Understanding Climate Change Mitigation Measures Adopted by Women Aquafarmers: the tilapia culture in Cambodia

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As the population of Cambodia reached almost 16 million in 2017 with an estimated growth rate of 1.6 % per annum, this necessitated improved food and nutrition security for the growing populace while economic development is being sustained. Rice and fish play important role in the diet of the people of Cambodia particularly those in the rural communities, providing them with the crucial elements in nutrition. Recent reports have indicated that the average annual per capita fish consumption of the people of Cambodia is 63 kg, and fish production comprises the important source of income for fishers and fish farmers of the whole country, and comes mainly from wild catch, the main source of which is the Great Lake, as well as the Mekong, Tonle Sap, and Bassac Rivers, with about 24 % coming from aquaculture in 2017. Nevertheless, the country's fisheries sector is faced with the challenge of providing sufficient supply to meet the demand while making sure that the supply would continue to be available for future generations notwithstanding the recent decline in fish production from the wild due to intensive fishing during the past years despite the government's efforts to regulate fishery catch. In order to mitigate such a situation, small-scale aquaculture of tilapia had been introduced throughout the country as an important means of improving food security and nutrition as well as generating employment and income opportunities. This has also given rise to the involvement of women in aquaculture ventures, and significantly contributing to the economy of the country.

As with the other farming activities, aquaculture relies heavily on the use of water and appropriate area or space for fish production (Jamu *et al*., 2003). Women household members have been actively engaged in on-farm and off-farm aquaculture operations while men household members are involved in productive endeavors outside their communities. In Cambodia, women have been practically participating in each step of aquaculture operations from planning, decision making, preparing the ponds to stocking of fingerlings, fertilizing the ponds, preparing feeds, feeding, pond maintenance, harvesting, and sale and marketing, generally helping significantly in increasing household incomes (FiA, 2016).

Recently however, variations in the climate had affected the country's aquaculture endeavors, as water supply becomes insufficient and water temperature had been rising, while frequent incidences of flooding occur during fish culture periods. In addressing such concern, the Government of Cambodia advocated the development of human capacity to improve the understanding of stakeholders on the status of the resources, and promote sustainable fish culture management (FiA, 2014). Nonetheless, water shortage has remained a great challenge confronting the fish farmers, because of long drought that continues to take place until the present time. There had been instances when some of the country's fish farmers were forced to harvest their fish stocks earlier than the scheduled harvest, producing fish that were below table sizes—around 0.1 kg per head, earning for them less income and low return of their investments. A study was therefore carried out to be able to understand the issues confronting the tilapia aquaculture industry in Cambodia, especially the impacts of climate change and the adaptation measures to mitigate such impacts, on the income-generating activities of its women populace. With support from the Department of Aquaculture Development (DAD) of Cambodia and the International Foundation for Science (IFS) of Sweden, two aquaculture producing Provinces in Cambodia (Kampong Thom and Siem Reap) were considered as pilot sites for the study (**Figure 1**) which was pursued through survey and interviews of sampled fish farmers, who were involved later in the fish culture trials.

Cambodia is located in the Indochina Peninsula, sharing international borders with Lao PDR, Viet Nam, and Thailand, and lies entirely within the tropics with its southernmost point slightly more than 10° above the equator. Cambodia has a total land area of 181,035 km^2 and is surrounded by low mountains and lowlands where the Mekong River runs across from the northeastern border with Lao PDR to the southern border with Viet Nam. Bounded on the southwest by the Gulf of Thailand, Cambodia embraces a coastline with extensive

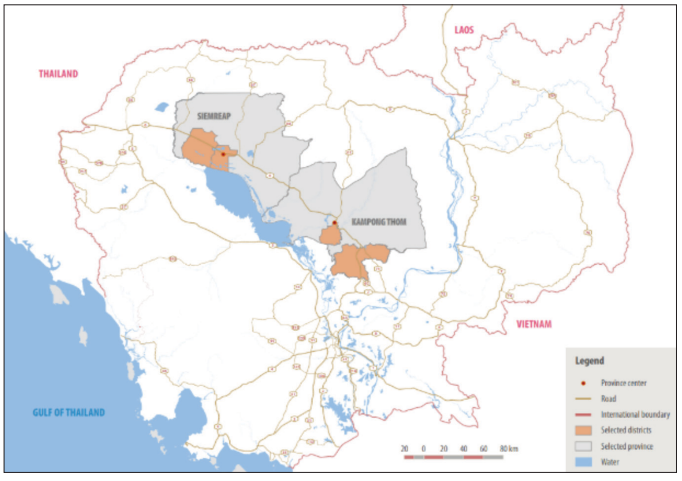

Figure 1. Map of Cambodia showing the pilot sites of the study: Siem Reap and Kampong Thom

mangrove forest of about 440 km. About 86 % of the country (including Kampong Thom and Siem Reap) lies within the Mekong catchment area. The Tonle Sap Great Lake, which is situated in the central western part of the country, and the largest and the most productive lake in Southeast Asia, serves as a natural reservoir of the Mekong River system, expanding from 2,500-4,000 km^2 in dry season to 10,000-15,000 km^2 in wet season, and has 4,800 km of flooded forest coverage (So & Buoy, 2005).

The climate of Cambodia is the same of the rest of Southeast Asia, being dominated by monsoon, and recognized as tropical dry and wet. It also specifically marks seasonal difference, the south-western and north-eastern monsoons, separated by a short transition period. The south-western monsoon or the wet season normally from May to October, dominates when atmospheric pressures are comparatively low over Asia, while the north-eastern monsoon or dry season from November to April, dominates when atmospheric pressure is high.

