish aquaculture households in Thot Not district.

Selection of pond location

The selection of an appropriate pond location is a fundamental environmental management approach for managing water quality in aquaculture systems in the case study area. When selecting a pond location, households need to consider the required area, rental costs, the availability of an appropriate water supply and wastewater treatment system, the distance from residential areas, and the potential flood risk. Household heads were asked to rank these measures on a scale of importance when selecting an appropriate site for a pond.

The three most important criteria identified by households were rental costs, proximity to an appropriate water supply, and the provision of a water treatment system (**Table 2**). For example, 43.8% of the respondents suggested that the quality of water supply was extremely important, while 34.4% gave the same response with respect to the availability of an appropriate wastewater treatment system.

Participants were also asked to assess the importance of several design criteria of intensive aquaculture ponds, namely the pond location, surface area, and depth, for achieving good water quality outcomes (**Table 3**). The results showed that 78% of households suggested that pond depth was important, while 75% of households asserted the importance of the pond's location.

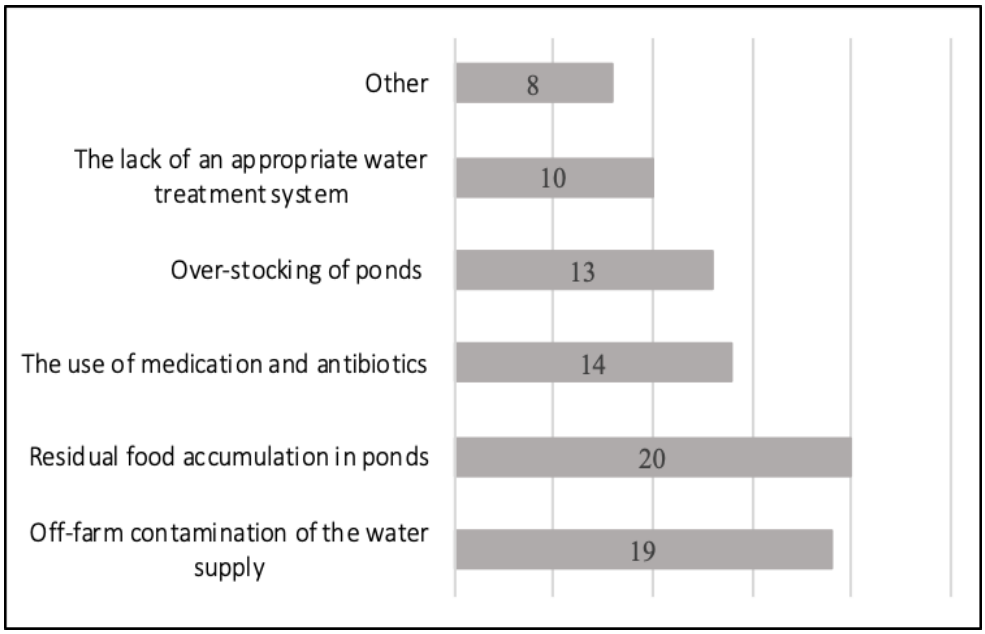

Figure 2. The main causes of water quality decline in household aquaculture systems as perceived by householders

Table 2. Criteria for pond site selection used by the surveyed households

Criteria	Evaluation rate (n = 32)			
	Important (%)	Very important (%)	Extremely important (%)	Unimportant (%)
Available area	18.8	9.4	15.6	56.2
Rental cost of land	12.5	37.5	43.8	6.2
Water supply	28.1	15.6	43.8	12.5
Sewage disposal system	18.8	34.4	34.4	12.4
Neighboring properties	21.9	25.0	15.6	37.5
Potential for flooding	25.0	12.5	62.5	0.0

Table 3. Assessment of the farmer's perceptions regarding the importance of pond characteristics on water quality

Criteria	Relative importance (n = 32)		
	Important (%)	Neutral (%)	Unimportant (%)
Pond location	75.0	18.8	6.2
Area	31.3	53.1	15.6
Depth	78.1	18.8	3.1

The surface area of the pond was considered to be much less important. *Pangasius* catfish ponds are on average four meters deep. This enables residual organic matter from food and fish waste to settle as sediment at the bottom of the pond, which can be routinely removed by draining the pond.