Aquaculture in Cambodia

The fisheries sector of Cambodia has for many years contributed significantly to the employment and livelihoods of the rural communities, food security, as well as to the country's GDP and foreign exchange balance. While offering employment (full-time, part-time, and seasonal) to more than 6 million of the 16 million people, the country's fisheries sector (capture fisheries and aquaculture) significantly provides the animal protein in the Cambodian diet, especially that fish forms part of their cultural heritage (FiA, 2010). The country's aquaculture has recently showed signs of rapid growth (**Table 1**), although still at a critical stage of development, it has the potential to meet the likely future shortfall in supply of fish, and generate employment for rural communities in the country. Nevertheless, there is a need to facilitate the development of more profitable and sustainable aquaculture, while at the same time conserve valuable fishery resources, and maximize its contribution to nutrition and poverty alleviation. Specifically, small-scale aquaculture in inland domain has potential benefits to the rural communities, and freshwater aquaculture is simple to operate and require less operations costs (TGAC, 2016). Although small-scale fish farmers have been encouraged to culture indigenous fishes, exotic fish species like tilapia has been preferred as its culture offers better returns of investment, especially that tilapia has recently become a more popular fish for domestic consumption, contributing significantly to improved food nutrition and income generation of local people especially the women's groups in Cambodia (Dr. Hav Viseth, personal communication, 2016).

In Cambodia, women comprise the major stakeholders in the fisheries sector, where their involvement is about 50 %, not only in fish farming but also in fish processing and trade. The Fisheries Administration (FiA) recognizes and promotes the role of women in fisheries, as reflected in the gender policy of Ministry of Agriculture, Forestry and Fisheries (MAFF). Under the umbrella statement of the MAFF, the gender mainstreaming strategy of FiA aims to enhance gender equality in the fisheries sector by recognizing the active role of both women and men in the sustainable development of fisheries and aquaculture (Chin, 2016).

Issues Confronting Tilapia Aquafarmers of Cambodia

In order to assess the adaptation measures that local tilapia fish farmers (or aquafarmers) advocate to mitigate the impacts of climate change and variations, a survey was carried out in two tilapia-producing provinces in Cambodia: Siem Reap and Kampong Thom. These provinces were chosen for the study due to the following reasons: 1) the provinces support a number of small-scale aquaculture ventures resulting from the projects implemented by FiA and some non-governmental organizations (NGOs); 2) most of fish farmers in these provinces are women; 3) the provinces' experiences in severe drought and flooding; 4) tilapia seeds are locally produced in Siem Reap; and 5) aquaculture ventures in these provinces have received strong support from the government as well as from NGOs (Chin, 2014; FiA, 2014).

Study sites

Kampong Thom Province (**Figure 2**) is located in the center of Cambodia on the floodplain of Tonle Sap Great Lake, covering a land area of 13,814 km^2. It is bordered by Preah Vihear to the north and Siem Reap to the west, Kampong Chhnang to the south, and Stung Treng and Kratie to the east. With a total population of 677,260 (327,013 men and 350,247 women) in 2019 and density of 45 people per km^2 (NIS, 2019), the Province consists of eight districts, 81 communes, and 766 villages. The daily maximum temperature has been increasing by 2–4 °C throughout the year, and typically daily maximum

Table 1. Fishery production of Cambodia (2014-2018) by quantity (t)

	2014	2015	2016	2017	2018
Total fishery production	**745,310**	**731,889**	**808,550**	**857,018**	**943,205**
Production from marine capture	120,250	100,984	126,700	121,025	153,600
Production from inland capture	505,005	487,905	509,350	528,493	535,555
Production from aquaculture	120,055	143,000	172,500	207,500	254,050