Selection of pond bank structure

Currently, *Pangasius* catfish are cultured in the Mekong Delta by one of two pond based systems: pond cultures used in inland provinces such as Can Tho, An Giang, Dong Thap, and Vinh Long, and intensive pond cultures used in coastal provinces such as Ben Tre and Soc Trang.

For inland catfish culture systems, such as those used in Can Tho province, water is supplied to the ponds from the Hau river. An important measure for reducing the contamination of receiving water bodies surrounding the pond is to build a stable pond bank. Of the surveyed households, 78% had planted fruit trees such as coconut and guava to help stabilize the bank; 16% had not planted trees, and 3% had pond banks constructed from bricks, with a concrete lining. Pond banks constructed from bricks are much more stable and prevent soil erosion, while also allowing the pond to be easily drained and dried out once the fish have been harvested. However, they are also quite costly and beyond the capacity of many households to afford.

Earthen pond banks were chosen by a majority of householders, many of whom plant trees around the pond to prevent erosion. Others also laid plastic lining around the edge of the pond to prevent residual food from being retained at the base. In these systems, if the soil composition is appropriate, water can be drained easily and the pond can be dried as part of a post-harvest treatment. However, if the pond bank consists of sandy soil, as found in many areas of Tan Loc commune, the pond can be susceptible to erosion. Renovation of pond banks, however positive for the future operation and environment, is an expensive undertaking and can affect the profitability of the household.

Treatment for the pond bottom

To maintain good water quality during the period of culturing *Pangasius* catfish, households often prepare the base of the pond after each harvest, prior to starting a new culture. The treatment involves applying bentonite clay to the mud at the bottom of the pond before leaving it to dry, and then spreading lime on top to seal it. Applying bentonite was a widely used measure, with 97% of householders practicing this approach. However, due to differences in pond bank structures, only 63% of householders left the base of the pond to dry as part of this process. Most (94%) households spread lime. In addition, other treatments were used, such as applying chlorine, copper sulphate, and other salts.

Fry selection and fish density

After implementing measures to prepare the ponds, before starting a new culture, households make decisions about fry selection, such as where to source the fry and the number of cultures batched. These decisions can both affect water quality. Decisions are made based on the availability of fry in the market, the productivity of each species, the density of fish in the pond, and the risk of disease. Achieving an appropriate fish density and the risk of disease were the factors that most strongly influenced the decisions of the householders interviewed when purchasing fry. Reducing the risk of disease was considered to be the most important factor in making decisions about fry selection and stocking density, with 43.7% of participants ranking this as extremely important (**Table 4**).

According to the heads of households interviews, as *Pangasius* catfish species are air-breathing species, they can tolerate low levels of dissolved oxygen. As such, *Pangasius* catfish are

Table 4. Assessment of householders about the importance of fry selection and stocking density

Criteria	Evaluation rate (n = 32)			
	Important (%)	Very important (%)	Extremely important (%)	Unimportant (%)
Fry market availability	78.0	6.3	6.3	9.4
Fish productivity	28.1	31.3	34.3	6.3
Fish density	37.5	28.1	21.9	12.5
Risk of disease	15.6	21.9	43.7	18.8

usually cultured at high stocking densities. However, this can also produce a high volume of sediment in the ponds. If the water quality in ponds is not managed, the culture may become diseased, reducing the yield of the batch. Therefore, making the decision to stock fish at an appropriate density can help to prevent diseases that limit fish growth, as well as improve water quality.

Selection of feeding style

There are a range of feeding methods that can be applied in intensive household *Pangasius* catfish production. This is an individual choice that every farmer must consider. Each method will have a different impact on how water quality is managed in their ponds. Involved in the method are the choices of feed type, the amount of food added, and the feeding schedule. Households identified the feed type and feed schedule as most important in determining feed consumption over feed waste. Residual food in the pond decreases water quality and wastes food (**Table 5**). Managing the feeding schedule was considered extremely important, according to 34.4% of households, as it helps to control the amount of food remaining in the pond.

Regarding the type of feed, households generally use floating pellets. These are more porous and will float before eventually sinking. With catfish being an air-breathing fish that naturally eat insects on the surface, floating pellets are considered to give the best results. This feed is sourced from companies namely Viet Thang, Green Feed, CP, and Con Co. While these companies produce food of a reasonably uniform quality, households indicated they generally preferred to purchase fish food from CP or Con Co., as the fish usually eat a greater quantity of the latter type. While composition, and thus quality, might be different across different brands, the overall type is floating pellets. Feed cost was described as the largest single operating expense for household-scale *Pangasius* catfish production. While feed prices have increased over time, the sale price has decreased, which has significantly affected smallholder profits, causing many to switch to cheaper brands that are perhaps of lower quality.

Selection of water supply for fishponds

Good water quality conditions for fish growth can be achieved by changing the pond water constantly during the culture period. Households generally check the water in the pond between one and two times per day. The decision to change the water is dependent on their assessment of its quality. The pond water is changed by a method where water is both drained and added at the same time. Approximately 40 to 50% of the volume of water in the pond is exchanged by this process. This is dependent on the water quality both in the pond and the source. The survey results showed that many households practice measures to reduce water contamination. For example, 65.6% of catfish producers checked the quality of the intake water. This was conducted by visual inspection based on experience in 44% of the surveyed households. A small number of farmers (6%) used handheld water quality testing equipment that measures the concentration of dissolved oxygen and other gases, such as hydrogen sulphide and ammonia in the pond.

Table 5. Perceptions of the relative importance of different fish feeding practices to improve water quality

Criteria	Evaluation rate (n = 32)			
	Important (%)	Very important (%)	Extremely important (%)	Unimportant (%)
Food selection	37.5	25.0	21.9	15.6
Feed method/volume	18.8	40.6	21.8	18.8
Feed schedule	15.6	37.5	34.4	12.5

The schedule used to change the pond water also varied between households, with 81% of producers claiming they practiced regular water exchange, 28% change the water when prompted by the presence of a bad odor from the pond, 22% change the water when a clean water supply became available, 38% change the water when it change color, and 28% change the water when they find dead fish in the pond. These measures were considered temporary solutions for poor water quality by the heads of the households interviewed, as they do not significantly improve water quality long-term. Moreover, these measures do not treat the water, thus when it is discharged, it decreases the water quality in the canals and rivers it is released into. This impacts other users of these water resources as the environment has a limited capacity to buffer polluted water from the aquaculture ponds.

Selection of pond water treatment measures

In addition to changing the water, some *Pangasius* catfish producers use water treatment methods to improve water quality in their aquaculture ponds. These methods include either surface aeration or the use of chemical and biological products. Surface aeration was applied in only 3% of households, with the majority of households using treatment products. A typical chemical treatment involves using potassium permanganate for its antiseptic and antibacterial properties to reduce the build-up of algae and prevent aquatic diseases. This was used in 56% of the surveyed households. Other chemicals such as chlorine or copper sulphate were used in 88% of surveyed households. Alternatively, 38% of households used biological treatment products to consume sediment at the base of the ponds. In this case, probiotics were usually mixed with the feed.

The amount of feed and chemical inputs used in intensive pond-based aquaculture is significant. Untreated waste discharged from ponds can pollute the surrounding waste bodies. As only 28% of households had sediment holding ponds, this can have significant environmental impacts. Moreover, many of the treatment methods used are quite basic and the total daily volume of water released to the environment from all the household ponds combined is significant. When this is considered, these measures are inadequate. However, even these basic treatment strategies were not widely used, with only 12.5% of households equipped with a sediment settling pond and 28% treating wastewater with both chemical and biological products.