Source: *Southeast Asian Fisheries Development Center (2020)*

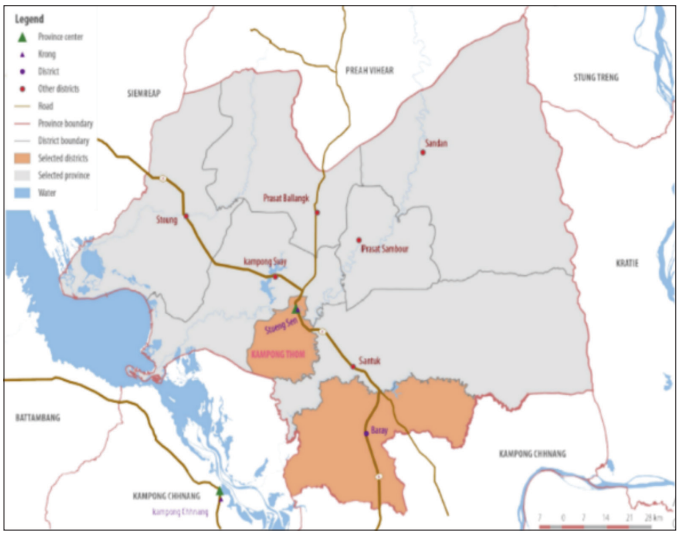

Figure 2. Location of Kampong Thom Province in Cambodia

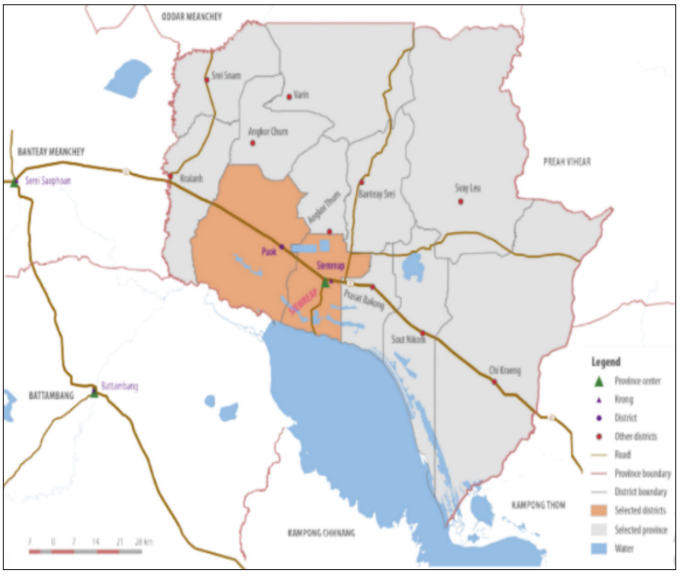

Figure 3. Location of Siem Reap Province in Cambodia

temperature of 33 °C usually occurs in March. Precipitation during the rainy season had also increased by 40 mm per month in September or by 18 %.

Siem Reap is located in northwestern part of Cambodia (**Figure 3**) and covers an area of 10,299 km^2 and comprises 12 districts, 100 communes, and 875 villages. It is one of the five (5) provinces around Tonle Sap Great Lake, and bordered by Oddor Meanchey to the north, Preah Vihear to the east, and Kampong Thom and Banteay Meanchey to the west. In 2019, the Province's total population was 1,006,512 (491,568 men and 514,944 women), and with an average household size of 4.6, its population density was 98 people per km^2 (NIS, 2019). Its climate is dominated by seasonal winds/monsoons, where the wet season starts in May and finishes at the end of October. The dry season is from November until April.

The Survey

From the list of fish farmers in Kampong Thom and Siem Reap Provinces, the respondent-fish farmers for the survey 2017 were selected through systematic random sampling and since women have been taking part in the country's aquaculture operations, the women fish farmers were targeted as respondents of the survey. The criteria for the respondents included: 1) at least two years experience in tilapia fish culture; 2) a household head; 3) having fishpond with an area of not more than 250 m^2; and 4) high responsibility in the aquaculture operations. Eight women fish farmers (four women fish farmers from each province) who met the criteria were considered for the survey. The respondent-fish farmers had experiences in fish culture at varying periods between 2 and 12 years, and received technical advice from both government extension officers and local NGO officers. From this group, 32 respondents were selected from the two provinces, *i.e.* 16 respondents for Kampong Thom and 16 for Siem Reap.

The Results

Generally, most of the fish farmers in Cambodia are women because women are always at home while the men go out from their communities to earn a living. So from the 16 respondents from Kampong Thom Province, three were men, while from the 16 respondents from Siem Reap Province only one was male (**Table 2**). High proportion of women involvement in fish farming is observed in Cambodia, especially in the grow-out stages. Increased participation of women family heads in fish production had been observed since 2012 due to the productive work of the male household members outside of their villages (Chin, 2013). Moreover, in the Cambodian tradition of land donation, there exists a key rural push factor where in order to address the lack of land, close relatives such as parents, uncles/aunts or siblings donate land to their daughters, nieces or women siblings, especially when they are establishing new households and are unable to obtain or access land in their village of origin (Maltoni, 2007).

The high proportion of female aquafarmers in the fish grow-out farms is probably due to important role of women in the pond maintenance and management which is already embedded in rural households of Cambodia (FiA, 2016). Although all family members (women and men) carry out the activities in the aquaculture sub-sector, the women put in an equal share of effort as with the men even in pond construction. Women are actively engaged in on-farm and off-farm tasks, participating in each step of the fish culture operations. It should also be noted that in Cambodia, high percentage of women are taking care of their families as part of their daily chores, but this does not interfere with their aquaculture endeavors as means of increasing their household income (Chin, 2015).

Table 2. Gender, ages, and educational attainment of the respondent-fish farmers

Gender	Respondent-fish farmers			Age (years)		Educational level		
	Kampong Thom	Siem Reap	Total (n)	Max (n)	Min (n)	None	Primary	Secondary
Female	13	15	28	68	24	3	25	0
Male	03	01	04	52	30	0	04	0
Total	**16**	**16**	**32**			**3**	**29**	**0**

The ages of the respondent-fish farmers ranged from 24 to 68 years old (**Table 2**). Age is important for pond management considering the need for experienced and matured fish farmers in fish culture operations. The ages of women involved in aquaculture vary from 24 to 68 years while those of men age vary from 30 to 52 years, while the high proportion of the respondents' ages falls in the range between 42 to 50 years old.

In terms of education, the respondent-fish farmers from Kampong Thom and Siem Reap Provinces attended the primary level only (**Table 2**). Of the 28 women respondents, 25 attended primary school and three did not have the chance to attend school. It should be noted however that the ages of women fish farmers that range from 40 years and 50 years, suggest that they were born during the civil war and Pol Pot Regime, and thus, must have not been able to pursue further education. Meanwhile, only four men respondents availed of primary school education. Educational background of fish grow-out farmers is an essential factor in absorbing new knowledge, technology, adaptive occupations, and in improving fish farm management. Furthermore, the limited educational background of the women respondents must have been a reflection of Cambodia's traditional culture that women do not necessarily have to go to school–they are bound inside the house to do household chores. Nonetheless, lack of information materials had been one of the constraints that women and men fish farmers encountered, limiting their capacity in decision making on fish farms and in obtaining additional knowledge on improved and advanced ways for culturing fish. In spite of the limited educational background of the respondents, FiA through the DAD and development partners supported the target women and men to undergo special training on aquaculture planning, farm management, and marketing. With enhanced knowledge and skills, they were able to practice on-farm and out-farm activities that include planning, seeking for customers, extending aquaculture techniques to new fish seed producers and grow-out farmers.

Almost all respondent-fish farmers have been working as rice farmers (90.6 %) and have not been involved with any other secondary occupations (**Table 3**). However, one of the fish farmers in Siem Reap gets her main income from bamboo basket making and two out of 16 fish farmers rely on fish culture. The majority of household head in Kampong Thom and Siem Reap provinces reported that rice farming is their main occupation, and had been doing rain-fed cropping each year. This figure is lower than the findings of Chin (2013) which indicated an average involvement of 99.0 % of fish farmers in rice farming but higher than that indicated in the report of Cramb *et al*. (2020) which was almost 80.0 %.

Climate variations affecting tilapia culture in Cambodia

One of the main objectives of the survey was to determine how the fish farmers were coping with the impacts of climate variations on their aquaculture endeavors. The respondents indicated that they have been confronted with incidences of flooding and drought (**Table 3**).

They reported that longer drought period is usually experienced from February to June, and flooding from September to October. Ten of the 16 respondents from Kampong Thom and 12 of the 16 respondents from Siem Reap had suffered losses from their fish culture ventures because of floods while six out of 16 respondents from Kampong Thom and three of the 16 respondents from Siem Reap have lost revenues due to long incidence of drought. There was however, one (1) fish grow-out farmer from Siem Reap who had never experienced losses caused by natural disasters (drought or flood) since she started culturing fish in 2012, because her fishpond is located on higher grounds and she adopts a shorter culture period (3–4 months), and her produce is mainly for household consumption.

During the dry season in Cambodia, fishponds usually receive limited water supply from natural water bodies for fish culture forcing fish farmers to harvest smaller size fish to avoid losses from drought. Nonetheless, to cope with the impacts of drought, fish farmers plant aquatic weeds near fishpond dikes and install green sheds in fishponds. In September when

Table 3. Main occupations of respondents and types of disasters that confront their tilapia culture endeavors

	Main occupations			Disasters affecting tilapia culture		
	Rice farming	Fish culture	Basket weaving	Flooding	Drought	None
Kampong Thom	16	0	0	10	6	0
Siem Reap	13	2	1	12	3	1
Total	**29**	**2**	**1**	**22**	**9**	**1**

heavy rains continually occur for three days to one week, fish farmers put nets around fishpond (burying the net at least 20 cm in fishpond bottom), install traps in front of water gates, and set cages in fishponds to avoid the escape of fish stocks.

Measures adopted by fish farmers to mitigate impacts of climate variations on tilapia culture

Majority of the respondents (29 out of 32) have never attended disaster prevention training although two respondents from Kampong Thom and another one from Siem Reap had undergone training from the FiA and FAO on flood prevention measures for aquaculture ventures, *e.g.* installing cages in fishponds and transferring the fish stocks from the pond to the cages, which was practiced by the three respondents (**Table 4**). However, in order to limit the cages installed in ponds as installation is costly by reducing the number of fish to fit into the cages, fish farmers usually size the fish stocks and sell the almost marketable sizes by end of August or early September. Such measures however are meant to address only the problems caused by flooding as they have not yet established measures that could mitigate the impacts of long drought on their fish culture operations, although they also learned that having a reservoir pond could help but this would entail using a reserved pond which could be used to culture more fish, besides this is sometimes not possible in rural areas where pond area is costly and space is limited.

Vulnerability of respondents to disasters caused by climate variations

Most of the respondents have experienced floods and/or droughts that led to revenue losses. For example, an average loss of KHR 230,800 or USD 57.70 per household could be incurred per year or maximum loss of KHR 735,500 or USD 183.90 per household per year, due to disasters caused by climate change. Such losses are high, especially for those in the remote areas, so that they would rather rely on more reliable source of livelihood such as rice farming. The impact of such losses is suffered mostly by women/wives more than men/husbands from Siem Reap as shown in **Table 4**, with minimal effect on women/wives and men/husbands altogether. The contrast happened in Kampong Thom where nine out of 16 respondents replied that women/wives and men/husbands altogether worry about income losses while seven out of 16 respondents said that women/wives took more responsibility than the men/husbands. Interestingly, the wife is concerned with the situation of fish farms, even during rains and at night time, in addition to her main duty of looking after everything inside the households, a recognized culture of traditional Cambodians.

As a result, income losses could put more mental pressure on women/wives than on men/husbands because in the Cambodian culture the caretaker of the household revenues is the wife. Therefore, any losses in income could have an impact on the household living expenses, affecting the financial stability of families.

Institutional support after disasters

Almost all respondents did not receive support from the government nor from any NGOs to enable them to recover their losses from fish culture due to floods or drought. Only one respondent received support from a project sponsored by FAO and FiA for the recovery of the losses incurred because of flooding in 2014, but after the project ended there was no further support. Any external support from relevant agencies is welcome especially by small-scale or family-scale fish culture ventures in Cambodia, considering that the limited budget of the government does not include allocation of funds for such purpose.