Cost-benefit analysis of measures used for water quality management

The management of water quality in the aquaculture industry is not a new research topic. Researchers have focused their attention on the management of water quality parameters such as temperature, dissolved oxygen, salinity, and ammonia (Boyd, 1998). However, *Pangasius* catfish producers in the Mekong Delta typically rely on their own experience to assess water quality and few have knowledge of the industry technical standards for environmental management. Many of these standards require significant levels of investment to meet, which is beyond the financial means of many households. For example, mechanical aeration is highly efficient in improving oxygen levels in ponds but is also very costly to implement (Datta, 2012).

Less expensive measures that are simpler to implement were most often used to manage water quality in household-scale aquaculture systems in Thot Not. These included pond preparation and water treatment activities such as applying lime to the base of the pond. Other less expensive measures used in Thot Not households included the use of chemical products or probiotics to maintain water quality levels.

Declining prices and a more competitive global market have reduced the farmers' investment opportunities in water quality management. To be able to sustain these water quality management measures, *Pangasius* catfish producers need to strongly consider the costs and benefits of each approach. Assessing the options help provide insights into the choices these households face.

Thus, a comparative assessment of the costs of implementing three different water quality management scenarios was conducted (**Table 6**).

These were considered over the full cycle of pond preparation, post-harvest pond treatment to prepare for a new culture, and water treatment to improve the productivity of the new culture. It was found that 130 USD was the standard cost for maintaining average water quality for every 1000 m^2 area of pond managed. However, if the pond was operated with water of high quality, this figure could be reduced to 100 USD and in the case of poor water quality being used, the costs could rise to 165 USD.

Post-harvest water treatment prior to the development of a new culture cycle includes draining the pond, removing the mud or sediment from the pond bed, and spreading lime powder. In terms of operating costs per season, treatment options for more highly contaminated ponds include the cost of removing sediment (1.2 million VND), adding lime to the base of the pond (0.43 million VND), and the purchase of chemicals such as salt and chlorine (0.91 million VND). Water treatment costs include exchanging the water in the pond, surface aeration, chemical treatment, and sediment removal from the base of the pond.

Removing and replacing water in the pond represent the highest cost due to the costs of operating the diesel pump. It was found that households that consistently monitor and improve the water quality in their ponds spent an average of 17 million VND on replacing water in their ponds, whereas a household with lower water quality may spend more than 20 million VND on this activity. This cost was significantly higher during peak culturing times, as households often need to pay to replace water once or twice per day. Other significant water treatment costs for aquaculture systems included chemical treatment and sediment removal (mud suction) as demonstrated in **Table 6**.

Factors affecting the decisions of catfish farmers to apply water quality management measures

In summary, catfish producers in Thot Not need to consider several measures for water quality management in aquaculture ponds. The factors relevant to these decisions include the ease of implementation, cost, and effectiveness of each approach. Through FGDs with the heads of households, an assessment of nine water quality improvement measures was provided. The results indicated the perceptions that household decision-makers have when choosing one approach over another, with respect to the factors described (**Table 7**).

Besides the application of technical measures to manage water quality in household aquaculture systems catfish producers are also required to comply with local environmental water quality regulations, such as: Official Letter No. 2274/UB of the People's Committee of Can Tho on the settlement of environmental pollution

Table 6. Costs of water treatment measures in catfish culture ponds

Unit: million VND/1000 m^2

Water quality	Pond preparation	Post-harvest pond treatment and prior to starting a new culture				Water treatment during the culturing phase			Total
		Drying pond	Suction of mud from pond bed	Lime powder	Other	Water replacement	Chemical treatment	Suction of mud at streambed	
Water under normal circumstances	3.00	1.50	0.92	0.30	0.72	17	10.50	1.84	36.08
More contaminated for next culture cycle	3.76	1.90	1.20	0.43	0.91	20	14.50	2.40	45.60
Cleaner/Less contaminated	2.25	1.10	0.85	0.25	0.27	15	9.60	1.70	36.02

Note: 22,300 Vietnam dong (VND) was assumed to equal to one US dollar at the time of analysis.