Adopting Tilapia Culture Techniques that Address the Impacts of Climate Change

From the respondent-fish farmers, eight qualified respondents were chosen as partners in the follow-up project that would adopt tilapia culture techniques that could address the impacts of climate change and variations. Four fish farmers from Kampong Thom and another four from Siem Reap were provided technical support and cost of operation for two-year tilapia fish culture, from pond preparation until post-harvest (**Box 1**). As project partners, the fish farmers were responsible for the management of the fishponds following the measures recommended through the previous survey for mitigating the impacts of climate change on tilapia culture, *i.e.* deepening of ponds and shortening of the culture period. The project partners were divided into two groups, where each group comprised two fish farming households per province. The first group worked on deepened ponds (from 1.0 m to 1.5 m water depth) and shortened period of fish culture from seven months to four months, while the second group raised tilapia following the usual method, *i.e.* 7-month culture period and

Table 4. Experience gained by respondents on disaster prevention and vulnerability of respondents to such disasters

	Attendance in training on disaster prevention		Persons most affected by disasters			Support after disasters	
	Yes	No	None	Women	Women + Men	Received support	No support
Kampong Thom	2	14	0	7	9	0	16
Siem Reap	1	15	1	13	2	1	15
Total	**3**	**29**	**1**	**20**	**11**	**1**	**31**

Box 1. General information on the project partners					
Name of project partner	Age (years)	Location of ponds	Pond size (m^2)	Pond depth (m)	Culture period (months)
Ms. Say Rathana	47	Pouk Thmey Village, Pouk Commune, Pouk District, Siem Reap Province	200 (10 m × 20 m)	1.5	4
Ms. Yi Sinoun	66	Pouk Thmey Village, Pouk Commune, Pouk District, Siem Reap Province	225 (15 m × 15 m)	1.5	4
Ms. Noun Ei	43	Chrey Village, Sambour Commune, Siem Reap District, Siem Reap Province	238 (14 m × 17 m)	1.0	7
Ms. Noun Art	40	Chrey Village, Sambour Commune, Siem Reap District, Siem Reap Province	240 (15 m × 16 m)	1.0	7
Ms. Met Chenghor	42	Tros Village, Balang Commune, Baray District, Kampong Thom Province	150 (10 m × 15 m)	1.5	4
Ms. Tith Ros	38	Kampong Sdach Village, Krovar Commune, Baray District, Kampong Thom Province	144 (12 m × 12 m)	1.5	4
Ms. Long Meth	58	Kampong Sdach Village, Krovar Commune, Baray District, Kampong Thom Province	208 (16 m × 13 m)	1.0	7
Ms. Yin Mom	54	Achar Leak Village, Achar Leak Commune, Stung Sen District, Kampong Thom Province	234 (13 m × 18 m)	1.0	7

using the traditional depth of ponds (1.0 m water depth). The parameters to be measured during the culture period by the two groups include water temperature, pH, amonia, nitrite, and oxygen.

Pond management

Proper pond preparation should be practiced by draining their ponds using water pump, but mud may not be removed after draining the pond. Agriculture lime should be applied at 100g/m^3 before stocking the fingerlings to reduce acidity of the pond water. Lime is spread on the pond bottom if it is already dry or mixed with water and sprayed if the pond has already been watered. After applying lime, the pH (using pH paper) should be checked to 11, otherwise additional lime should be applied until the pH reaches 11. Secchi Disk (**Figure 4**) is used to monitor the water quality and control the level of water. The five colors on the pole (*i.e.* red, yellow, green, light green, and blue) reveal the information indicated in **Box 2**.

Figure 4. Secchi disk

Box 2. Information on water quality using Secchi disk

- **blue (> 60 cm):** clear water, inadequate fertilizer, plankton just growing, fish may get stress due to low oxygen, must add more fertilizer
- **light green (45-60 cm):** not enough plankton in the water, should add appropriate amount of fertilizer
- **green (30-45 cm):** enough plankton in the water, good condition to grow fish (normal)
- **yellow (20-30 cm):** plankton increased and water quality decreased, should monitor the water quality and if possible, do not need to add more feed and fertilizer
- **red (0-20 cm):** excess plankton in the pond, bad condition to grow fish, insufficient oxygen in the morning, does not need to add more/ reduce feed, fertilizer until water quality turns to normal (green color)

Green pond water indicates enough plankton production, but when visibility is up to light green, it means insufficiency in plankton and requires increased fertilization. The quality of water in fishponds should be observed two times per day because when pond water is yellow, there is excessive plankton production reducing the oxygen in the pond water particularly at night and on cloudy days, and can lead to fish mortality. When this happens, feeding and fertilization should be stopped until the color of the pond water becomes lighter.

Net could be installed around the fishpond before stocking to avoid the fish from escaping, especially during low flood and prevent predators from jumping into the pond to devour the stocked fish. The fishponds should be cleared of floating or submerged weeds as these would tend to block the penetration of sunlight into the water. Wild fish and other wild aquatic animals such as water snakes, crabs, and frogs should be removed as these wild animals could harm the newly stocked fingerlings, resulting in high mortality/losses of stocks in the ponds.

Five parameters should be checked for water quality, *i.e.* water temperature, pH, ammonia, nitrite, and oxygen, and monitored two times per day (morning at 7 a.m. and evening at 6 p.m.). Results of water quality monitoring in 2017–2018 and 2018–2019 in the pilot sites, illustrated that the temperature between the 1.0-meter depth pond and 1.5-meter depth pond had no significant difference (**Table 5**). The average pH was also not significantly different and was found to be suitable for tilapia culture.

Stocking

At the start, each project partner received 500 red tilapia fingerlings per year (one cropping). The stocking period depended on the availability of water supply from the nature

Table 5. Results of water quality monitoring in project partners' ponds (average for Kampong Thom and Siem Reap)

	Average temperature (˚C)	Highest temperature (˚C)	Lowest temperature (˚C)	Average pH	Ammonia/ nitrite (mg/l)	Oxygen (mg/l)
2017-2018						
1.5-meter depth pond	29.20	31.06 (Nov)	27.44 (Dec)	7.33	0.0	5.00
1.0-meter depth pond	28.63	31.06 (Aug)	26.35 (Feb)	7.38	0.0	4.29
2018-2019						
1.5-meter depth pond	30.07	31.05 (Nov)	29.52 (Aug)	7.33	0.0	5.00
1.0-meter depth pond	28.92	31.02 (Nov)	26.32 (Jan)	7.31	0.0	4.29

(rainwater). Availability of water is an important factor for tilapia culture in the target areas, where rainwater could come in May to November. During the first year of project trial in 2017, stocking took place in July and August, and for the second trial in 2018, stocking was made in July. The weight of fingerlings varied from 20.00 g/head to 20.15 g/head and length from 10.40 cm/head to 10.43 cm/head, and bought at KHR 1,200 or USD 0.30/head. The size of fish seed is higher than the FiA recommended size at 5–7 cm or 3–5 g fingerlings as fish could reach table size earlier, particularly in cases where water in the ponds could be available only for 5–6 months (FiA, 2010). The fish seeds should be released gently and gradually to avoid stress while letting the seeds adapt to the temperature of the pond water.

The fish seeds for this project came from a local producer, the Ratha Da Fish Seed Producer in Siem Reap Province. Ratha Da Fish Seed Producer was selected to supply the fish seeds for the project because it is recognized by FiA as a good tilapia fish seed supplier in Cambodia; its fish seeds are of good quality and reasonably priced; owner of farm had been trained by FiA and USAID/HARVEST; and promoted by the Government of Cambodia as an aquaculture-related enterprise in the country. Furthermore, the fish seeds supplied by Ratha Da Fish Seed Producer were of good quality, in bright color, good shape, uniform in size and age, disease resistant, fast growing, healthy, high survival rate, and no environmental effects.

Feeding

In this project, pellet feeds containing 30 % protein was fed to the fish as it could increase fish growth and production. In order to attain good production, feeding was given twice per day in 1.0-meter depth fishpond and four times per day in 1.5-meter depth pond. In the 1.0-meter depth pond, fish was fed at 8:00 in the morning and 16:00 in the afternoon. For the 1.5-meter pond depth, feeding was done in the morning at 7:00 and 10:00, and in the afternoon at 13:00 and 16:00. The daily feeding ratio is shown in **Table 6**.

Monitoring of cultured fish

In the project sites, growth rate, mortality rate, and survival rate were monitored every 15 days (**Figure 5**), and generally, mortality rate of the tilapia cultured was lower in Kampong Thom than in Siem Reap (**Table 7**). For example, during the first year (2017–2018) of fish culture trial in the 1.0-meter depth pond in Siem Reap, 20 fish were found dead in one night because of the sudden change in temperature brought about by cloudy skies and non-stop rain in more than two days. In cases such as this and during critical situations, the pond water should be aerated using aerators and feeding should be stopped the following day. The dead fish from the Siem Reap ponds were found to have air in their stomach with bubbles, as well as some of parts of pellet feeds. Nonetheless, disease diagnosis could not be performed in the fishponds due to insufficiency of any disease diagnostic equipment.

In the first year of trial (2017–2018), the average feed conversion ratio (FCR) for 4-month grow-out period was 1.44 and 1.47 for the 7-month culture period. There was no significant difference between the FCR of tilapia cultured in 1.5-meter depth fishpond and 1.0-meter depth fishpond. The lowest FCR was 1.4 and the highest was 1.5.

As with the first-year trial (2017–2018), the parameters during the second-year trial (2018–2019) such as growth rate,

Table 6. Daily feeding ratio

Fish body weight (g)	1.0-meter depth pond		1.5-meter depth pond		Feed size (mm)	Feed protein content (%)
	Feed (% fish body weight)	No. of feeding per day	Feed (% fish body weight)	No. of feeding per day		
20 g	1.33 %	4	1.33 %	4	Powder	35
25 g	1.47 %	3	1.47 %	4	2	35
100 g	1.60 %	2	1.60 %	4	3	30
200 g	0.85 %	2	0.85 %	4	4	30
> 300 g	0.75 %	2	0.75 %	4	5	30