Table 7. Factors affecting the decisions of catfish farmers whether to implement water quality management measures

Criteria	Implementation	Cost	Effectiveness in improving water quality
Selection of pond location	Difficult	High	High
Concrete lining of the pond bank	Average	High	Normal
Treatment of the base of the pond	Easy	Normal	High
Controlling fish density	Easy	Low	High
Adjusting the volume and composition of feed	Easy	Normal	High
Selection of an appropriate water supply	Difficult	Normal	High
Treating the water supply	Difficult	High	High
Aeration	Average	Very high	Normal
Use of biological treatment	Easy	High	Normal

Note: These factors were discussed with male heads of households only.

in aquaculture areas; Guide No. 126/HD CCTS by the Fisheries Department on intensive catfish culture and minimizing environmental pollution.

These regulations enable local authorities in Can Tho province to focus on managing the environmental aspects of the development of catfish farms. However, from a social perspective, they do not address the potential outcomes that may be realized from more gender inclusive practices in intensive household aquaculture production. Women in households that use aquaculture as a livelihood strategy are often bypassed when technology is transferred and remain excluded from the benefits of larger-scale production processes, except for roles in processing fish products. Their effort and control of the industry is often confined to small-scale production (World Fish, 2011). Moreover, the participation of women in decision making about aquaculture production is low in all levels from the household to the community. In developing countries, customary beliefs and social norms reduce women's access to land and water resources for aquaculture (World Fish, 2011).

This literature is consistent with the observations of this case study of the 32 *Pangasius* catfish producing households in Thot Not. Very few women participate in decision-making or implementing water quality control measures. They also have very limited opportunities to participate in extension activities. This is perpetuated by low levels of experience and a perception by some men that the participation of women in aquaculture activities may bring bad luck. Therefore to improve sustainability outcomes, it will be necessary to adapt extension services, innovation, policies, and institutional practices to specifically focus on the inclusion of women in aquaculture (Rahman, 2005).

Gender roles in water quality management

In recent years, the focus on gender roles in natural resource management and environmental protection in Southeast Asia has increased (Elmhirst & Resurreccion, 2012). Women and men are said to experience the natural environment and its resources differently through their distinct gender roles and responsibilities. As a result, men and women hold gender-differentiated interests in natural resource management, based on the knowledge held within these roles. Thus, an understanding of this knowledge is critical in shaping the

processes of ecological change, viable livelihoods, and the prospect of sustainable development (Elmhirst & Resurreccion, 2012). In the aquaculture sector, many activities require physical strength or skills that men have gained from years of experience. For example, the research completed for this study on *Pangasius* catfish production in the Mekong Delta generally observed men's involvement in aquaculture to a greater extent than women.

Measures to improve water management measures in catfish producing households include the selection of a pond location and pond bank structure, post-harvest treatments to remove sediment prior to starting a new culture, selecting fry and an appropriate fish density and feeding schedule; and choosing an appropriate water supply and water treatment system. In each household, different measures are selected to manage water quality based on factors such as economic status, the scale of production, or awareness of the impacts on surrounding water bodies. The measures are selected to manage water quality in the most effective way based on the knowledge that the decision makers hold. In the case of this case study site, decisions whether to adopt water quality management measures or not are primarily made by men. Women, generally play a minor role in decision-making.