Table 7. Stock monitoring of cultured tilapia in 2017-2018 trial

	No. of culture days	Average growth (g/day)	Mortality rate (%)	Survival rate (%)	Average feed conversion ratio
Siem Reap Province					
• **1.5-meter depth pond**					
Ms. Say Rathana	124	2.34	4.00	96.0	1.5
Ms. Yi Sinoun	124	2.44	1.60	98.4	1.4
• **1.0-meter depth pond**					
Ms. Noun Ei	212	1.37	2.20	97.8	1.5
Ms. Noun Art	212	1.38	1.40	98.6	1.5
Kampong Thom Province					
• **1.5-meter depth pond**					
Ms. Met Chenghor	122	2.39	1.80	98.2	1.5
Ms. Tith Ros	122	2.47	0.40	99.6	1.4
• **1.0-meter depth pond**					
Ms. Long Meth	212	1.36	3.00	97.0	1.5
Ms. Yin Mom	212	1.35	2.00	98.0	1.5

Table 8. Stock monitoring of cultured tilapia in 2018-2019 trial

	No. of culture days	Average growth (g/day)	Mortality rate (%)	Survival rate (%)	Average feed conversion ratio
Siem Reap Province					
• **1.5-meter depth pond**					
Ms. Say Rathana	128	2.08	0.40	99.6	1.6
Ms. Yi Sinoun	128	2.25	0.80	99.2	1.5
• **1.0-meter depth pond**					
Ms. Noun Ei	247	1.19	1.60	98.4	1.5
Ms. Noun Art	248	1.19	0.80		1.4
Kampong Thom Province					
• **1.5-meter depth pond**					
Ms. Met Chenghor	126	2.33	1.20	98.8	1.5
Ms. Tith Ros	126	2.37	0.80	99.2	1.4
• **1.0-meter depth pond**					
Ms. Long Meth	243	1.20	2.00	98.0	1.5
Ms. Yin Mom	247	1.17	1.40	98.6	1.5

Figure 5. Growth rate measurement of tilapia stock

mortality rate, and survival rate were also monitored every 15 days. Results indicated that mortalities were low in both groups. The highest survival rate in the second-year trial was 99.6 %, while the lowest survival rate was 98.0 %. There was a significant difference between the average daily growth rate of the 1.5-meter depth pond (2.41 %) and 1.0-meter depth pond (1.37 %). The highest daily growth rate in the 1.5-meter depth pond was 2.47 % while in the 1.0-meter depth pond, the highest growth rate was 1.80 %, and the lowest daily growth rate in the 1.5-meter pond depth was 2.34 %, it was 1.36 % in the 1.0-meter depth pond (**Table 8**). There was significant difference between the average daily growth rate in the 1.5-meter depth pond (2.26 %) and 1.0-meter depth pond (1.19 %). The highest daily growth rate of 1.5-meter depth pond was 2.37 % while it was 1.20 % in the 1.0-meter depth pond, and the lowest daily growth rate in the1.5-meter depth pond was 2.08 % while in the 1.0-meter depth pond the lowest daily growth rate was 1.17 %.

The average FCR for the 4-month grow-out period was 1.49 while for the 7-month culture period FCR was 1.46. This average FCR could be considered normal compared to the FiA (2016) experience where the FCR of tilapia fish culture using pellet feed containing 30 % protein ranged from 1.20 to 1.80. There was no significant difference between FCR of tilapia fish culture in 1.5-meter depth pond and 1.0-meter depth pond. The lowest FCR was 1.40 and the highest FCR was 1.60.

Harvesting

In the first year trial (2017–2018), tilapia stocked in the 1.5-meter depth pond in Siem Reap Province was harvested in November 2017 and in Kampong Thom Province the stock was harvested in January 2018. For the stock in the 1.0-meter depth pond, the stock was harvested in March 2018 when the size of fish reached about 0.5–0.6 kg. There was no significant difference in the average fish yield in the study sites. The average fish yield in the 1.5-meter depth pond in the first-year trial was 299.0 kg, and 292.3 kg in the 1.0-meter depth pond (**Table 9**, **Figure 6**).

During the second year trial (2018–2019), the stock from the 1.5-meter depth tilapia pond was harvested in November 2018 and from the 1.0-meter fishpond depth in March 2019. The average tilapia yield from 1.5-meter pond depth was 289.0 kg and 294.4 kg from the 1.0-meter depth fishpond (**Table 9**). The fish farmers decided to put up their produce on farm sale, so that retailers come to the farm and collect the fish at the farms. This was, shipping cost for transferring tilapia cultured production to the market was not necessary.

Socioeconomic analysis

The tilapia stocks were harvested during the dry season, and sold directly to fish retailers. The fish farmers in Siem Reap were able to sell their fish at higher price (USD 2.50–3.0/kg) than those from Kampong Thom at USD 2.25/kg because Siem Reap is a popular tourist area and demand for fish is more than in Kampong Thom. Here, the project partners were not asked to return any money after completing the tilapia culture trial periods, as the income from the fish produced was considered as revenue of the respective fish farmers. The average income from the 1.5-meter depth pond in the first year trial was USD 747.63 which was higher than the average income from the 1.0-meter depth pond in the second trial year. This was followed by the average income from the 1.5-meter depth pond in the first trial year and the average income from the 1.0-meter depth pond in the second trial year at USD 736.10, USD 730.80, and USD 722.30, respectively.