Table 8 shows that decisions made regarding water quality measures, such as the selection of an appropriate pond location, pond bank structure, and pond water supply are made solely by men. These are important design factors determining the success or failure of both the intensive aquaculture system, as well as how it impacts environmental water quality. Women played a very minor role in decisions about how the sediment layer at the base of the pond is managed (16%) or water treatment in the pond (6%). Overall, the participation of women in making decisions about household *Pangasius* catfish production was very low. This gender bias may be due to factors influenced by economic reform processes in Vietnam. These processes often reinforce social hierarchies within communities, and patriarchal power within family structures more broadly in Vietnam. This creates a barrier to gender inclusive decision-making when important issues need to be resolved in any form household production as a livelihood activity (Elmhirst & Resurreccion, 2012).

For more insight into gender roles in water quality management, information on the participation of women in different activities related to household aquaculture production was gathered. The activities assessed were applying lime to the base of the pond, discharging water from the pond, and applying chemicals and biological agents to treat water in the pond. It was found that women have very low participation in these activities. For example, the activity with the highest female participation level was fish feeding (22%), which was described by women in the group interviews as a role of less importance that was easy to implement. Other tasks such as applying lime to the pond foundation were found to only have 3% female participation (**Table 9**).

The results are associated with the traditional division of labor in the families in the Mekong Delta. Women are usually assigned reproductive roles and are chiefly responsible for

Table 8. Participation in making decisions about water quality management measure by gender

Selected measures	Male (%)	Female (%)	Mann Whitney U-Test
Pond location	100	0.0	2.37**
Bank structures	100	0.0	1.95*
Pond bottom treatment	84.4	15.6	2.66*
Fry and fish density	87.5	12.5	0.68
Feed type	96.9	3.1	0.06
Water supply source for fishpond	100	0.0	3.61***
Pond water treatment	93.8	6.2	1.01

*Note: ***, **, and * indicate significance at 1, 5, and 10 percent, respectively.*

Table 9. Implementation of water quality management measures by gender

Water management measures	Male (%)	Female (%)	Mann Whitney U- Test
Pond bottom layer treatment	96.9	3.1	1.97*
Feed style	78.1	21.9	0.49
Water supply source for fishpond	100	0.0	2.41**
Pond water treatment	93.8	6.2	2.08*

*Note: ***, **, and * indicate significance at 1, 5, and 10 percent, respectively.*

housework, such as cooking and caring for children (Elmhirst & Resurreccion, 2012). Women have traditionally been dependent on men through marriage, both in terms of decision-making and the implementation of livelihood activities such as agriculture, forestry, or fishing (Elmhirst & Resurreccion, 2012). FGDs with women suggested that a majority believed their primary role was to conduct housework and care for children. Women suggested they were happy with these roles and confirmed that decisions related to water quality management in *Pangasius* catfish production were usually made by men. They participated in light, supporting roles based on their perceived abilities.

Low female participation in aquaculture activities was also reflected in the opportunities to participate in aquaculture extension training, where women are rarely are invited to attend. This training is organized by the local government to improve the awareness of water quality issues among household *Pangasius* catfish producers. It was found that 83% of participants in extension training in the case study area were men, either in the role of household head or as a male employee (**Figure 3**). The few women participating in these training events were either from female-headed households, or were attending in place of their husbands who were not available. Women in