From this project, it was found that the 1.5-meter depth pond and four months culture period provided significant result as the culture period was short but provided the appropriate market size of fish, sufficient amount of water for fish culture, and lower risk in terms of losses as flooding period could be avoided. Because of the remaining time (three months after culturing fish), the fish farmers adopting the 1.5 -meter depth pond and 4-month culture method could find alternative jobs,

Table 9. Production from study sites during 2017-2018 and 2018-2019 (kg)

	2017-2018 Production (kg)		2018-2019 Production (kg)	
	Siem Reap	Kampong Thom	Siem Reap	Kampong Thom
1.5-meter depth pond				
Ms. Say Rathana	292.8		268.8	
Ms. Yi Sinoun	305.5		290.3	
Ms. Meth Chenghor		294.6		295.8
Ms. Tith Ros		303.3		300.8
Average	**299.0**		**289.00**	
1.0-meter depth pond				
Ms. Noun Ei	293.4		295.2	
Ms. Noun Art	295.8		297.6	
Ms. Long Meth		291.0		294.0
Ms. Yin Mom		289.1		290.9
Average	**292.3**		**294.4**	

Table 10. Income incurred from study sites during 2017-2018 and 2018-2019 (USD)

	2017-2018 Income (USD)		2018-2019 Income (USD)	
	Siem Reap	Kampong Thom	Siem Reap	Kampong Thom
1.5-meter depth pond				
Ms. Say Rathana	732.00		672.00	
Ms. Yi Sinoun	763.75		725.75	
Ms. Meth Chenghor		736.50		739.50
Ms. Tith Ros		758.25		752.00
Average	**747.63**		**722.30**	
1.0-meter depth pond				
Ms. Noun Ei	733.50		738.00	
Ms. Noun Art	739.50		744.00	
Ms. Long Meth		727.50		735.00
Ms. Yin Mom		722.75		727.25
Average	**730.80**		**736.10**	

some worked as the dish-cleaners at restaurants in Siem Reap and/or produced handicrafts and souvenir items for sale.

It is recognized that women in Cambodia could give all out efforts to undertake aquaculture ventures as better source of livelihood and income. In this study, the women participated in every step of operating fish farms from planning, decision making, preparing the pond to stocking of the fingerlings, fertilizing pond, preparing feed, feeding, pond maintenance, harvesting, sale, and marketing. After the trials, the project partners from Kampong Thom and Siem Reap managed their incomes and decided to: save for the next tilapia culture; expand the pond size for fish culture; support some priority household expenses; and save for children's education at higher levels. It is important to note that one of the project partners could send her daughter to a university to study economics and finance, using the money she earned from the project study. This implies that with the adaptations that fish farmers had to undergo to mitigate the impacts of climate change on tilapia culture, the socioeconomic well-being of the rural populace could be improved, as the next generation could attend higher educational levels, improving the lives of families dependent on fish farming in the near future.

Conclusion

The socioeconomic indicators of the respondents from Kampong Thom and Siem Reap, particularly in terms of educational attainment were not very favorable, and most of the fish farmers rely on rice field farming as their main occupation. High proportion of women's involvement is found in the fish culture ventures in Cambodia considering that male farmers are involved in productive work outside their villages. The women participate in each step of the fish farm operations starting from planning, preparing the pond to stock fingerlings, fertilizing ponds, preparing feeds, feeding, pond maintenance, harvesting, sale, and marketing as well as in decision making. There was however a big challenge for small-scale fish farmers in Kampong Thom and Siem Reap Provinces, because of the long drought during February to June, and flooding from September to October. The existing system of setting cages in the ponds or netting the fishponds (for low flood) were adopted by few families only because of the high cost incurred.

Deepened fishponds and shortened period of fish culture were considered good method to adapt to the impacts of climate change although in the study, there was no significant difference between water quality, mortality rate, and FCR in 1.5-meter depth pond and 1.0-meter depth pond in Kampong Thom and Siem Reap Provinces. However, there was significant difference between daily growth rates of tilapia stocked in 1.5-meter depth pond and in the 1.0-meter depth pond until the fish to reach table size. Nevertheless, the use of 1.5-meter depth fishpond in culturing fish for four months provided significant result as the fish culture period is short, faster harvesting of the appropriate market size of fish, enough water supply for fish culture; and with low risk in losing fish during flooding period. Moreover, the fish farmers in the 1.5-meter depth pond could find alternative jobs such as working as the dish-cleaners at restaurants in Siem Reap and/or make handicraft products during their spare times (three months) after culturing the fish. Deepened fishpond and shortened period of fish culture could help improve the socioeconomic status of the rural poor as it could provide them with better income and allow them to send their children to attain higher education bringing welfare to improve their lives in the near future.

This research contributed to determining the suitable and adaptable methods to deal with the long drought period after dry season which often caused suffering to the poor groups of women. Help is needed by women fish farmers to be able to raise fish during the critical times of the year. At the moment, high percentage of rural households in Cambodia now relies on the aquaculture sub-sector as their main source of income.

The positive result of this trial will be expanded and utilized to be adaptable in the areas located close to study areas, and is expected to secure the livelihoods and nutrition of women's groups in the target provinces. This is one of the important approaches that aim to eliminate poverty in the rural areas of Cambodia.

Recommendations

Based on the results of this study, some recommended actions could be promoted in order to improve the aquaculture situation of Cambodia. These are indicated in **Box 3**.

Box 3. Recommended actions to improve the aquaculture situation in Cambodia

- Government and development partners should create awareness programs on prevention of flood and drought to mitigate their impacts on aquaculture in the whole country
- Government and development partners should establish special aid to help fish farmers to recover from natural disasters (flood and drought)
- The lessons learnt about 1.5-meter fishpond depth should be studied further to know the weaknesses and strengths to apply for other provinces.
- In order to test the qualification of 1.5-meter fishpond depth method applicable to use in the whole country, government and development partners should expand trial program in different provinces.

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