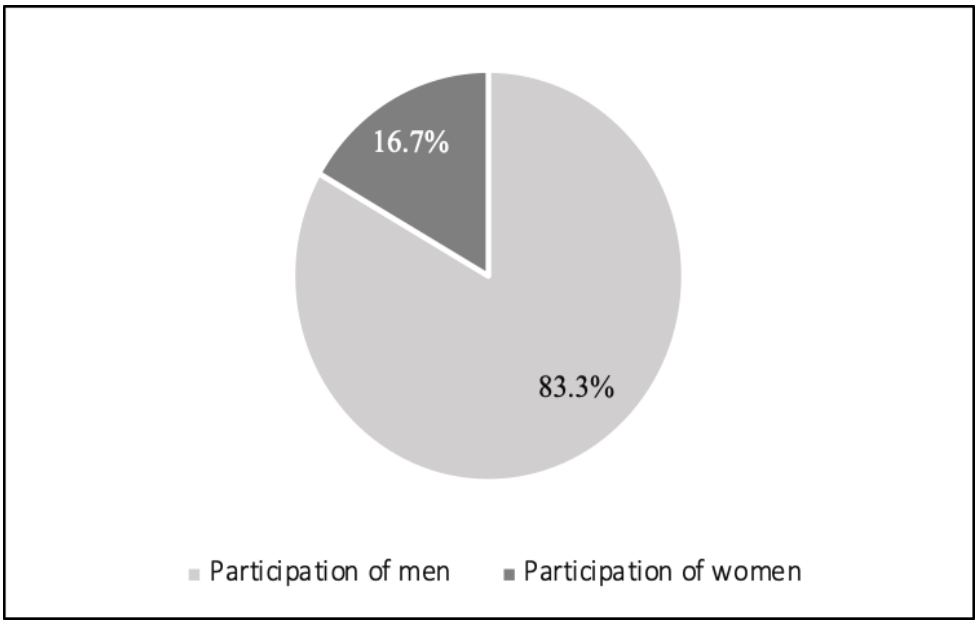

Figure 3. Gender participation in extension training

the FGD inferred that the content of the extension workshops was focused on fish care techniques and managing water quality in the fish ponds. They did not attend because this was perceived to be a male activity.

Low participation of women in aquaculture activities was found in roles related to water quality management at both the individual household level, as well as at the community level. This is consistent with other literature on the gendered access and control of natural resources and how this relates to socio-economic differences in Southeast Asia (Miller & Ravazi, 1995).

The gendered participation in aquaculture activities at the household level has been analyzed through the role of men and women within a traditional family unit. However, this also applies to male and female workers who are hired by households to provide services related to aquaculture. All *Pangasius* catfish producing households in Thot Not were found to employ staff to support their work. The number of employees ranged between 3 and 20 people depending on the size of the operation and varies seasonally.

Commonly, *Pangasius* catfish are cultured over two cycles per year. During the culture period, a typical household aquaculture system requires between three and five regular labour workers to feed fish and conduct other activities to manage water quality in the ponds. During harvest time, households also require seasonal labourers. Both male and female employees are hired and the division of labour was assessed for a number of roles. It was found that 80% of the engineers, technicians and technical advisors employed were men. Furthermore, 100% of the employees hired to conduct activities such as digging and dredging ponds, replacing water, as well as tending and harvesting fish were also men. Households also employed seasonal workers to help with housework and prepare meals for the labour workers, particularly during harvest periods. All of these roles were fulfilled by women (**Table 10**).

There was also a difference between the salaries paid to male and female employees. For example, male workers were paid an average of 3.5 million VND (160 USD) per month, while female employees were paid 2.5 million VND (115 USD) per month. The household heads explained that the level of direct involvement with activities specific to aquaculture, as well as the physical labour and long hours involved, were the reasons for men being paid higher wages.

Conclusions

In summary, a number of methods have been identified to control water quality in intensive household production of *Pangasius* in Thot Not. Of these measures, householders prefer low cost options with higher effectiveness, such as post-harvest treatment of the base of the pond, controlling fish density, adjusting the volume and combination of feed inputs, and basic water supply treatments. From an environmental perspective, these approaches to managing water quality contribute to developing an environmentally sustainable approach to catfish farming in the Mekong Delta. However, from a perspective of social inclusion, it was found that the majority of the activities used to manage water quality control are controlled by men. Consequently, the knowledge of women is not

Table 10. Gender divisions in the roles of staff hired to support household aquaculture operations

Work division	Unit	Male	Female
Technical advisor	%	80.0	20.0
Manual labor	%	100	0.0
Seasonal housemaid	%	0.0	100
Wage	USD	160	115

effectively applied to water quality management in intensive household-scale aquaculture. For this reason, local authorities should encourage women to participate in water quality management activities to make household *Pangasius* catfish production more socially sustainable.

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